# Canadian Wildland Fire Strategy: Background Syntheses, Analyses, and Perspectives

K.G. Hirsch and P. Fuglem, Technical Coordinators

Canadian Council of Forest Ministers

Conseil canadien des ministres des forêts

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## Abstract

In September 2004, the Canadian Council of Forest Ministers established a federal, provincial, and territorial task group of assistant deputy ministers (ADMs) and commissioned the development of the Canadian Wildland Fire Strategy (CWFS). The ADMs created an intergovernmental team of analysts, experienced fire managers, and researchers, known as the CWFS Core Team, to consult with Canadian and international experts, collate information, conduct analyses, and present the findings. This team was directed to assess the current state of wildland fire management in Canada, examine the key influences and trends, and identify possible desired future states and how they could be achieved. This publication comprises a collection of nine reports written by the CWFS Core Team members and their associates. Collectively these papers include syntheses, analyses, and perspective articles that address a variety of the social, economic, and biophysical aspects of wildland fire and its management as well as policy, science, and operational issues in Canada.

## Résumé

En septembre 2004, le Conseil canadien des ministres des forêts a établi un groupe de travail fédéral-provincial-territorial constitué de sous-ministres adjoints (SMA) chargés de développer une stratégie canadienne en matière de feux de forêt (SCFF). Les SMA ont répondu à l'appel en établissant une équipe fédérale-provinciale d'analystes, de chercheurs et de gestionnaires d'expérience en matière de feux de forêt (l'équipe de base de la SCFF), pour consulter les experts du Canada et du reste du monde, réunir de l'information, effectuer des analyses et communiquer les résultats. Cette équipe avait pour instruction gestion des feux de forêt au Canada, d'examiner les principales influences et tendances en la matière, et de définir les objectifs à atteindre avec les moyens afférents. Cette publication comprend une série de neuf rapports préparés par l'équipe de base de la SCFF et leurs associés. Ces rapports comprennet des synthèses, des analyses et des articles d'opinion sur les aspects sociaux, économiques et biophysiques des feux de forêt et de leur gestion, et sur les enjeux stratégiques, scientifiques et opérationnels posés par les feux de forêt au Canada.

# Contents

## Syntheses



## Analyses



## Perspectives

# Foreword

In October 2005, the federal, provincial, and territorial forest ministers unveiled the Canadian Wildland Fire Strategy (CWFS) Declaration. Just 1 year earlier, at their annual Canadian Council of Forest Ministers (CCFM) meeting, the ministers identified the need for a new approach to wildland fire management in Canada and commissioned an Assistant Deputy Minister (ADM)-level task group with its development. Recognizing that productive debate and progressive policy is based on sound and accessible evidence, the co-leaders of the ADM task group, from Natural Resources Canada (NRCan) and British Columbia Ministry of Forests and Range, established a seven-person core team to provide the task group with the analytical and technical support needed during the development of the CWFS. The initial directions to the Core Team were

- conduct an environment scan of the current state of wildland fire and its management in Canada,
- identify and assess the major trends and risks over the next 10–20 years, and
- seek out best practices and policies used within Canada and in other countries for consideration in designing the desired future state of wildland fire management in Canada.

The Core Team consisted of analysts, experienced fire managers, and researchers, whose collective experience covered many, but by no means all, socio-economic and biophysical aspects of wildland fire management. Consequently, on a number of occasions, the Core Team drew upon expertise and support from the broader fire management and natural hazards community within Canada and internationally.

Most of the information gathering and analysis was completed in the 6-month period between October 2004 and April 2005. The results were then presented to the ADM task group and used as one of the primary inputs in the development of the CWFS.

This report is a compilation of the major works completed by the CWFS core team and their associates. It is intended to serve as a companion document to the CWFS Vision for those interested in further exploring the rationale behind the CWFS and its key initiatives. It also has potential application for use by those seeking new funding to implement initiatives under the CWFS. The report has three distinct types of papers:

- comprehensive syntheses,
- specific analyses, and
- individual perspectives on selected topics.

These papers are presented here as a contribution to the continuing dialogue on current and future challenges of wildland fire management in Canada and how these challenges can be addressed in creative and innovative ways.

We express our thanks for the opportunity to work on this important initiative and experience the value of working together as an inter-governmental team to achieve a common goal. Our sincere appreciation is extended to our colleagues who wrote or contributed to papers in this document: Pete Bothwell, Tyler DesRoches, Bonnie McFarlane, Tony Mogus, Brian Peter, Brad Stennes, Steve Taylor, Bill Wilson; the many individuals who provided technical assistance and review comments; the administrative, editorial and publishing support staff (Sandra Williams, Debbie Lyzun, Brenda Laishley, and Sue Mayer); Gordon Miller for his guidance and feedback; and the CWFS ADM task group members, particularly the co-chairs, Brian Emmett and Tim Sheldan, for their direction and support.

## CWFS Core Team Members

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Phil Taudin-Chabot, British Columbia Ministry of Forests and Range
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# SYNTHESES

# Integrating Canadian Wildland Fire Management Policy and Institutions: Sustaining Natural Resources, Communities and Ecosystems

**S.W. Taylor**,[1] **B. Stennes**,[1] **S. Wang**,[1, 2] and **P. Taudin-Chabot**[3]

## Introduction

Forest or wildland fires occur naturally in Canadian forests. Since 1980, an annual average of 8 600 wildland fires have occurred in Canada, which have burned an average of approximately 2.5 million hectares of forest and wooded land annually. The fire regime, values at risk of damage from fire, and fire management capability vary within provinces and territories and across the country. Wildland fires in Canada can be considered as threats to timber, human life and property, or important ecological processes, depending on when and where they occur.

There are approximately 400 million hectares of forest and wooded land in Canada where wildland fires occur (Figure 1). The managed forest[4] portion of this total covers approximately 145 million hectares, largely in southern Canada, and supports an $81.8 billion forest industry. Since the early 1900s, it has been recognized that fire management is a cornerstone of forest management in Canada. Contemporary analysis using timber supply simulation models confirms the importance of fire management to sustainability of the forest harvest in the presence of fire risk (Reed and Errico 1985; Armstrong 2004; Peter and Nelson 2005). Presently, approximately 735 000 hectares of managed forest are burned annually resulting in a loss of 70 million cubic metres of wood with a value of about $1 billion (Simard 1997). The remaining forest and wooded land that is not managed for wood products is largely located in northern Canada and is de facto wilderness or wildland, but it also includes national, provincial, and territorial parks throughout Canada.

In areas with high timber or other values, a full fire-suppression response is used in attempts to control fires as quickly as possible. In areas with low values at risk to fire, a modified fire-suppression response, which attempts to control fires in a limited way, is usually used: isolated values threatened by fire are protected, or the fire is simply monitored. While only 5% of the fires detected during 1990–2004 received a modified response, they accounted for about 60% of the area burned (see Figure 2 in Peter et al. 2006 this volume).

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[3]British Columbia Ministry of Forests and Range, Coastal Fire Centre, 665 Allsbrook Road, Parksville, BC V9P 2T3
[4]A forest is considered to be managed if the harvest volume exceeds losses from natural disturbance agents such as wildfire and if harvesting shapes the forest age class distribution and composition (Clutter et al. 1983).

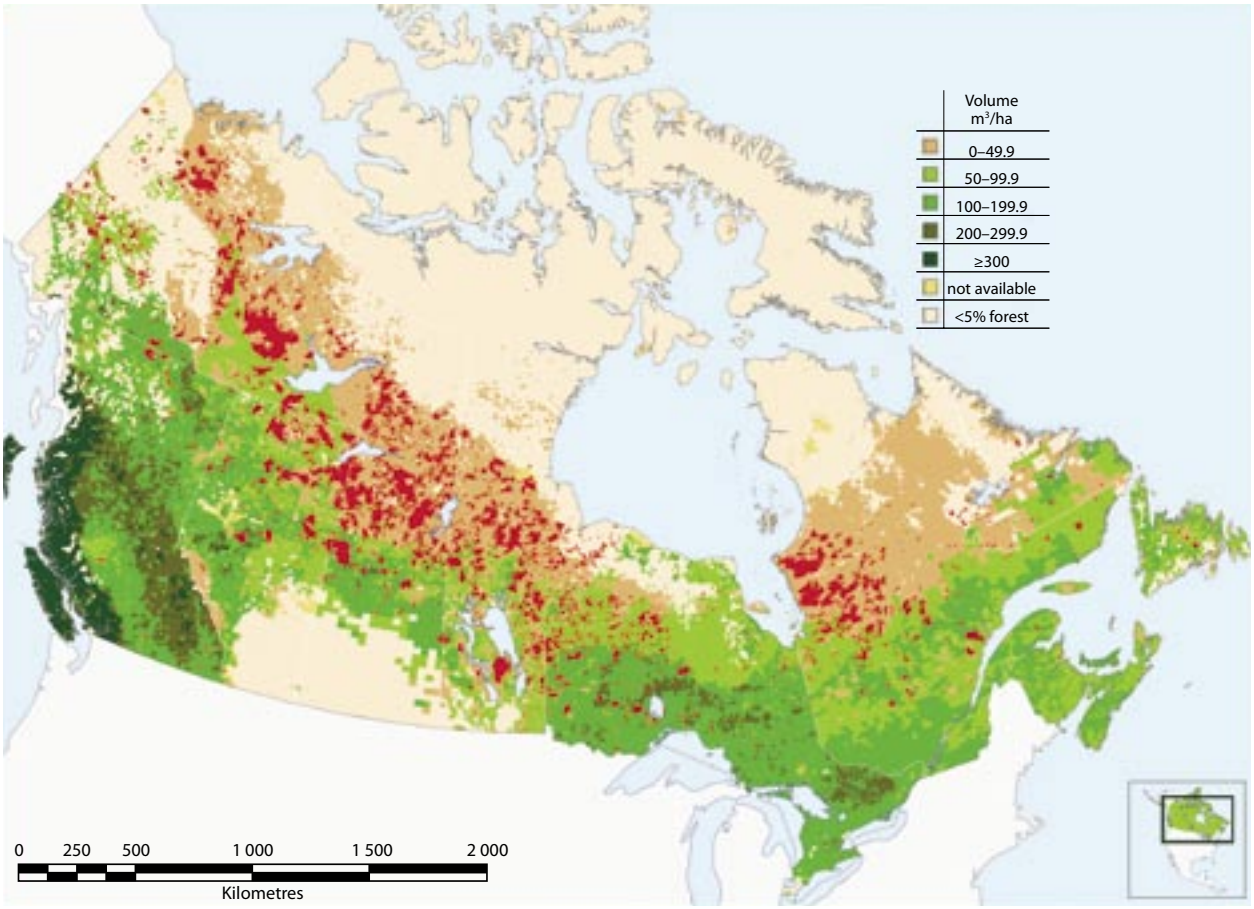


**Figure 1. Distribution of fires greater than 200 hectares (red polygons), 1980–2001 as recorded in the Canadian Large Fire Database (Stocks et al. 2002) with respect to mature forest volume in Canada's National Forest Inventory (Gillis 2001).**

Although Canada is largely an urban nation, many thousands of communities border on or are scattered throughout Canada's wildlands and are connected by highways, pipelines, transmission lines, and telecommunications facilities. Fires that start in or reach the outskirts of settled areas are referred to as wildland–urban interface (WUI) fires. The area burned by such fires is small, but the risk to life, property, and infrastructure is significant. The cost of suppressing fires at the WUI may be about 10 times the cost to suppress wildland fires of comparable size. Between 1986 and 2003 at least 136 000 people were evacuated because of wildland fire threats to communities all across Canada (Office of Critical Infrastructure Protection and Emergency Preparedness Disaster Database [*see* http://www.ocipep.gc.ca/disaster/default.asp] (Figures 2 and 3a).

Canada's forests and wildlands are largely under public ownership, and wildland fire management is therefore carried out mainly by government agencies acting in the public interest and paid for with public funds. Provincial governments have title to most of the forest and other wildland regions in Canada and thus have had responsibility for fire management on provincial crown lands since Confederation. However, the federal government also has a long-standing role in wildland fire management that began with fire suppression on federal lands in western and northern Canada in the late 1800s and has broadened in response to national needs. Large private landowners, mainly forest companies, are responsible for fire management on their lands. Although most wildland fires occur in undeveloped areas, fires that start in or spread to WUI areas enter the jurisdiction

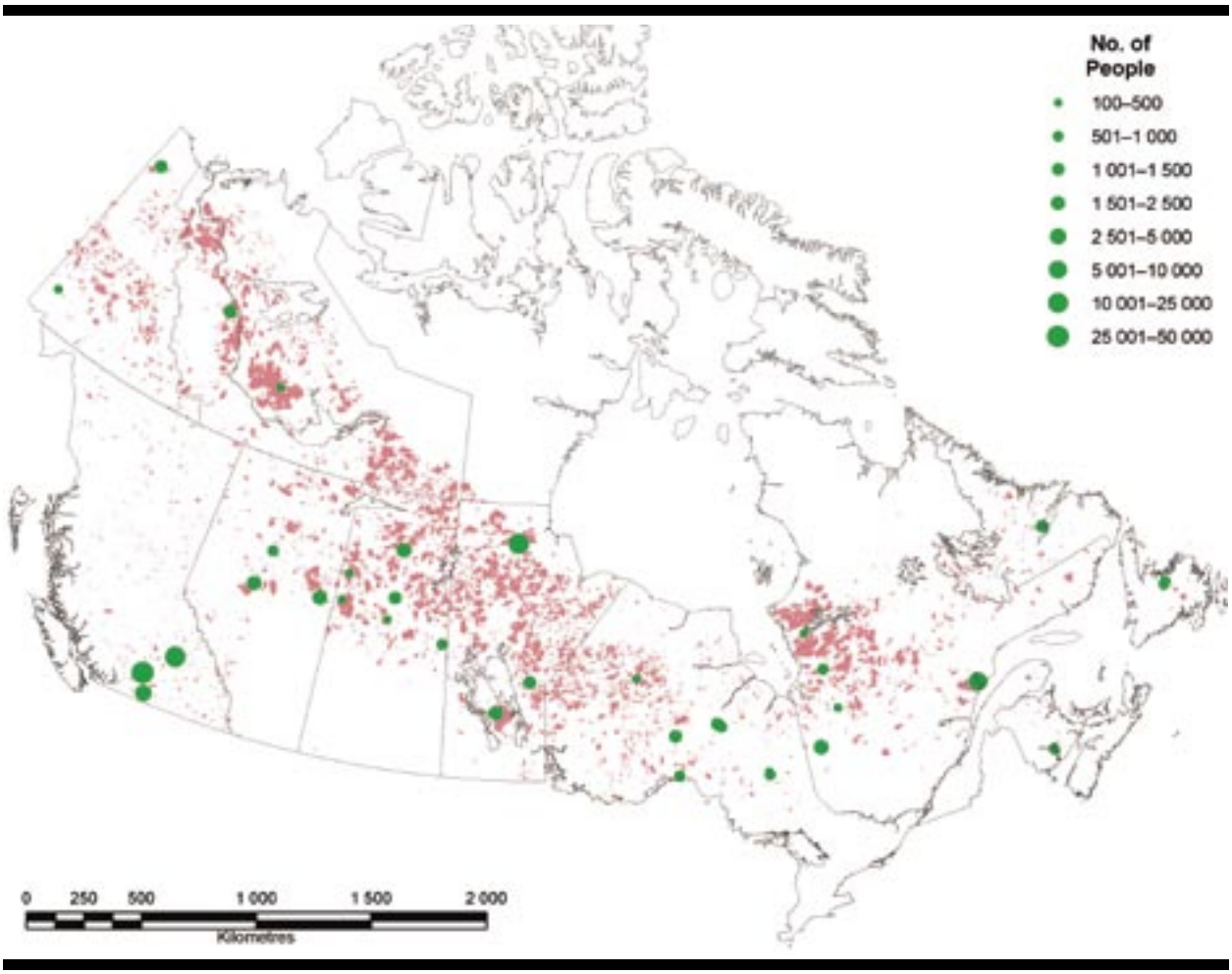


**Figure 2. Significant evacuations due to forest fires in Canada, as recorded in the Office of Critical Infrastructure and Emergency Preparedness Disaster Database (Bellisario 2002) (green circles), 1986–2003, with respect to fires greater than 200 hectares (pink polygons), as recorded in the Large Fire Database (Stocks et al. 2002).**

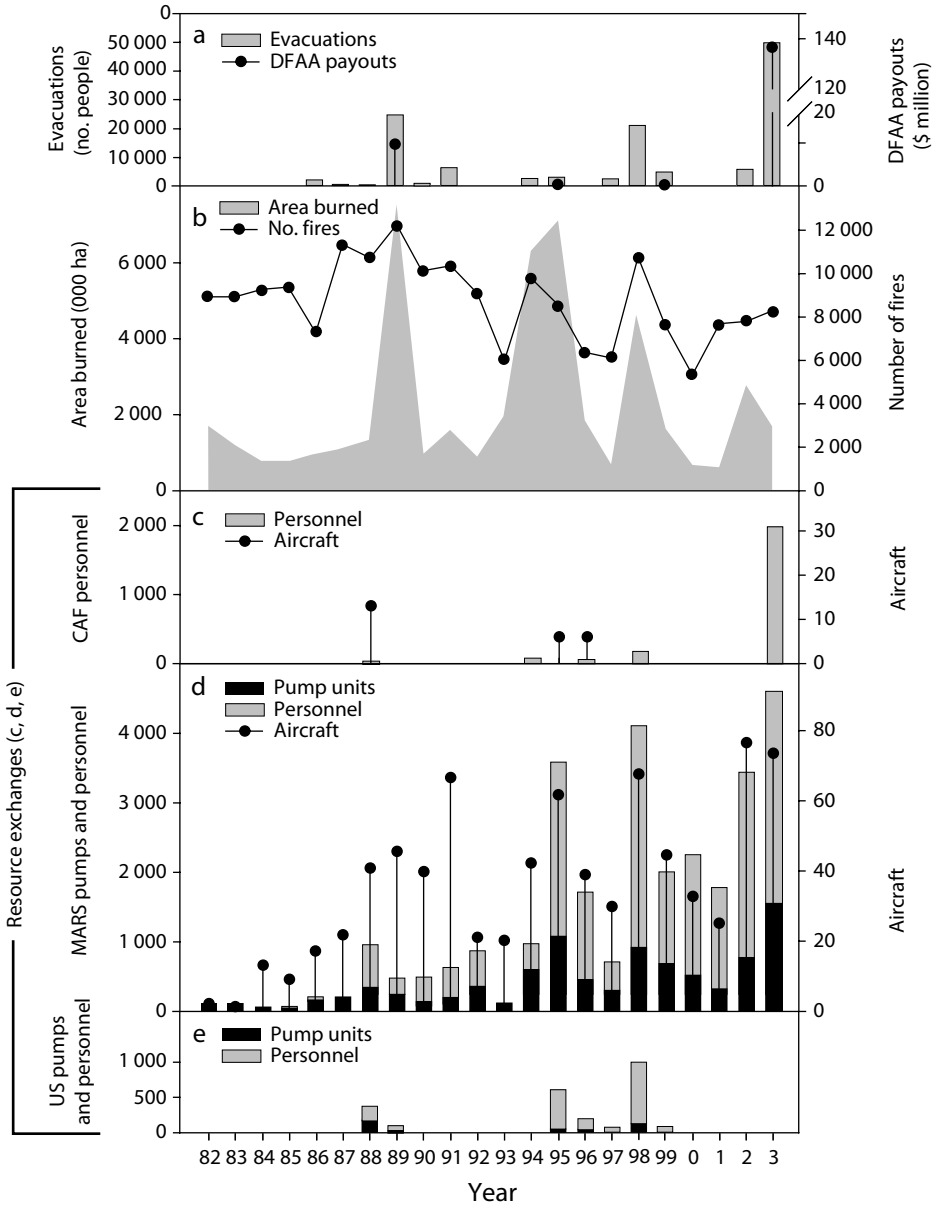


**Figure 3. Fire occurrence and resource exchanges, evacuations and disaster relief for wildfires in Canada 1982–2003.** (a) Number of people evacuated because of wildand fires as recorded in the Canadian disaster database (Bellisario 2002) and payments under the Disaster Financial Assistance Arrangement (DFFA) (personal communication, D. Borg, Public Safety and Emergency Preparedness Canada); (b) number of wildland fires and area burned in Canada (Johnston 2004); (c) Canadian Armed Forces (CAF) personnel and aircraft deployed in wildland fire operations (personal communications with senior provincial fire management staff: J. Price, B.C. Ministry of Forests and Range; W. Born, Alberta Sustainable Resource Development; D. Jessop, Saskatchewan Environment; T. Mirus, Manitoba Conservation; D. Curran, Ontario Ministry of Natural Resources; G. Lemaire, La Société de protection des forêts contre le feu; T. Greer, New Brunswick Natural Resources); (d) resource units transferred between Canadian fire management agencies under the Mutual Aid and Resource Sharing Agreement (MARS) (Johnston 2004); (e) resource units imported from the United States (personal communication, T. Johnston, Canadian Interagency Forest Fire Centre).

of local governments. As more Canadians move into the interface zone, putting more private property at risk from wildfire, the prominence of WUI fires is likely to increase. Superimpose on this an increasing recognition of fire as an important ecological process and the threat of changing climate on fire activity (Amiro et al. 2001), and it becomes clear that there will be stress on current institutional arrangements.

Wildland fire management in Canada is largely a public economy with total expenditures in excess of $500 or $600 million annually. Economics provides a conceptual framework for understanding the role of institutions in organizing, producing, and distributing these fire services. This paper examines the role of Canadian institutions with responsibilities related to wildland fire in terms of four key aspects of comprehensive emergency management—mitigation, preparedness, response, and recovery—as well as environmental management. Specific examples of alternative institutional and policy models are described from two other jurisdictions facing similar challenges: the United States and Australia.

## Mitigation

### Prevention

Since the time of European settlement, human activities, including clearing land, logging, railway operation, smoking, improperly attending to campfires, and arson, have caused wildland fires. Today, over 50% of wildland fires in Canada are caused by people (Simard 1997), and the percentage is much higher at the WUI. In the early 1900s it was recognized that fire control involved "legislation, propaganda and the perfecting of organizations to prevent and control fires" (Whitford and Craig 1918). Fire prevention, through legislation and public information campaigns, has been the main form of mitigating losses due to wildland fire in Canada. All of the provinces and territories have developed legislation and regulations limiting public and industrial use of forests during times of high fire risk or requiring that forest users have fire-fighting equipment. The Canadian Standards Association and other groups have developed standards to reduce fire starts caused by equipment, such as the requirement for spark arrestors on forestry equipment (e.g., Gonzales 2001). Provincial and territorial agencies use the media and road signs to inform the public of fire danger. The Canadian Forestry Association, provincial forestry associations, and forest agencies participate in programs such as National Forest Week to create an awareness of forest fires. However, fire and land management agencies have found it challenging to communicate to the public and government the message that reducing fire hazard and maintaining other values may sometimes require the use of fire or allowing natural wildfires in wildlands. Indeed, Canada lacks a clear national wildland fire prevention message and strategy that recognizes the duality of wanted and unwanted fire and prevention through fuels management.

### Community Planning

WUI fire risk can be mitigated either by reducing the potential for and severity of fires reaching interface areas through traditional fire prevention, suppression, and fuels management or by reducing the susceptibility of communities and structures to fire through design and the use of noncombustible building materials. However, the responsibility for these activities falls with different agencies. While provincial governments and local fire services may both be involved in fire suppression adjacent to and within communities, regulatory actions and planning processes that may reduce community susceptibility are beyond their statutory authority. Indeed, because much of the wildland urban interface is privately owned, and development on these lands is under the planning authority of local governments (e.g., cities, towns, municipalities, and regional districts), land owners and local governments have a primary role in reducing WUI fire susceptibility.

Local and regional efforts at reducing wildland urban interface fire risk have been increasing over the past 20 years, particularly in western Canada. In the mid-1980s the Thompson-Okanagan Inter-agency Committee was formed in British Columbia to address WUI fire and other emergency issues. In 1994, British Columbia published the *Beware and Prepare Community Planner,* the first comprehensive wildfire safety planning aid for people living in the WUI. This resource kit, designed to address the problems posed by the growth of interface areas, was created for BC Forest Service staff, local fire and other emergency services personnel, municipal and community leaders, property and homeowner association leaders,

property developers, and residents. The community planner has four main parts: solutions and options for fire protection in the WUI, which sets recommended minimum standards to reduce wildfire hazards and risks; forms and procedures for assessing fire hazard in the WUI; recommendations for public education, to develop local awareness and prevention options; and guidance on developing a local community fire plan.

The FireSmart program was initiated in Alberta in the late 1990s with the goal of creating awareness and communicating solutions to the problem of vulnerable interface communities (Partners in Protection 2003). The program encourages homeowners to assess risks to their own property, local planners to consider FireSmart design principles for communities, and land managers to consider mitigating strategies in landscapes surrounding interface communities. The second edition of FireSmart, published in 2003, was a collaboration between several provincial, territorial, and federal agencies and represents an unofficial Canadian standard for the prevention of interface fires.

Successful community-wide FireSmart programs have been initiated in Fort McMurray, Kamloops, Hinton, and Banff (Partners in Protection 2003). Some larger-scale projects have also been set up. The First Nations Forestry Program of the Canadian Forest Service (CFS) funded FireSmart projects in several First Nations communities across Saskatchewan (Canadian Forest Service 2004). The Yukon government has a territory-wide FireSmart program, and in 2004, $1.5 million was allocated for projects across the territory (Department of Finance 2004).

FireSmart programs rely on public education, with the responsibility for implementation left to communities or individual property holders, on a largely voluntary basis. Few local governments have made wildland fire risk reduction activities compulsory, even in historically fire-prone areas. This may be due in part to a lack of regulatory tools or capacity. In 1987, the then mayor of Penticton, Dorothy Whitaker, addressed the Northwest Fire Council (Whittaker 1988):

> What we are lacking are very specific rules for fire prevention under the *Municipal Act*. Some of the specific rules that are so desperately needed are such things as (1) insurance that a secondary access is created; (2) regulations that no shake roofs be used in subdivisions that are out in the forested area; and; (3) at the building permit stage, an inspection to find out whether the property owner has cleaned out his property so that there is not miscellaneous material lying around which would add fuel to any potential fire.

The development of model plans and bylaws (e.g., Buchan 2002) may assist other local governments with limited resources in developing their own planning and regulatory tools. Pearce (2003) notes that disaster management and community planning should be integrated, but that they are not traditionally linked.

### Fuels Management

Most provinces do not have fuel management or mitigation programs, and the few that do exist are in the early stages of development, with limited funding. In some cases there may be regulatory barriers to fuels management, such as a requirement that forest plantation stocking levels be maintained following forest management activities on Crown land or that timber cut during fuel treatments be included in the annual allowable cut.

### Building Standards

The *National Building Code of Canada* 2005 (Canadian Commission on Building and Fire Codes 2005) is designed to ensure that buildings are structurally sound, safe from fire, free of health hazards, and accessible. The *National Fire Code of Canada* 2005 (Canadian Commission on Building and Fire Codes 2005) establishes an adequate level of fire safety for both occupants and emergency responders, inside and outside of buildings and facilities. The national building and fire codes are used as models for virtually all building code regulations in Canada. The National Research Council of Canada's Institute for Construction Research provides research in support of objective-based code development. However, neither the national building or fire codes nor the corresponding provincial codes deal with the threat of wildland fire to structures and life. Accounting for wildfire risk in Canadian building design and construction standards, commensurate with risk (in

a manner similar to that for earthquake risk), could considerably reduce structural losses and potential insurance and disaster relief claims arising from wildland fire.

### Private Insurance Incentives

Prior to 2000, payouts for insured property losses due to wildland fire have been low relative to other natural disasters such as flooding and hailstorms, with no single fire event resulting in a loss in excess of $10 million before 2000 (Kovacs 2001). Thus the private insurance industry has paid little attention to wildland fire risk factors when setting premiums for structures in the wildland-urban interface. More recently, however, the 2003 Okanagan Mountain Park Fire, which spread to the outskirts of the City of Kelowna, resulted in payouts from private insurers totalling more than $200 million. In the future, insurers may use preconditions for insurance as a way to direct homeowners to address certain risk factors in order to minimize their losses. The roles of insurance in preparedness were recognized in the *Firestorm 2003 Provincial Review* (Filmon 2004). The most important role for private insurers is to develop premiums that reflect the true level of risk for the insured property. If premiums do not reflect the true risk, inefficient decisions about fire protection may result (Hesseln 2001). Indeed in some cases insurance coverage may promote high-risk behaviour, the so-called moral hazard problem. A moral hazard exists when the act of insuring creates an incentive for the insured party to use less than optimal inputs for safeguarding the insured property or to underemploy levels of a precautionary activity (Turvey et al. 2002).

## Preparedness

### Forest Fire Danger Rating

In Canada, differences in weather and ignition potential cause fire danger to vary within provinces and across the country from day to day over the fire season. Because fire management resources are costly and limited, some means is needed to determine fire danger, which can then be used to allocate appropriate resources accordingly over space and through time.

The Canadian Forest Fire Danger Rating System (CFFDRS), developed by the CFS, is used by all fire management agencies in the country and provides a common basis for assessing fire danger, setting preparedness levels, and allocating resources. It is implemented through various means from simple tables to the sophisticated Spatial Fire Management System (SFMS) (Taylor and Alexander 2006). The CFS provides SFMS and other danger rating material at no cost to any agency in Canada that wishes to use it. Extensions of the CFFDRS have resulted in two information systems for monitoring fire activity for national level reporting (Lee et al. 2002): the Canadian Wildland Fire Information System and the Fire Monitoring, Modelling, and Mapping System. The CFFDRS and its extensions indicate fire potential, but they do not track or forecast the availability of fire management resources. Canada does not have a formal national preparedness system to monitor the national state of readiness to deal with a national-scale fire situation, if the fire suppression service demand approaches national capacity.

### Fire Weather Forecasting

Fire weather forecasts, in concert with fire danger rating, are crucial to fire prevention and preparedness. Canada's national weather service (now called the Meteorological Service of Canada [MSC]) became involved in providing weather information and forecasts to support forest fire management in the early 1900s. The MSC provided fire weather forecasts or forecasters to most provinces on a seasonal basis from the late 1960s to the mid-1990s. Since the mid-1990s, when the MSC implemented a cost recovery program for forecast services, many provincial agencies have made alternative arrangements or reduced use of MSC forecast services. In addition, many of the trained MSC fire weather personnel have retired or are near retirement, and they have not been replaced. However, the MSC still has a statutory responsibility for issuing extreme weather advisories. There may be efficiencies to be gained in a coordinated national approach to fire weather forecast services.

### Positioning Resources

Since the early 1980s, there has been a fundamental shift by Canadian fire management agencies to move resources within their jurisdictions in anticipation of potential wildland fires, as indicated by fire danger and fire weather forecasts. Ground and aerial fire-fighting resources are moved to areas where the expected

number of wildfires starting (e.g., through lightning activity) and potential fire behaviour will necessitate quick deployment of resources for successful initial attack. The success of this strategy depends on accurate fire weather forecasts and projections of fire danger and potential fire behaviour.

Throughout the fire season, neighbouring provincial and territorial fire management agencies communicate with each other and through the Canadian Interagency Forest Fire Centre (CIFFC) regarding resource availability and potential requirements for fire suppression along common border areas. However, resource sharing is largely reactive with limited planned resource allocation on a national basis.

### Detection

Because the success of fire control activities declines with increasing fire size at the time of initial attack, detecting fires soon after ignition and responding to them when they are small constitute an important strategy for fire management in Canada. Most fires are detected by members of the public; commercial air flights, forest industrial operators, lookouts, and directed air and surface patrols are other important detection sources. Since the 1980s, lightning location systems have been used to direct fire patrol flights to areas of lightning strikes after the occurrence of lightning storms. Currently, the MSC operates a national lightning location system to which provincial and territorial agencies may subscribe on a cost-recovery basis.

## Response

### Fire Suppression on Provincial Crown Land

Provincial and territorial governments have title to most forest and other wildland in Canada and thus have the primary responsibility for wildland fire response. However, fire management objectives vary across the country and within provinces and territories, depending on land management objectives and on forest resources and other values at risk. Many provinces use forms of zonation whereby fires in the managed forest and other high-value areas are suppressed more vigorously than fires in other areas. The less vigorously protected areas are known by different names, such as observation zones (Saskatchewan) and ecological fire management zones (Alberta). In other jurisdictions, including British Columbia, the threat posed by an individual fire is evaluated and action taken on a case-by-case basis. In the Yukon and the Northwest Territories, suppression effort is focused on areas around settlements.

Provincial and territorial governments spend a significant proportion of their overall budgets on fire suppression. However, because of the annual variation in fire weather, almost every fire management agency in Canada experiences considerable annual variation in fire load (Figure 3b) and expenditures. For example, in 2003 the British Columbia Ministry of Forests paid $370 million for fire suppression, much more than the average of $53 million over the preceding 10 years (source: BC Ministry of Forests and Range Protection Program). Most agencies have a base budget to cover preparedness and typical suppression expenditures and must seek more money from their provincial legislatures in extreme fire years. In 2002, Alberta managed its fire suppression budget by purchasing insurance. While it has not been practical for Alberta to continue this practice (because of an increase in the insurance premium and other conditions proposed by the insurer), this option is still being explored.

Most provincial and territorial fire management agencies fund fire suppression from general revenue. However, in the province of Quebec, La Société de protection des forêts contre le feu (SOPFEU), a partnership between the forest industry and the provincial government, shares the costs of fire management in southern Quebec. In 2004, British Columbia introduced its *Wildfire Act* and initiated a cost-sharing program for which clients contributed $28.1 million, close to 24% of the budget, through negotiated agreements. Current and future clients include the forest industry, private landowners, utilities, railways, and the federal government.

Many agencies have established targets for measuring the success of fire management within the managed forest. In British Columbia, for example, initial attack is judged successful if unwanted wildfires are limited to 4 hectares. Cumming (2005) determined the degree of effectiveness of fire suppression in reducing the size of fires in northern Alberta through statistical modelling. However, the return on investment through increased timber production and value has not been well quantified.

### Fire Suppression in National Parks and on Other Federal Lands

National parks constitute 2% of the land area of Canada. Fire management in national parks began over 100 years ago, and Parks Canada now has designated fire management staff who are responsible for all aspects of fire management, including planning, initial and sustained attack, and the use of prescribed burning. Through CIFFC, Parks Canada can request resources from provincial agencies, particularly if a fire in a national park threatens values on adjacent provincial crown land. In contrast, fire suppression on Indian reserves and Department of National Defence lands is usually carried out through agreements with provincial agencies, who may charge back their costs to the federal government.

### Fire Suppression on Private Land

In most provinces, private forest landowners and tenure holders are responsible for suppressing fires that begin on their lands. On smaller private properties, provincial agencies often take fire suppression action, particularly if crown resources are threatened, charging back the costs to the landowner. In provinces where there are significant private holdings, individual companies or consortiums carry out fire suppression. Most notable is SOPFEU in Quebec, whose private members contribute half of the operating costs. On Vancouver Island, four major forest companies operated a consortium called Forest Industry Flying Tankers for many years, although there is now only one remaining member company, which owns Flying Tankers Inc. and its two Martin Mars water bombers. These aircraft can be dispatched by the B.C. Forest Service and are used as part of its provincial air tanker fleet.

### Fire Suppression in Municipalities and Rural Fire Protection Areas

Municipal and volunteer fire departments suppress grass, brush, and forest fires that start within municipal and rural fire protection areas. Most local governments have mutual aid agreements with neighbouring jurisdictions to augment their own resources if necessary to respond to any type of fire. In addition, many local governments have agreements or operating guidelines with provincial agencies to draw on provincial resources if wildland fires escape initial attack. In some jurisdictions, including New Brunswick, which does not use provincial initial attack crews, firefighters from volunteer fire departments are often the first responders. The number of wildland and WUI fires attended by local fire departments in Canada is not accounted for in national reporting and so is unknown, but it is believed to be significant.

### Community Evacuations and States of Emergency

Provincial and territorial fire management agencies must work with civil authorities to effect evacuations when wildland fire threatens communities. In British Columbia, for example, certain Ministry of Forests and Range employees, including fire crew members, are designated as officials with legislative authority to order all persons to leave an area so that their safety is not compromised by a fire or fire fighting operations; this is referred to as a tactical evacuation. However, if a wildfire is anticipated to spread into a community, the Incident Commander requests an evacuation alert or order by the local government authority or provincial Fire Commissioner; this is referred to as a strategic evacuation. Evacuation orders are enforced by the Royal Canadian Mounted Police or other police services, while the Provincial Emergency Program works with the local government authority to coordinate reception centres and support services for evacuees. Provincial agencies do not have the legislative authority to order people to evacuate Indian reserves, Department of National Defence reserves, or other federal lands. The default practice is for the provincial agency representatives to advise people living on such lands that it would be prudent to leave, and the RCMP or other police services help to promote this safety message. This practice may be interpreted by those affected as an evacuation order, even though there is no legislative requirement to leave.

Civil authorities may declare a state of emergency to access the extraordinary powers needed to implement an emergency plan. In British Columbia, for example, a local government may declare a state of local emergency, and the solicitor general may declare a provincial emergency. The declaration of a state of emergency gives the declaring agency wide-ranging powers under the *Emergency Program Act*. A provincial state of emergency has been declared on two occasions in British Columbia, both times in response to wildland fire.

During a provincial state of emergency, or when all other civilian resources are committed, the attorney general in a provincial government may request assistance (military aid of the civil power) from the Department of National Defence (chief of defence staff). Military personnel do not regularly receive training in forest fire suppression and so must undergo a basic training course before going to the fire line. Military personnel are usually employed for sustained action in cases of contained fires or in mop-up activities. Military aircraft and other transport services have also been used to move firefighters and to evacuate remote communities. Since 1977, the Department of National Defence has been deployed in at least 20 incidents in New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia (personal communications with senior provincial fire management staff: J. Price, B.C. Ministry of Forests and Range; W. Born, Alberta Sustainable Resource Development; D. Jessop, Saskatchewan Environment; T. Mirus, Manitoba Conservation; D. Curran, Ontario Ministry of Natural Resources; G. Lemaire, La Société de protection des forêts contre le feu; T. Greer, New Brunswick Natural Resources) (Figure 3c). Presently, military aid within Canada is being coordinated through Canada Command.

## Mutual Aid and Resource-Sharing

In 1981 the CIFFC was formed to manage the exchange of fire suppression resources across Canada under the Canadian Interagency Mutual Aid and Resource Sharing (MARS) Agreement. The MARS Agreement outlines three categories of resources: equipment, personnel, and aircraft. Mutual aid serves to address two important problems in fire management (Oakerson 1999): 1) problems that cross jurisdictional boundaries; 2) peak-load problems created by occasional extreme demands on service capacity. The driving force behind cooperation and mutual aid is self-interested reciprocity (Oakerson 1999).

The CIFFC, located in Winnipeg, operates as a private nonprofit corporation with two levels of management. The Board of Corporate Trustees is made up of deputy ministers responsible for forestry representing each of the provinces and territories and the federal government. This group sets policy, gives direction, and approves annual budgets for the fire centre. The Board of Directors is made up of the directors responsible for forest fire management in each of the provinces and territories and a representative of the federal government. This group prepares budgets and policies and controls the operation and expenditures of the fire centre. Fire centre staff operate the centre and implement programs approved by the Board of Directors and the Board of Corporate Trustees. In addition, six working groups, made up of staff from the member agencies, have been formed to address common problems and issues, share resources, and set national standards for aviation, resource management, fire equipment, fire science and technology, national training, and forest and fire meteorology. The CIFFC working groups' projects are funded on a case-by-case basis by the member agencies.

Since the inception of CIFFC, exchanges of fire management staff between agencies in Canada have increased steadily (Figure 3d). Such exchanges involve trained, experienced personnel, ranging from fire crew members to incident command teams. The most common request is for experienced and cohesive fire crews. However, because highly trained crews are in demand by both lending and receiving agencies they may not always be available. In essence, resource transfers are a means of managing the risk of extreme demands on resources that are characteristic of the Canadian fire environment and have become a crucial element of wildfire management. Personnel transfers have resulted in efficiencies for fire management agencies and have provided broader experience for fire management staff. However, the existence of a professional fire management workforce, trained to a national standard of best practices, is essential for such resource transfers to be successful.

Canada has also established cooperative relationships with the United States to exchange fire fighting resources. A diplomatic note signed by the Canadian and United States governments authorizes the sharing of resources for fire suppression across the international boundary. The Canada/United States Reciprocal Forest Fire Fighting Arrangement (CANUS), combined with several other exemptions, allows for quick movement of resources through the customs and immigration services of each nation. Resource exchanges are managed in Canada by the

CIFFC and in the US by the National Interagency Fire Center. US crews and equipment were imported to Canada during eight separate years between 1988 and 2004 (Figure 3e).

In addition to the national-level resource transfers, several provinces and individual US states have formed mutual aid associations, which allow direct cross-border sharing of resources. New Brunswick, Nova Scotia, Quebec, and seven New England states have formed the Northeastern Forest Fire Compact; Ontario, Manitoba, Michigan, Wisconsin, and Minnesota are members of the Great Lakes Forest Fire Compact; and Alberta, British Columbia, the Yukon, Alaska, and four Pacific Northwest states are members of the Northwest Wildland Fire Compact.

Mutual aid is not a complete solution to all peak-load problems. In addition to enlightened self-interest, mutual aid depends on there being low spatial autocorrelation in the demand for fire suppression resources (fire danger is not extreme in every province and territory at once). When fire load does increase across several provinces or territories at once, demand for resources can exceed the national supply. Furthermore, mutual aid is strictly voluntary: agencies must continually balance the benefits of lending resources with the risk of not meeting their internal demand for fire services.

While there is a significant degree of resource sharing, fire management agencies may at the same time compete for contracted resources such as rotary-wing aircraft, particularly when fire danger is high across several provinces or territories at once.

### Incident Command System

A common command-and-control framework for wildfire management across the country is important for facilitating resource exchanges such as those described above for personnel and equipment. The Incident Command System (ICS) provides such a framework. The ICS is a standardized organizational structure that was originally developed in California in the 1970s for use in wildfire situations; it is now used to manage a variety of major emergencies (Hannestad 2005). In 2002, under the auspices of the CIFFC, all Canadian fire management agencies adopted a Canadian ICS. In addition, the ICS is used by a number of provincial emergency management organizations, but it has not been universally adopted by all federal, provincial, and local government agencies. The WUI fire that occurred in Kelowna in 2003 brought a host of federal, provincial, regional, and municipal agencies together, which highlighted the importance of having a standard command-and-control structure.

### Health and Safety of Firefighters

In most provinces, Workers' Compensation Board regulations apply to fire management operations, but the specifics vary across the country. In British Columbia, for example, a danger tree assessment is required before workers can enter a burned-over area to carry out mop-up operations.

In 2004, in response to the Westray Mine disaster, Bill C-45 (Criminal Liability of Organizations) came into force at a national level. Article 3 of the bill provides that:

> Every one who undertakes, or has the authority, to direct how another person does work or performs a task is under a legal duty to take reasonable steps to prevent bodily harm to that person, or any other person, arising from that work task.

More simply, Bill C-45 requires that employers take steps to provide a safe workplace for their workers. Although Canada has a generally good safety record in forest fire management, Bill C-45 is increasing awareness of the duty of care to forest firefighters and the need to provide appropriate training.

### National Air Tanker Fleet

Since the 1960s, water bombers and land-based air tankers carrying fire retardant have become central to initial attack in Canada. In 1983, under the Cooperative Supply Agreement developed by the Canadian Council of Resource and Environment Ministers, the federal government and six provincial governments acquired a total of 29 Canadair CL-215 water bomber aircraft. The federal government purchased 14 of these planes (the balance were purchased by individual provinces), which were leased to Newfoundland, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and the Northwest Territories for a period of 15 years, after

which time title was transferred to the lessees. The lessee provinces were responsible for operating and maintaining the aircraft and making them available to other members, as directed by CIFFC, when not required for higher-priority situations in their own jurisdictions. In practice, however, all provincially owned or contracted aircraft in Canada are essentially part of a national fleet and, through the MARS Agreement, are available to other agencies when not required in the home province or territory and are the most frequently shared resource.

### Private Sector Suppliers of Fire Suppression Equipment and Services

In British Columbia and the Yukon, the fleet of air tankers is owned by the private sector rather than the public sector, and services are provided to the provincial forest agencies on a contractual basis. Western firms include Conair Ltd., Air Spray, and Flying Tankers Inc. Several provinces use a mix of aircraft from public, private, and public–private partnership fleets. Alberta and the Northwest Territories use contract air tankers, but each also owns a number of Canadair CL-215s. The New Brunswick government is a member of Forest Protection Ltd. (FPL) along with 6 of the largest private forest companies. FPL owns a fleet of 9 single-engine air tankers and associated spotter planes. In addition, helicopters and small planes for fire detection are hired on a contractual basis in many provinces. Rotary-wing aircraft are primarily supplied by the private sector on a contractual or casual hire basis, depending on demand.

Forest companies and forest industry contractors are the primary suppliers of heavy equipment, such as bulldozers and excavators, for fire suppression operations. In most jurisdictions, provincial or territorial fire management agencies may requisition equipment as an emergency resource, and the owners are paid a statutory rate. Private fire suppression contractors have also provided crews in western Canada and the Northwest Territories. Private contractors are generally used within a province and are not transferred between provinces unless they meet contract qualifications and performance standards in the receiving jurisdiction.

## Recovery

### Wildland Rehabilitation and Recovery

Many fire management agencies require rehabilitation following fire suppression operations, such as the rehabilitation of fireguards. In addition, some land management agencies reforest managed forest land or fell dangerous trees in accessible areas of parks. The rehabilitation costs associated with fire suppression operations are generally treated as part of the overall suppression expenditure, while costs for rehabilitation or revegetation of burned areas are generally treated as forest management costs.

### Disaster Financial Assistance

Since 1970, the federal government has provided assistance to provinces for expenditures incurred in responding to and recovering from large-scale natural disasters. Dore (2003) defines disasters as situations which are beyond a community's capacity to deal with internally. Assistance is provided through Disaster Financial Assistance Arrangements (DFAAs) administered by Public Safety and Emergency Preparedness Canada according to a funding formula (Table 1).

**Table 1. Formula for Disaster Financial Assistance Arrangement**

| Eligible provincial or territorial expenditures | Government of Canada share (%) |
|---|---|
| First $1 per capita | 0 |
| Next $2 per capita | 50 |
| Next $2 per capita | 75 |
| Remainder | 90 |

Source: Emergency Preparedness Canada (1988).

DFAA assistance is paid directly to the provinces and territories, which determine the nature of payouts from this program; DFAA funds do not go to individuals or communities. Between 1975 and 1995, forest fires were the third largest hazard type for which DFAA payouts were made (Brun et al. 1997). Since 1992, payments through this program for wildland fire losses have totalled $150 million, with the 2003 fires in British Columbia accounting for $137 million of the total (Figure 3a).

The federal government has recently consolidated a number of agencies into Public Safety and Emergency Preparedness Canada, and PSEPC has engaged in a consultative process with the provinces, territories, and stakeholders such as the insurance industry, towards developing a national disaster mitigation strategy. Some approaches that were recommended to encourage disaster mitigation included using financial incentives (tax breaks, reduced insurance premiums, grants and loans) as well as awards and recognition (Hwacha 2005).

### Private Insurance Industry

As mentioned previously, the private insurance industry had low payouts for WUI events before 2000 (Kovacs 2001). In 2003, the private insurance sector paid out over $200 million in claims, making it a very important institution for recovery from WUI fires in that year. Within Canada, insurance companies have not yet placed conditions on the construction or reconstruction of buildings to obtain insurance in fire-prone areas. State Farm Insurance, the largest insurance company in the United States, is starting to address this situation.

## Fire and the Environment

### Ecosystem Management

About 9% of Canada is designated as protected park and wilderness area. As a result of formal and informal designation of wildfire protection zones, there is an additional 255 million hectares (or approximately 65% of Canada's forest and wooded land) of de facto wilderness in northern Canada where wildfires occur as a more or less natural ecological process. Indeed, approximately 60% of the average annual area burned in Canada is accounted for by large fires burning freely in remote locations outside of the managed forest that have low values at risk.

The management of fire to achieve ecological objectives is of increasing importance in protected areas. In the 1970s national park policy recognized the natural role of fire in many ecosystems and allowed for limited suppression of wildfires (so-called "let burn" practices) and prescribed fire where such approaches were compatible with resource management objectives. Subsequently, fire management plans for each park have been prepared, which give direction for suppression action and use of prescribed fire. Parks Canada is developing a business plan for prescribed burns to improve the use of prescribed fire across the park system. Since the federal government enacted the *Species at Risk Act* in 2002, all aspects of fire management in Parks Canada must now give due consideration to species at risk.

Provincial park agencies in many provinces allow fires that occur within larger provincial parks to burn without suppression, or they set prescribed fires to meet ecological objectives or to enhance wildlife habitat. However, meeting these objectives is challenging in many provinces, because of shortages of personnel, funding, and fire management expertise. Using fire to meet ecological objectives in the smaller parks in southern Canada is difficult because of the need to be a "good neighbour" and related concerns about smoke and risk to adjacent populated areas (Cole et al. 1996).

### Air Quality

In the early 1970s, the federal government established National Ambient Air Quality Objectives, which set acceptable 24-hour average reference levels for concentrations of $PM_{10}$ (inhalable particulates less than 10 microns in diameter) and other pollutants. Environment Canada coordinates the National Air Pollution Surveillance Network, which monitors particulates, but there is no enforcement of the objectives at a national level. Emissions from prescribed fires, but not wildfires, are tracked in national inventories. In the United States, the Clear Air Act aims to maintain visibility in class 1 areas (mainly national parks), sets standards for $PM_{10}$, and requires individual states to inventory emissions and file a reduction plan.

The Canada–US Air Quality Agreement, signed in 1991, deals mainly with reduction of sulfur dioxide and nitrous oxide ($NO_x$) emissions. However, it requires that each nation give notice of significant new sources of emissions, including particulates, within 100 kilometres of the border, which may influence prescribed burning in the boundary region. In Canada, notification is administered by the Transboundary Air Issues Notification Branch in the Environmental Protection Service of Environment Canada.

Provincial and territorial agencies are also concerned with the health impacts of smoke. In British Columbia, for example, the Ministry of Environment administers the Open Burning Smoke Control Regulations under the *Waste Management Act.*

The MSC issues a ventilation index in some parts of the country to assist fire managers in assessing whether atmospheric conditions are suitable for the dispersion of smoke from open-burning and prescribed fires.

### The Carbon Budget of Canada's Forests

In 1997, Canada and more than 160 other countries agreed to reduce greenhouse gas (GHG) emissions. The agreement that set out those targets, and the options available to countries to achieve them, is known as the Kyoto Protocol. Canada's target is to reduce its GHG emissions to 6% below 1990 levels during the period between 1 January 2008 and 31 December 2012. Canada played a key role in persuading the international community to acknowledge the contribution of forest and agricultural land management practices that absorb and store carbon dioxide from the atmosphere to achieving the Kyoto GHG emissions limitation and reduction targets. Under Articles 3.4 and 3.7 of the agreement, Canada has until 2006 to decide whether to include forest management in its commitments (Kurz and Apps 2006). This issue is being examined by the Interdepartmental Sinks Committee (which consists of representatives from Natural Resources Canada, the Department of International and Foreign Affairs, Environment Canada, and Agriculture Canada).

Forestry technical analyses are being prepared by the National Forest Sinks Committee, and federal and provincial groups. The analyses to date have suggested that because of their inherent variability, natural disturbances (especially forest fires) constitute a major source of uncertainty over whether Canadian forests would be a net carbon source or sink over the Kyoto commitment period, or indeed any particular 5-year period.

## Intergovernmental Cooperation

Cooperative arrangements between federal and provincial governments have had an important influence on wildland fire management in Canada since organized fire protection began in the early 1900s. Wilson (2000) discussed four models of federalism pertaining to delivery of health care services in Canada that can also be seen in delivery of Canadian fire management services, namely (Table 2): disentangled federalism; provincial collaboration; federal unilateralism; and cooperative federalism. Following Confederation, fire management followed a type of disentangled federalism, with each agency and level of government operating independently. Very soon, however, cooperative fire management activities began. During 1913–1914 the Commission on Conservation Canada's Committee on Forests examined forest fire protection issues across the country (Leavitt et al. 1915). This work resulted, in part, in changes to regulations to reduce railway fires. Subsequently, a national conference on forest fires in 1924 brought federal and provincial fire management agencies together for the first time.

Following the transfer of federal resources in western Canada to the provinces in the late 1920s and devolution of northern resources to the governments of the Northwest Territories and Yukon in the 1990s, provincial and territorial governments in Canada took on a increasing responsibility for forest fire response. However, cooperative relationships also continued to grow. Between 1952 and 1997, the Canadian Committee on Forest Fire Control (CCFFC), later renamed the Canadian Committee on Forest Fire Management (CCFFM), operated under the auspices of the National Research Council of Canada. Representatives of fire management agencies, universities and technical schools, the forest industry, and the CFS contributed to this group. Over its 45-year life, various subcommittees and task groups on fire research, terminology, equipment, training and education, and communications, among other topics, addressed important common issues. Although the CCFFM and its predecessors did not provide direct funding for fire research or management, it was an important vehicle for communication. Since the 1980s, there has been an increasing trend to share resources among provinces and territories under the Canadian Interagency MARS Agreement, a form of provincial collaboration and inter-dependence.

While the direct federal role in fire management has been greatly reduced since the early 1900s, other roles have expanded, and presently at least

**Table 2. Types of federalism in Canadian fire management**

| Definition | Example | Strengths | Weaknesses |
|---|---|---|---|
| **Disentangled federalism:** Federal and provincial governments work independently with little interaction. | Fire control after Confederation until the 1980s. | Jurisdictional autonomy, potential for provincial experimentation | Difficult to establish national programs and national standards |
| **Interprovincial collaboration:** Provinces work collaboratively, with limited federal involvement, to attain policy goals. | Canadian Interagency Mutual Aid and Resource Sharing (MARS) Agreement | Jurisdictional autonomy, potential for provincial experimentation | No guarantee of collaboration in absence of federal hedgemony, potential for absence of national standards |
| **Federal unilateralism:** Federal government directs provincial policy, usually through conditional funding. | *Federal Disaster Financial Assistance Act* | Most effective for national programs and associated benefits (economies of scale, reduced overlap and duplication) | Infringes on jurisdictional autonomy |
| **Collaborative federalism:** Federal and provincial governments work collaboratively to attain policy goals | Canadian Forest Fire Danger Rating System | Allows for national programs while protecting jurisdictional autonomy | Potential for excluding the public, requires effective dispute resolution mechanism, blurs accountability |

Adapted from Wilson (2000). "Health care, federalism and the new Social Union" — Reprinted from *CMAJ* 18-Apr-00; 162(8), Page(s) 1171–1174 by permission of the publisher. © 2000 Canadian Medical Association.

9 federal departments and agencies have some interest in wildland fire management (Table 3). In developing these roles the federal government has acted collaboratively in some cases and unilaterally in others. Asselin (2001) noted that governments have the power to legislate, tax, and spend, which are distinct and not necessarily connected. Although the federal, provincial, and territorial governments cannot legislate on matters beyond their jurisdiction, they can fund programs or enter into cost-shared agreements to achieve their aims in those matters. Thus, where the federal government does not have a direct responsibility (as for fire management on provincial lands) it has exercised influence to meet policy goals through its power to spend (e.g., the Cooperative Supply Agreement) and the expertise of the federal bureaucracy. Asselin (2001) also noted that Canadian federalism is characterized by unity and diversity, shared responsibility and autonomy; this is certainly reflected in Canadian wildland fire management policy and institutions. However, the Canadian federation is increasingly evolving towards greater levels of cooperation and consensus building while still respecting the constitutional jurisdiction of each order of government (Dion 1999). Cooperative or collaborative federalism is based on the premise that since each level of government possesses strong jurisdictional powers, effective governance depends on coordination (Simeon 2001). A recent collaborative prototype was the 1994 federal provincial Agreement on Internal Trade to reduce internal barriers to trade.

In 2005, the Canadian Council of Forest Ministers signed the Canadian Wildland Fire Strategy Declaration, an agreement to enhance Canadian fire management. The challenge for a national wildland fire management strategy is to build national capacity through sharing risk, responsibility and resources among all levels of government while respecting jurisdictional interests and maintaining the strengths conferred by autonomy and diversity.

**Table 3. Summary of the Government of Canada's interests and responsibilities related to wildland fire**

| Federal department/agency | Authorities and policy instruments | Role |
|---|---|---|
| Natural Resources Canada, Canadian Forest Service | *Forestry Act*<br>Canada US Australia Agreement on Wildand Fire Science Research | Forest fire research and funding contributions to Canadian Interagency Forest Fire Centre |
| Environment Canada and Natural Resources Canada | Kyoto Protocol to the UNFCCC (United Nations Framework Convention on Climate Change) | Greenhouse gas reporting<br>Carbon budget of Canadian forests |
| Environment Canada, Meteorlogical Service of Canada | *Government Organization Act* 1979; *Department of the Environment Act* | Extreme weather advisories<br>Lightning location system<br>Ventilation forecasting |
| Environment Canada | Canada US Agreement on Air Quality | Transboundary smoke emissions |
| | *Canadian Environmental Protection Act*; National Ambient Air Quality Standards | Particulate standards and monitoring |
| | *Species at Risk Act* | Conservation of species at risk on federal lands |
| Public Safety and Emergency Preparedness Canada | *Emergency Preparedness Act*<br>Disaster Financial Assistance Arrangements | Financial compensation for uninsured losses in natural disasters |
| Department of National Defense | *Department of National Defense Act* | Aid to civil authorities<br>Fire management on defense reserves |
| Department of Canadian Heritage, Parks Canada | *Canadian Parks Act* | Fire management in national parks |
| Department of Indian and Northern Affairs | *Indian Act* | Community protection and fire management on Indian Reserves |
| Department of Trade and Foreign Affairs | Canada US Reciprocal Forest Fire Fighting Arrangement | Facilitating cross border fire fighting resource movement |
| National Research Council | National Building and Fire Codes | Model building codes |

## Trends in Other Jurisdictions

Although the United States and Australia have fire environments, patterns of land ownership, and institutional structures that differ from those in Canada, both countries have significant fire problems,[5] and their experiences may provide useful lessons and models for Canada.

### Mitigation

There has been a shift in the funding allocated for wildland fire management in the United States in the past few years, after a number of very serious fire years with significant losses at the WUI. As a result of the increased costs associated with these serious fire events, President Clinton directed the secretaries of agriculture and the interior to submit a joint report, which culminated in the release of the National Fire Plan (NFP) in the fall of 2000 (Steelman et al. 2004). As part of the NFP the secretaries of agriculture and the interior, along with the governors of the western states, developed a 10-year comprehensive strategy to manage wildfire in the western part of the country. The NFP provides funding (through both state and federal agencies) and addresses 5 key areas: firefighting, rehabilitation, hazardous fuels reduction, community assistance, and accountability.

The NFP and the 10-year strategy represent a key shift to a more proactive stance on wildfires from the largely reactive role of the past (US GAO 2002), with an increased emphasis on mitigation. Between 2000 and 2004, US$1.7 billion was expended on hazardous fuel mitigation. In August 2002, President Bush announced the Healthy Forests Initiative as a means to implement core components of the NFP's 10-year Comprehensive Strategy and Implementation Plan. For lands managed by the US Department of Agriculture Forest Service or agencies within the Department of the Interior, the underlying legislation allows for "categorical exclusions" from either environmental impact statements or environmental assessments for activities to reduce hazardous fuels, including prescribed fire and mechanical methods, and activities necessary for the rehabilitation of habitat, watersheds, historic or cultural sites, and infrastructure affected by wildfire or wildfire suppression.

The government of California has been proactive in dealing with its WUI challenges and has been able to secure significant funding to implement various mitigation programs. However, the sobering fact remains that risks can be reduced but not eliminated, especially under extreme fire weather conditions. This was clearly demonstrated by the devastating wildfires in the southern part of the state in 2003.

However, in the United States, as in Canada, there is only anecdotal evidence at present for the effect that mitigation activities have on reducing risk at a landscape scale, in part because until recently there has not been a lot of mitigation work and because it is difficult to test treatment effectiveness experimentally. Based on case studies of WUI structure losses in the western US and modelling work, Cohen (2000) has maintained that reducing home ignitability is key to mitigating interface disasters.

### Federal Cost-Sharing for Natural Disasters

In Canada, federal disaster relief for wildfire is usually available only when fires have destroyed substantial amounts of property. However, in the United States, Fire Management Assistance Grants are available to states for "fires which threaten such destruction as would constitute a major disaster" (which essentially means when structures are threatened), and where the costs of fighting an individual fire exceed a specified cost threshold. The cost threshold for an individual fire is based on a calculation of 5% × $1.04 multiplied by the state population, or $100 000, whichever is higher (FEMA 2001). Grants are paid to individual states through the Disaster Relief Fund, which is administered by the Federal Emergency Management Agency (FEMA), and are made available to individuals, business enterprises, and both state and local governments for recovery from disasters. The final decision on assistance is made by a FEMA regional director, and funds are made available to cover 75% of eligible fire-fighting and emergency response costs. Over the 5-year period from 2000 to 2004, an average of 53 fire management assistance directives have been issued annually (FEMA 2004).

[5]On average, about 900 structures were lost annually between 1985 and 1994 in WUI fires in the United States (Platt 2001), and the numbers have been similar in more recent years. Well-documented examples are the 1991 Oakland/Berkely Hills fire that burned 2621 homes and killed 25 people and the Cerro Grande fire in 2000 that destroyed 235 homes and led to damages of approximately $1 billion (US GAO 2002).

### Cost-Smoothing Mechanisms

Some states are examining new funding mechanisms to cover suppression activities in extreme fire years. The State of Oregon began using private insurance to risk manage forest fire protection in 1930. The present Oregon Forest Land Protection Fund (OFLPF) began in 1959 and operates as an insurance fund to provide financial resources for the 5% of fires in Oregon that go beyond the capability of local protection forces. Revenue of $7 million per year is generated by a combination of a harvest tax (US$0.50/thousand board feet or $US 0.30 cubic metre harvested) for timber harvests in the state, area-based fees for protected land (US$0.06/acre or $US 0.15/hectare), and a fee on all individual lots. Additional insurance, with a US$10 million deductible, is purchased to increase the total state coverage, which will pay out up to $43 million (Oregon Department of Forestry 2005). If the OFLPF runs out of funds as a result of an extreme fire year, money is borrowed from the state treasury, and the revenue sources are increased the following year.

### Private Funding for Fire Management

The insurance industry in Australia represents a major source of funding for fire-fighting resources in that country. In New South Wales (NSW), insurers contribute $287 million to NSW fire brigades and A$89 million to the NSW Rural Fire Service. This is the main source of funding for these two groups, representing 75% of their respective budgets (Henri 2003). Both private insurance companies and re-insurers are represented by the Insurance Council of Australia (ICA). Along with commonwealth, state, territorial, and local governments, the ICA works with the Insurance Disaster Response Organisation (IDRO) in the event of natural disasters. Bushfires have accounted for over A$1 billion in costs to the IDRO and its predecessor over the period from January 1967 to January 2003 (House of Representatives Select Committee into the Recent Australian Bushfires 2003).

### Insurance Incentives

In 2003, State Farm, the largest insurance company in the United States, began inspecting WUI homes in 4 western states (Colorado, Arizona, New Mexico, and Nevada). These inspections use the principles of Firewise (the US version of FireSmart) to determine the hazards and risks of wildfire to each property (e.g., National Wildland/Urban Interface Fire Program 2003). After receiving an inspection report, homeowners have 18–24 months to comply with a to-do list (for hazards reduction) or lose their coverage. The long lead time allows those who qualify to apply for NFP funding.

### Building Codes for Fire-Prone Areas

In the United States, the National Fire Protection Association (NFPA) promulgates a variety of standards, including one for protection of life and property from wildfire (NFPA 2002). Building codes that have been developed in a number of jurisdictions throughout the western United States (notably California, Colorado, and Oregon) preclude the use of anything other than class A rated (least-combustible) roofing materials for new construction.

Australia also has a building standard for fire-prone areas (Standards Australia Ltd. 2001) that is recognized in the Australian Building Code. In New South Wales, new buildings in bushfire-prone areas must be constructed with bushfire safety in mind. Since 2002, building standards for such areas have included set-back distances from the bush, creation of reduced-fuel areas, correct positioning of the building, and good access roads for firefighters and residents (NSW Rural Fire Service 2001).

### Use of Volunteer and Local Firefighters

Australia has a highly decentralized system for fighting bushfires, which depends heavily on volunteer brigades coordinated by state agencies. For example, in New South Wales, the NSW Rural Fire Service oversees the activities of 2 200 community-level fire brigades, which are responsible for fire suppression and prevention on 90% of the land base. The remaining 10% is the responsibility of either the NSW National Parks and Wildlife Service or the State Forests. In Canada, provincial or territorial fire management agencies are responsible for wildland fire management on over 95% of the wildland.

### Fire Management Policy

In Western Australia, the Department of Conservation and Land Management (CALM) has redrafted its Fire Management Policy as a result of a change in statutory

mandate. Western Australia has a large amount of fire-prone wildland, and the policy stresses the need for appropriate response. Some highlights from the policy (CALM 2005) are that:

- Fire will be used to achieve a range of land management objectives. . . .
- A variety of fire regimes incorporating different frequency, intensity, season and scale will be applied at the landscape scale. . . .
- The Department will respond to fires . . . to a degree that is appropriate to the values at risk, the prevailing and forecast weather, availability of resources, the cost of suppression operation, and the likelihood of long-term net gains to the environment.

In a review of CALM's fire operations, Muller (2001) recommended that the *Bushfire Act* be amended "such that prime responsibility for adequate protection [of property] clearly rests with the person(s) who establish vulnerable assets in fire-prone areas" although CALM's Fire Management Policy (CALM 2005) states that as occupiers of the land, CALM has a common-law responsibility to reduce risks on its publicly held lands.

## Discussion and Conclusions

A diverse group of institutions are involved in formulating policy and in producing and distributing services that affect fire management in Canada.

This is because wildland fires have both land management and emergency management dimensions; they occur on public and private wildlands and in the WUI, and they involve federal, provincial, and local government and private interests. Enhancing the effective governance of wildland fire management in Canada will require improving coordination between and within the three orders of government and with civil society and the private sector to better achieve public and private interests in forest resources and public safety.

### Land and resource management

Protection of timber from fire provided much of the original impetus for the development of forest fire management in Canada. It was recognized in the early 1900s that fire losses must be minimized if the forest industry is to be sustainable. This is still true today. Wildfire losses can significantly affect sustainable harvest levels at a regional scale and can severely affect local resource-based economies and resource-dependent communities. Unlike structures, a forest takes many decades to be "rebuilt." However, there are limits to the degree to which fire can be managed, and these limits may vary across the country, with ecological conditions and the fire regime. It may not be economically or ecologically desirable to eliminate fire from landscapes with low timber values or other property values. More work is needed to determine the levels of protection appropriate for economic, ecological, and public safety objectives.

The Kyoto Protocol has significant potential to influence fire management objectives in Canada by providing an incentive to reduce the area burned to realize carbon credits. While there may be potential to expand the area of intensive fire suppression to realize carbon credits, the ecological impacts of reducing fire in these predominately natural areas should be recognized.

### Community Protection

WUI fires are an increasingly significant part of the suppression expenditures for many fire management agencies in Canada. A very few large fires cause most of the property loss and suppression costs. Where life and property are at risk resources are applied at much higher levels than if timber values alone are threatened. Rehabilitation and restoration costs are also often significant near populated areas.

It is not possible to entirely eliminate the risk of damaging WUI fires under extreme fire weather conditions simply by increasing suppression resources. Indeed, the perception that fire services are infallible in their ability to suppress interface fires may deter property owners from taking responsibility for reducing the risk of WUI fire in their communities (the moral hazards problem).

Managing fuels and reducing the susceptibility of structures are important means of mitigation. There is increasing interest in fuels management and other mitigative activities to reduce the fire behaviour potential of forest lands both around communities and across forest landscapes in Canada.

Provincial wildland fire management agencies cannot deal effectively with interface issues on their own. Structures and, in many cases, forest fuels are on private land and hence mitigation measures involving land management, public information, and regulation of private development are beyond their jurisdictional authority. For fuels located on provincial Crown land, the timber cut is often included as part of an annual allowable cut for the region, which may be an institutional barrier to the ability to influence treatment. Where the timber harvested is of small size or low market value and there is little return from the sale of the timber, treatment costs can be high. At present, there is no national program to promote or support activities to mitigate fire risk in the WUI.

Canada has not developed national standards for construction in fire-prone rural areas such as have been developed in parts of the United States and Australia. Accounting for wildfire risk in Canadian building design and construction standards, commensurate with risk (in a manner similar to that for earthquake risk), could considerably reduce structural losses and potential insurance and disaster relief claims.

## Sharing Risks and Resources

Most of Canada's approximately 400 million hectares of forest and wooded land is under public ownership. Although responsibility for forest management has been transferred, to various degrees, to private companies with long-term tenure on managed forest land across Canada, the responsibility for forest fire management has largely been retained by public agencies. This is because fire management has a community protection function, in addition to the protection of commercial timber values, and so it is seen largely as a public good. However, because fire management in Canada has focused on increasing the effectiveness of suppression, this may create a problem of moral hazards, whereby communities and private property owners who benefit from fire protection are less aggressive in mitigating their risk.

Following the transfer of federal resources in western Canada to the provinces in the late 1920s and devolution of northern resources to the governments of the Northwest Territories and Yukon in the 1990s, provincial and territorial governments in Canada have the primary responsibility for forest fire response. In most provinces and territories, fire management agencies are engaged in the direct delivery of fire services (although there is some use of contract aircraft and fire crews in some jurisdictions) and the operating costs of fire suppression agencies are paid out of general revenue. A notable exception is Quebec, where costs are shared between the provincial government and the forest industry through a private organization, SOPFEU. British Columbia has also recently introduced mechanisms for sharing a portion of fire suppression costs with the forest industry, utilities, and insurance companies through fees and other levies. Nonetheless, the federal government has a primary responsibility for the health and safety of Canadians and is the "insurer" of last resort in providing disaster assistance. At least 9 federal agencies are involved in some aspect of wildland fire.

Despite the patchwork of wildfire management interests among agencies, various national efforts have emerged within the federal system. In particular, because fire activity varies considerably from year to year within most jurisdictions in Canada and across the country, resource-sharing arrangements are an important mechanism for meeting aircraft, equipment, and personnel needs in times of high fire suppression service demand. Most notably, the CIFFC administers resource transfers between provinces and territories under the MARS Agreement and between Canada and the United States under a diplomatic note. Bill C-45 (Criminal Liability of Organizations) may require that mechanisms be developed to ensure that fire management personnel exchanged between agencies and jurisdictions have current and appropriate training in the best fire management practices. However, mutual aid is strictly voluntary; in times of extreme fire danger, sharing mechanisms may not provide all needed resources. Furthermore, fire management agencies also engage in competition for contracted resources such as rotary-wing aircraft, which become scarce during times of elevated fire danger.

Indeed, because of the high level of cooperation and resource sharing wildland fire management in Canada has become, de facto, a national concern especially in severe fire years. However, these interrelationships have developed usually in response to crisis situations and without a national fire policy or accord (excepting

the MARS Agreement) that integrates the various policy interests and jurisdicational mandates in a collaborative governance framework. Extending the degree of cooperation among jurisdictions may provide opportunities to enhance the safety of Canadians and achieve economic efficiencies. Extending cooperation might include, for example, extending ICS throughout Canadian emergency management organizations to facilitate communications; enhancing common standards for fire management resources (equipment and personnel) and operations to improve resource-sharing; monitoring the national state of readiness and enhancing long-range forecasting of extreme fire activity to allow advance positioning of nationally shared resources; and better engaging and supporting other stakeholders, particularly local governments and First Nations.

In the early 1900s it was recognized that control of the fire problem involved legislation, public education, and the development of organized, systematic fire management. These are still the three major tools available to government today. Current policies and institutional arrangements in Canada are adequate for average fire seasons. However, the system is challenged by extreme fire years such as the 1995 fire season in eastern Canada and the 2003 fire season in western Canada. There is a need for a national strategy that better integrates Canadian wildland fire policies and services to meet these challenges. Successful fire management programs must integrate technological, scientific, institutional, and human elements in a spirit of common cause (e.g., Taylor and Alexander 2006).

## Recommendations

A review of fire management policy and institutions in Canada and some recent trends in other jurisdictions has helped identify some elements that should be considered in developing a national fire strategy, including:

- Coordinate a Canadian wildland fire strategy with other governmental initiatives, including a national disaster mitigation strategy.
- Share resources and expertise to develop tools to better identify timber, communities, and structures and other values at risk to wildland fire.
- Implement a risk management approach to levels of protection based on quantitative evaluations of fire risk to timber, communities, and structures with optimum levels of protection.
- Further develop a national wildland fire preparedness system, and a planning process to anticipate extreme fire years.
- Engage and support local government, First Nations, and the public capacity to take responsibility for and mitigate risk to values they have established in fire-prone wildland areas.
- Evaluate the benefits of implementing FireSmart mitigation measures around communities.
- Investigate and develop model building codes that reduce risks to structures in wildfire-prone areas.
- Investigate and develop model wildland urban interface fire management plans and bylaws for local governments.
- Develop institutional mechanisms to foster communication between structural and wildland fire agencies in Canada, and promote and foster mitigation activities at a national level.
- Examine the feasibility of extending the Incident Command System throughout Canadian emergency management organizations to better facilitate communications and coordinated responses during large-scale evacuations.
- Enhance common standards for resources (equipment and personnel) and operations related to fire management, to improve resource-sharing.
- Better engage other agencies, levels of government, universities, and technical schools to enhance fire management education and training.
- Ensure that fire management personnel who participate in exchanges between agencies and jurisdictions have current and appropriate training in the best fire management practices.

## Literature Cited


Amiro, B.; Stocks, B.; Alexander, M.; Flannigan, M.; Wotton, B. 2001. Fire, climate change, carbon and fuel management in the Canadian boreal forest. Int. J. Wildland Fire 10:405–413.

Asselin, R.B. 2001. The Canadian social union: questions about the division of powers and fiscal federalism. Parliamentary Research Branch, Ottawa, ON. Rep. PRB 00-31E.

Armstrong, G.W. 2004. Sustainability of timber supply considering the risk of wildfire. For. Sci. 50:626–639.

Bellisario, L. M. 2002. The Canadian disaster database: an introduction. Office of Critical Infrastructure and Emergency Preparedness, Ottawa, ON. Rep. 2002-01.

Brun, S.E.; Etkin, D.; Law, D.G.; Wallace, L.; White, R. 1997. Coping with natural hazards in Canada: scientific, government and insurance industry perspectives. Prepared for Round Table on Environmental Risk, Natural Hazards and the Insurance Industry by Environmental Adaptation Research Group, Environment Canada, and Institute for Environmental Studies, University of Toronto, Toronto, ON.

Buchan, R.B. 2002. An interface fire hazard planning model: a case study of the District of Langford. District of Langford, Victoria.

[CALM] Department of Conservation and Land Management. 2005. Policy Statement No. 19: fire management policy. Western Australia Department of Conservation and Land Management, Perth.

Canadian Commission on Building and Fire Codes. 2005. National Building Code of Canada 2005. National Research Council Canada, Ottawa, ON.

Canadian Forest Service. 2004. Program helped fund community FireSmart projects. Edge Magazine Media Match Communications, Edmonton, AB. February 2004:7.

Clutter, J.L.; Fortson, J.C.; Pienarr, L.V.; Brister, G.H.; Bailey, R.L. 1983. Timber management: a quantitative approach. Wiley, New York. 333 p.

Cohen, J.D. 2000. Preventing disasters — home ignitability in the wildland urban interface. J. For. 98:15–21.

Cole, F.T.; Babbitt, B.; Bacon, D.; Heathcott, M.; Long, M.C.; Sampson, R.N.; Sharpe, M. 1996. Are political and philosophical issues limiting the use of prescribed fire? Pages 432–448 *in* T.L. Pruden and L.A. Brenan, eds. Proc. 20th Tall Timbers Fire Ecol. Conf. 7–10 May 1996, Boise, Idaho Tall Timbers Res. Stn., Tallahassee, FL.

Cumming, S.G. 2005. Effective fire suppression in boreal forests. Can. J. For. Res. 20:1–16.

Department of Finance. 2004. 2004–2005 budget highlights. Yukon Government, Whitehorse, YK.

Dion, S. 1999. Collaborative federalism in an era of globalization. Pages 60–65 *in* S.A. Delacourt, and D.G. Lenihan, eds. Collaborative government: is there a Canadian way? Institute of Public Administration Canada. New Directions No. 6. 121 p.

Dore, M.H.I. 2003. Forecasting the conditional probabilities of natural disasters in Canada as a guide for disaster preparedness. Natural Hazards 28(2/3):249–269.

Emergency Preparedness Canada. 1988. Disaster financial assistance. Manual to assist in the interpretation of federal guidelines. Emergency Preparedness Canada Report EPC 22/88. 46 pp. Ottawa, ON. Accessed 20 July 2006. <http://dsp-psd.communication.gc.ca/Collection/D82-57-1988E.pdf>.

[FEMA] Federal Emergency Management Agency. 2001. Disaster Assistance; Fire Management Assistance Grant Program; final rule [on-line]. Fed. Reg. 66(220):57341–57353. Accessed 20 July 2006. <www.fema.gov/txt/library/firefr.txt>.

[FEMA] Federal Emergency Management Agency. 2004. Federally declared disasters by calendar year [on-line]. Washington, DC. Accessed 30 Jan 2005. <www.fema.org/library/drcys.shtm>.

Filmon, G. 2004. Firestorm 2003 provincial review. Province of British Columbia. Victoria, BC. 100 p. Accessed 20 July 2006. <http://www.llbc.leg.bc.ca/public/PubDocs/bcdocs/367694/Firestorm_Report.pdf>.

Gillis, M.D. 2001. Canada's national forest inventory (responding to current information needs). Environmental Monitoring and Assessment 67:121–129.

Gonzales, R.H. 2001. Spark arresters and the prevention of wildland fires. USDA Forest Service, Technology and Development Program. Technology and Development Center, San Dimas, CA. Rep. 5100 0151 1312-SDTC.

Hannestad, S.E. 2005. Incident command system: a developing national standard of incident management in the U.S. Pages 19–28 *in* B. Carle and B. Van de Walle, eds. Proceedings of the second international Information Systems for Crisis Response and Management Conference, April 18–20, 2005, Brussels, Belgium. Accessed 20 July 2006. <http://www.cip.umd.edu/reports/iscam2005%20hannestad%20revised.pdf>.

Henri, C. 2003. Fire policy: an insurance perspective. Pages 162–165 *in* G. Carey, D. Lindenmayer, and S. Dovers, eds. Australia burning: fire ecology, policy and management issues. CSIRO Publishing, Collingwood, Australia.

Hesseln, H. 2001. Refinancing and restructuring federal fire management. J. For. 99:4–8.

House of Representatives Select Committee into the Recent Australian Bushfires. 2003. A nation charred: report on the inquiry into bushfires. Parliament of the Commonwealth of Australia, Canberra, Australia. 414 p.

Hwacha, V. 2005. Canada's experience in developing a national disaster mitigation strategy: a deliberative dialogue approach. Mitigation and Adaptation Strategies for Global Change 10:507–523.

Johnston, T. 2004. Canadian Interagency Forest Fire Centre annual report. Can. Interag. For. Fire Cent., Winnipeg, MB.

Kovacs, P. 2001. Wildfires and insurance. Institute for Catastrophic Loss Reduction, Toronto, ON. ICLR Res. Pap. 11.

Kryzanowski, T. 1999. Tree insurance. Logging and Sawmilling Journal 30(6):32–33.

Kurz, W.A.; Apps, M.J. 2006. Developing Canada's national forest carbon monitoring, accounting and reporting system to meet the reporting requirements of the Kyoto Protocol. Mitigation and Adaptation Strategies for Global Change 11:33–43.

Leavitt, C. (compiler) 1915. Forest protection in Canada 1913-1914. Commission of Conservation Canada, Committee on Forests. Toronto, ON.

Lee, B.S.; Alexander, M.E.; Hawkes, B.C.; Lynham, T.J.; Stocks, B.J.; Englefield, P. 2002. Information systems in support of wildland fire management decision making in Canada. Comput. Electron. Agric. 37:185–198.

Martell, D. L. 1994. The impact of fire on timber supply in Ontario. For. Chron. 70:164–173.

Muller, C. 2001. Review of fire operations in forest regions managed by the Department of Conservation and Land Management. A report to the Executive Director. Government of Western Australia, Department of Conservation and Land Management, Perth, Australia.

National Wildland/Urban Interface Fire Program. 2003. Firewise communities: where we live, how we live. FireWise Communities Inc., Quincy, MA.

[NFPA] National Fire Protection Association. 2002. NFPA 1144 standard for protection of life and property from wildfire. National Fire Protection Assoc. Quincy, MA.

NSW Rural Fire Service. 2001. Planning for bushfire protection: a guide for councils, planners, fire authorities, developers, and home owners. NSW Rural Fire Service with Planning NSW, Sydney.

Oakerson, R.J. 1999. Governing local public economies. ICS Press, Oakland, CA. 160 p.

Oregon Department of Forestry. 2005. Protection from fire program review: final report. Institute for Natural Resources, Oregon State University, Corvallis, OR.

Partners in Protection. 2003. Fire Smart — protecting your community from wildfire. Second edition. Partners in Protection. Edmonton, AB.

Pearce, L. 2003. Disaster management and community planning, and public participation: how to achieve sustainable hazard mitigation. Natural Hazards 28:211–228.

Peter, B.; Nelson, J. 2005. Estimating harvest schedules and profitability under the risk of fire disturbance. Can. J. For. Res. 35:1378–1388.

Peter, B.; Wang, S.; Mogus, T.; Wilson, B. 2006. Fire risk and population trends in Canada's Wildland–Urban Interface. Pages 33–44 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

Platt, R.H. 2001. To burn or not to burn: summary of the forum on urban/wildlife fire, January 26, 2001: a report to the Natural Disasters Roundtable. National Academy Press, Washington, DC.

Public Works and Government Services Canada. 1999. A framework to improve the social union of Canada. An agreement between the Government of Canada and the governments of the provinces and territories. Ottawa, ON.

Reed, W.J.; Errico, D. 1985. Optimal harvest scheduling at the forest level in the presence of the risk of fire. Can. J. For. Res. 16:266–278.

Simard, A.J. 1997. Wildland fire in Canada - a national overview. Initial Attack Spring: 2–5.

Simeon, R. 2001. Recent trends in federalism and intergovernmental relations in Canada: lessons for the UK? Pages 47–61 *in* T.C. Salmon and M. Keating, eds. The dynamics of decentralization: Canadian federalism and British devolution. Round Table No. 354. November 18–20, 1999, Newcastle, Co. Down, Northern Ireland. McGill - Queens Univ. Press, Montreal, QC.

Standards Australia Ltd. 2001. AS 3959-1999. Construction of buildings in bushfire-prone areas. Standards Australia Ltd., Sydney.

Steelman, T.; Kunkel, G.; Bell, D. 2004. Federal and state influences on community responses to wildfire threats: Arizona, Colorado and New Mexico. J. For. 102:21–27.

Stephens, S.L.; Ruth, L.W. 2005. Federal forest-fire policy in the United States. Ecol. Appl. 15:532–542.

Stocks, B.J.; Mason, J.A.; Todd, J.B.; Bosch, E.M.; Wotton, B.M.; Amiro, B.D.; Flannigan, M.D.; Hirsch, K.G.; Logan, K.A.; Martell, D.L.; Skinner, W.R. 2002. Large forest fires in Canada, 1959–1997. J. Geophys. Res. 108(D1):FFRS, 1–12.

Taylor, S.W.; Alexander, M.E. 2006. Science, technology, and human factors in fire danger rating — the Canadian experience. Int. J. Wildland Fire 15:121–135.

Turvey, C.G.; Hoy, M.; Islam, Z. 2002. The role of ex-ante regulations in addressing problems of moral hazard in agricultural insurance. Agric. Finance Review 62:103–116.

[US GAO] United States General Accounting Office. 2002. Severe wildland fires: leadership and accountability needed to reduce risks and resources. Washington, DC. GAO-02-259.

Whitford, H.N.; Craig, R.D. 1918. Forests of British Columbia. Commission of Conservation Canada, Committee on Forests, Ottawa, ON. 409 p.

Whittaker, D. 1988. Public perceptions of fire management. Pages 30–31 *in* B.D. Lawson, B.C. Hawkes, and G.N. Dalrymple, eds. Proc.1988 Northwest Fire Council Annu. Meet., 14–15 November 1988, Victoria, BC. Northwest Fire Council, Victoria, BC.

Wilson, K. 2000. Health care, federalism and the new social union. Can. Med. Assoc. J. 162:1171–1174.

Taylor, S.W.; Stennes, B.; Wang, S.; Taudin-Chabot, P. 2006. Pages 3–26 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

# Human Dimensions of Fire Management in the Wildland–Urban Interface: A Literature Review

**B.L. McFarlane**[1]

## Introduction

The forested landscape in Canada is changing as human communities expand further into the wildland–urban interface[2] (WUI) and more crown land is designated for industrial forest management and other resource use. In recent years Canada has experienced some severe fire seasons, which have affected timber supply and put human communities at risk. For example, in 2003, about 3 300 Alberta residents were evacuated from their homes because of the threat of wildfire, and in British Columbia more than 45 000 residents were evacuated and about 330 homes and businesses were destroyed by wildfire (Filmon 2004). Scenarios of fire danger under conditions of climate change suggest that in the future a "normal" fire season may be more like the extreme fire seasons experienced today (Weber and Flannigan 1997).

As part of a comprehensive fire management strategy, fire management agencies in Canada are considering proactive approaches specific to the WUI to reduce the threat to private property and human life. Agencies' response to wildfire in the WUI has traditionally followed a common paradigm for reducing risk from natural hazards, stressing engineering solutions (e.g., creation of defensible space, use of fire-resistant building materials) based on technological judgments (e.g., fire behaviour models) (McDaniels et al. 1997). What is lacking in these engineering solutions is consideration of the psychological, social, cultural, and political factors that influence people's willingness to support and engage in risk reduction. The success of proactive management in the WUI depends, largely, on individual homeowners' and communities' willingness to support and engage in fire mitigation[3] and preparedness[4] measures. Although considerable research on the human dimensions of wildfire risk mitigation and preparedness has been conducted in the United States and Australia, it is unclear how property owners and communities in Canada perceive the threat of wildfire; similarly, their preferences for mitigation and preparedness measures and their willingness to use such measures are unknown. There is also little understanding of the individual and sociocultural factors that influence such responses or the role of municipal governments and other relevant agencies in influencing responses at the individual and community levels. This document reviews the human dimensions of managing wildfire risk and offers suggestions for research topics relevant to the Canadian situation.

[1]Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, AB T6H 3S5.
[2]The area where structures (such as homes) and other human developments meet or are intermingled with forest and other vegetative fuel types (Chisholm Fire Review Committee 2001).
[3]Mitigation refers to proactive and sustained adjustments intended to reduce a given risk.
[4]Preparedness refers to planning for a hazard incident.

## Defining the Wildland–Urban Interface

Defining the WUI, determining its extent, location, and characteristics (both biophysical and social), should be among the first steps in developing fire management strategies specific to the WUI. The location of the WUI in the United States has been defined and mapped on the basis of housing density and land cover characteristics (SILVIS 2004). That analysis identified the location of the WUI at both the national and the state level, providing a baseline for assessing WUI growth in the future. It did not, however, include an assessment of fire risk or community vulnerability. Other researchers have developed a framework to assess the relative risk of fire in the WUI using qualitative risk classes based on historical fire regimes and current fuels (Haight et al. 2004). Combining the fire risk map with a WUI map allows determination of numbers and densities of houses and people in high-risk areas.

The risk associated with wildfire is typically defined by biophysical conditions such as forest type, age-class distribution, topography, and forest health. However, in assessments of risk and vulnerability of communities, social factors (such as resource dependence, social capital, and attitudes toward and perceptions about fire) should be included because they affect a community's ability to mitigate, prepare for, respond to, and recover from fire. Understanding the risk factors and identifying areas of high risk will help agencies to identify communities at risk, aid in the development of risk reduction strategies, and serve as a valuable tool for prioritizing mitigation and preparedness activities (Kruger et al. 2003; Haight et al. 2004; Cottrell 2005).

## Public Education

Public education initiatives that rely heavily on the FireSmart[5] manual (Partners in Protection 2003) have been undertaken in several Canadian provinces with a goal of improving participation in the mitigation of wildfire risk. Increasing awareness of the risk and increasing mitigation activities and knowledge of fire are often cited as solutions to the WUI problem. However, simply providing information about mitigation activities does not necessarily result in their adoption (Brunson and Shindler 2004). Education programs that rely on printed materials emphasizing the threat of fire and what to do to reduce risk (such as the FireSmart manual) are not very effective in convincing homeowners to undertake mitigation activities (Monroe and Nelson 2004). McCaffrey (2004) found that the effectiveness of education depended on the media source. Newspapers, magazines, and television were not effective in educating homeowners about fire hazard and mitigation methods, but presentations targeted to specific audiences, computer-generated wildfire scenarios, and personal contact by fire management agencies were more effective.

A common observation in the United States is the importance of incorporating resident and community values in education and mitigation strategies. The values that homeowners associate with land near their homes can influence their acceptance of mitigation strategies, such as the creation of defensible space (Monroe and Nelson 2004; Nelson et al. 2005). Emphasizing values that are relevant to homeowners helps to motivate residents to engage in mitigation. The importance of homeowners' values is also evident in Canada. For example, residents of Alberta and British Columbia who had recently experienced wildfires were unwilling to remove trees close to their homes because of the values associated with them (McGee et al. 2005). Residents stated that they lived in the WUI because of the trees and the "naturalness" of the surroundings. Trees on their properties also functioned as windbreaks and provided shade, aesthetic appeal, and wildlife habitat. Public education should therefore emphasize the multiple benefits associated with mitigation activities, such as privacy, wildlife, aesthetics, and healthy forests, in addition to the protection of structures.

Understanding variability in mitigation preferences, the reasons for those preferences, and the factors that influence preferences have been identified as important components in developing public education strategies. Public education should be tailored to local situations and knowledge, and hence a "one-size-fits-all" approach is unlikely to be successful (Brunson and Shindler 2004).

[5]The FireSmart program recommends activities that individuals and communities can undertake to reduce the risk of fire losses and to enhance safety in the WUI (Partners in Protection 2003).

## Preferences for Fuel Management on Public Land

Applying risk reduction strategies (such as fuel modification) on public lands requires an understanding and incorporation of public preferences. Successful fuel management strategies depend on an understanding of variability in public acceptance and the reasons for variability across settings (Brunson and Shindler 2004). Much of the literature about fire management on public lands has focused on acceptability of, and preferences for, fuel management strategies, such as prescribed burning and mechanical thinning in the United States (e.g., Manfredo et al. 1990; Bright et al. 1993; Loomis et al. 2001; Daniel et al. 2003; Shindler and Toman 2003; Vogt et al. 2003; Winter 2003; Brunson and Shindler 2004; Kneeshaw et al. 2004). The results of these studies suggest that there is public support for fuels management aimed at reducing the risk to communities but that citizens differ in their preferences for how to reduce fuel loads. Residents in Arizona, Colorado, Oregon, and Utah, for example, differed in their knowledge about fire and fire issues and in their preferences for prescribed burning, thinning, brush removal, and livestock grazing. These studies also suggest an association between both the social (urbanization) and biophysical (dominant land use) environments and judgments of acceptability, highlighting the importance of understanding contextual circumstances in developing fire management strategies on public lands (Brunson and Shindler 2004). In other words, each WUI community may be unique in its preferences for fuels management on nearby public lands.

## Research on Homeowners

Studies specific to homeowners living in the WUI have focused on perceptions of risk, public education, and preferences for policy and mitigation, and information needs (e.g., Cortner et al. 1990; Vogt 2003). A few studies have examined perceptions of wildfire risk among WUI residents, including awareness of fire severity and probabilities of occurrence, participation in mitigation and preparedness activities, and policy preferences, with contradictory results. Gardner et al. (1987) found that residents in the WUI in southern California had a low awareness of fire severity, preferred public (rather than private) risk management strategies, and were not receptive to programs aimed at diminishing the fire hazard to residents. In contrast, Fried et al. (1999) found during in-person interviews that many WUI residents in Michigan participated in some form of risk reduction and were willing to invest resources to reduce their risk. However, in subsequent focus groups, it became apparent that residents viewed wildfire as uncontrollable and the resulting damage as random; as such, they preferred solutions that would reduce the number of ignitions rather than mitigation and control measures (Winter and Fried 2000). In contrast, residents of rural Australia were aware of wildfire risks and had undertaken mitigation activities, including clearing vegetation, planting fire-resistant ground cover and plants, maintaining access to water, having their own fire-fighting equipment such as hoses and portable units, and creating a plan of action in the event of a fire (McGee and Russell 2003). Jakes et al. (2003) also found several instances of a high level of wildfire mitigation and preparedness at the community level in the United States. Activities included running outreach campaigns for creating defensible space, organizing annual campaigns to clear neighbourhoods of woody debris, hiring mitigation specialists to coordinate public education, deploying mitigation teams to reduce fuels, and creating disaster communication systems.

Numerous studies have examined the factors that influence hazard mitigation performed by individuals, but few have focused on the WUI. Perception of risk, demographic characteristics, attribution of responsibility, perceived controllability of fire, experience with wildfire, trust in institutions, and community context are some of the factors cited as affecting an individual's engagement in hazard mitigation.

Generally, perception of the risk associated with a hazard influences participation in mitigation activities. People who have heard of and understand a risk are more likely to adopt mitigation and preparedness activities (Lindell and Perry 2000). In the wildfire literature, perception of risk has been associated with perceived importance of mitigation strategies (Gardner et al. 1987).

Gender, age, income, and other demographic characteristics influence risk perception. One of

the most consistent findings in research about risk perception is that women tend to more concerned about hazards than men (Davidson and Freudenburg 1996; Kraus et al. 2000; Slovic 2000a). Older people, whites, and those with higher levels of education and income tend to be less concerned about hazards (Savage 1993; Kraus et al. 2000; Slovic 2000b). In addition, demographic changes can affect a community's ability and willingness to undertake mitigation. For example, permanent residents differ from seasonal residents in risk perception, knowledge, and sense of community (Vogt 2003). Seasonal residents might not be as concerned about the community and might not have formed social bonds or developed a sense of community cohesiveness. Type and length of residence may be particularly important in the WUI, which continues to experience population growth and an influx of seasonal and new permanent residents (Smith and Krannich 2000). These findings highlight the importance of examining demographic changes in the WUI.

The perception of who is responsible for hazard mitigation and preparedness may influence homeowners' engagement in mitigation and preparedness. For example, Lindell and Whitney (2000) found a correlation between, on the one hand, homeowners' perceptions of responsibility for protecting themselves and their property and, on the other hand, planned and actual adoption of mitigation and preparedness for earthquakes. In Australia, residents who viewed landowners as responsible for risk mitigation had themselves undertaken wildfire mitigation activities (McGee and Russell 2003).

If homeowners believe that wildfire cannot be controlled, they are unlikely to expend resources on activities that they perceive as ineffective (Gregory et al. 1997; Winter and Fried 2000). For example, Winter and Fried (2000) found that many residents of Michigan had not taken steps to fireproof their homes, in part because they characterized wildfire as uncontrollable and suppression as futile. Similarly, a case study of the British Columbia fires in 2003 suggested that residents whose homes were destroyed perceived mitigation activities as ineffective against high-intensity wildfire and viewed suppression as the only effective strategy (McGee et al. 2005).

Experiencing a natural hazard (directly or indirectly, through friends or family) encourages mitigation and preparedness (Russell et al. 1995; Lindell and Perry 2000). However, instances have occurred in which experience had either no effect or a negative effect on preparedness (e.g., Drabek 1986; Whitehead et al. 2000). In Alberta and British Columbia, experiencing a wildfire firsthand through evacuation or destruction of a home seemed to increase awareness of wildfire risk and motivated some people to undertake more mitigation activities, although these activities were generally confined to yard and house maintenance. Experiencing a high-intensity fire did not motivate residents to create defensible space around their homes (McGee et al. 2005).

Trust in institutions has been identified as a key factor in homeowners' willingness to undertake mitigation and preparedness activities. Support of fuels management approaches may depend on the trust that homeowners have in the information they receive and in the individuals and agencies providing the information (Jakes et al. 2003; Vogt et al. 2005). For example, Slovic et al. (2000) described opposition to plans for disposal of nuclear waste as a "crisis of confidence" rooted in profound distrust of the scientific, government, and industrial managers of nuclear technologies. In the WUI, trust of fire agencies may be a key factor in the social acceptability of risk reduction policies and activities. Trust in the staff of fire management agencies to make appropriate decisions related to fuels management has been associated with perceived risks and benefits and with perceived competence of the agency (Winter et al. 2004). Residents who trusted the agencies viewed prescribed burning and mechanical thinning as methods of saving money, restoring areas to natural conditions, and improving wildlife habitat. Furthermore, higher levels of trust were associated with lower perceived risk from an escaped prescribed burn. The trust factor has also been evident for WUI fires in western Canada, where local citizens have been critical of the approach of fire management agencies and their communications to residents during fire events (Chisholm Fire Review Committee 2001; Mottus 2002); some residents are also suspicious of the motives of fire management agencies and view mitigation as a downloading of government responsibility to the homeowner (McGee

et al. 2005). Some British Columbia residents who lost their homes to wildfire did not trust FireSmart information and questioned the effectiveness of risk mitigation activities.

A homeowner's community context may facilitate or impede adoption of activities to reduce the risk associated with wildfire. A community's social capital (including leadership, networks, and mobilization of resources), human capital (including the knowledge and skills that an individual obtains through education and training), and cultural capital (including knowledge and skills possessed through heritage, experience, and place attachment) have been identified as influencing mitigation and preparedness on the part of homeowners (Jakes et al. 2003).

## Research on Communities

Much of the literature on disaster management related to communities has focused on natural hazards, such as floods and earthquakes, with little attention paid to the hazard of wildfire. One theme that has emerged from the hazards management literature is the importance of including the public when developing community mitigation and preparedness plans (Pearce 2003). Pearce (2003) noted that hazard mitigation should include community planning (e.g., land-use planning), the creation of partnerships among diverse interests through public participation, and local decision making. The importance of public participation has also been recognized as a key element to successful community mitigation and preparedness for wildfire (Beebe and Omi 1993; Tàbara et al. 2003). Steelman and Kunkel (2004) outlined a model of effective community response to wildfire that included structural (based on science, technology, and engineering) and social responses that foster collaboration in executing and enforcing a plan.

Recently, the United States has undertaken several initiatives in wildland fire management that require collaboration among federal, state, and local government agencies. In response, citizens and local organizations have formed community-based collaborations to reduce the risk of wildfire to the communities and adjacent lands. These collaborations bring together public land managers and local citizens in planning and implementing forest management strategies to reduce wildfire risk. Studies have been initiated to identify factors and processes that lead to effective collaborative fire management and enhance social capacity. These studies aim to identify the elements of social capacity that are critical for success and to determine how agencies can help build the capacity necessary for successful outcomes. Case studies have been completed in a total of 15 communities in Colorado, Florida, Minnesota, Mississippi, Montana, New Jersey, New Mexico, Oregon, South Dakota, Texas, Washington, and Wisconsin. Social capacity has been identified as the most critical element in community preparedness for wildfire (Jakes et al. 2003). On the basis of case studies in New Mexico, Steelman and Kunkel (2004) concluded that "relying on communities to identify and define their own alternatives as they build their capacity to respond to wildfire threats is the surest way to provide a long-term solution to the wildfire problem."

To assist fire management agencies, Shindler and Gordon (2005) developed a practical guide for creating productive collaborations between agencies and communities. The guide presents essential attributes for developing partnerships, identifies principles for an outreach strategy, and outlines seven steps for implementation. The guide accompanies a DVD (Communication Strategies for Fire Management. Creating Effective Citizen-Agency Partnerships) that uses case studies to illustrate successful agency communication programs.

## Research in Canada

Research into the human dimensions of wildfire has been conducted primarily in the United States and Australia. Although these studies provide valuable insight into fire management preferences, WUI residents' perception of risk, and their engagement in mitigation activities, their authors have suggested that the findings are not applicable across geographic areas with differing ecological, social, cultural, and political systems. Thus, there is a need to develop an understanding of risk perception and of mitigation and preparedness actions in the WUI in Canada. In addition, the WUI literature lacks information about the influence of cognitions (such as risk perception) and their interaction with demographic variables (such as gender) and community factors (such as social capital, economic characteristics, and community

preparedness) on the willingness of homeowners to engage in mitigation activities. The identification of processes, models, and frameworks for successful engagement of homeowners and communities is only beginning to emerge.

Research on the human dimensions of fire management in the WUI is in its infancy in Canada. The Canadian Forest Service (B.L. McFarlane, Northern Forestry Centre and author of this current paper) and the University of Alberta (T.K. McGee, Department of Earth and Atmospheric Sciences, Human Geography) initiated collaborative research focusing on mitigation and preparedness in the WUI in 2003. This research has so far consisted of two case studies of WUI residents. The case studies examined the experiences of residents and community leaders who went through the 2003 fires in Alberta and British Columbia to identify perceptions of risk and awareness of and engagement in mitigation and preparedness activities and also to identify obstacles and incentives to undertaking mitigation. More case studies and a survey of residents in six WUI communities in Alberta will be conducted in 2006 and 2007, respectively. Individuals' perception of risk and the mitigation activities that they carried out, as well as the individual and community factors influencing these actions, will be examined.

This collaborative initiative is limited in geographic scope (focused on Alberta) and thus does not cover the ecological, social, cultural, and political diversity found in Canada. In particular, special consideration may be needed for Aboriginal communities situated in the WUI. Their unique circumstances may necessitate alternative approaches that have not been identified through current research. For example, the role of traditional knowledge related to fire and resource use, the subsistence use of forests, and the cultural values of these communities are not well understood by fire management agencies and should be examined for their importance in fire management strategies.

Several research questions relevant to reducing the risk from fire in the WUI in Canada have emerged from this literature review. For example, how should we define the WUI in Canada, where is the WUI located, what are the characteristics of WUI communities, what are the risks and implications of WUI fire, what types of public education are effective, what is the perceived risk from wildfire among WUI residents, and how do social and cultural differences affect mitigation and preparedness? Specific research topics should include:

- Define, map, and determine the characteristics of WUI communities in Canada.
- Determine the biophysical and social factors that contribute to risk in the WUI.
- Identify communities at risk.
- Identify and develop tools and methods for improving public education and awareness of the role and impact of wildland fire for a range of local situations. Implement these tools and evaluate their effectiveness in model communities.
- Test social science models and processes developed elsewhere (the United States and Australia) for their applicability in Canada.
- Focus on Aboriginal communities to determine if unique approaches to, models of, and processes for risk reduction are necessary.

## Conclusions

This paper summarizes much of the literature on the human dimensions of WUI fire. This literature has emerged primarily since the 1990s and continues to develop. Most of the research has been conducted in the United States and Australia and is only beginning in Canada. Research from United States and Australia includes models of community mitigation and preparedness, public preferences for fuel management, methods of public education, and techniques for identifying and mapping the WUI. However, many researchers caution against transferring results across ecological, social, cultural, and political systems. Research in Canada should draw upon this literature to test models and other findings for their applicability. Several research topics appropriate for Canada were identified that are focused on addressing questions such as how should we define the WUI in Canada, where is the WUI located, what are the characteristics of WUI communities, what are the risks and implications of WUI fire, what types of public education are effective, what is the perceived risk from wildfire among WUI residents, and how do social and cultural differences affect mitigation and preparedness?

## Literature Cited


Beebe, G.S.; Omi, P.N. 1993. Wildland burning. The perception of risk. J. For. 91(9):19–27.

Bright, A.D.; Manfredo, M.J.; Fishbein, M.; Bath, A. 1993. Application of the theory of reasoned action to the National Park Service's controlled burn policy. J. Leis. Res. 25(3):263–280.

Brunson, M.W.; Shindler, B.A. 2004. Geographic variation in social acceptability of wildland fuels management in the western United States. Soc. Nat. Resour. 17:661–678.

Chisholm Fire Review Committee. 2001. Chisholm Fire Review Committee final report. Submitted to the Minister of Alberta Sustainable Resource Development, Edmonton, AB. Accessed 24 Jan 2006. <http://www3.gov.ab.ca/srd/forests/chisholm/pdfs/Chisholm.pdf>.

Cortner, H.J.; Gardner, P.D.; Taylor. J.G. 1990. Fire hazards at the urban–wildland interface: what the public expects. Environ. Manage. 14(1):57–62.

Cottrell, A. 2005. Communities and bushfire hazard in Australia: more questions than answers. Environ. Hazards 6:109–114.

Daniel, T.C.; Weidermann, D.E.; Hines, D. 2003. Assessing public tradeoffs between fire hazard and scenic beauty in the wildland–urban interface. Pages 36–44 *in* P. Jakes, compiler. Homeowners, communities, and wildfire: science findings from the national fire plan. Proc. 9th Int. Symp. Soc. Resour. Manage., 2–5 June 2002, Bloomington, IN. US Dep. Agric. For. Serv., North Cent. Res. Stn., St. Paul, MN. Gen. Tech. Rep. NC-231.

Davidson, D.; Freudenburg, W. 1996. Gender and environmental risk concerns: a review and analysis of available research. Environ. Behav. 28(3):302–339.

Drabek, T.E. 1986. Human system responses to disaster: an inventory of sociological findings. Springer–Verlag, New York, NY.

Filmon, G. 2004. Firestorm 2003 provincial review. Province of British Columbia, Victoria, BC. Accessed 24 Jan 2006. <http://www.llbc.leg.bc.ca/public/PubDocs/bcdocs/367694/Firestorm_Report.pdf>.

Fried, J.S.; Winter, G.; Gilless, K. 1999. Assessing the benefits of reducing fire risk in the wildland–urban interface: a contingent valuation approach. Int. J. Wildland Fire 9(1):9–21.

Gardner, P.D.; Cortner, H.J.; Widaman, K. 1987. The risk perceptions and policy response toward wildland fire hazards by urban home-owners. Landsc. Urban Plann. 14:163–172.

Gregory, G.; Loveridge, A.; Gough, J. 1997. Social and cultural aspects of natural hazard perception and response. N. Z. Geogr. 53(1):47–54.

Haight, R.G.; Cleland, D.T.; Hammer, R.B.; Radeloff, V.C.; Rupp, T.S. 2004. Assessing fire risk in the wildland–urban interface. J. For. 102(7):41–48.

Jakes, P.J.; Nelson, K.; Lang, E.; Monroe, M.; Agrawal, S.; Kruger, L.; Sturtevant, V. 2003. A model for improving community preparedness for wildfire. Pages 4–9 *in* P. Jakes, compiler. Homeowners, communities, and wildfire: science findings from the national fire plan. Proc. 9th Int. Symp. Soc. Resour. Manage., 2–5 June 2002, Bloomington, IN. US Dep. Agric. For. Serv., North Cent. Res. Stn., St. Paul, MN. Gen. Tech. Rep. NC-231.

Kneeshaw, K.; Vaske, J.J.; Bright, A.D.; Asher, J.D. 2004. Situational influences of acceptable wildland fire management actions. Soc. Nat. Resour. 17:447–489.

Kraus, N.; Malmfors, T.; Slovic, P. 2000. Intuitive toxicology: expert and lay judgments of chemical risks. Pages 285–315 *in* P. Slovic, ed. The perception of risk. Earthscan Publications, Sterling, VA.

Kruger, L.E.; Agrawal, S.; Monroe, M.; Lang, E.; Nelson, K.; Jakes, P.; Sturtevant, V.; McCaffrey, S.; Everett, Y. 2003. Keys to community preparedness for wildfire. Pages 10–17 *in* P. Jakes, compiler. Homeowners, communities, and wildfire: science findings from the National Fire Plan. Proc. 9th Int. Symp. Soc. Resour. Manage., 2–5 June 2002, Bloomington, IN. US Dep. Agric. For. Serv., North Cent. Res. Stn., St. Paul, MN. Gen. Tech. Rep. NC-231.

Lindell, M.K.; Perry, R.W. 2000. Household adjustment to earthquake hazard: a review of research. Environ. Behav. 32(4):461–501.

Lindell, M.K.; Whitney, D.J. 2000. Correlates of household seismic hazard adjustment adoption. Risk Anal. 20(1):13–25.

Loomis, J.B.; Bair, L.S.; González-Cabán, A. 2001. Prescribed fire and public support. Knowledge gained, attitudes changed in Florida. J. For. 99(11):18–22.

Manfredo, M.J.; Fishbein, M.; Hass, G.E.; Watson, A.E. 1990. Attitudes toward prescribed burn policies. J. For. 88(7):19–23.

McCaffrey, S.M. 2004. Fighting fire with education. What is the best way to reach out to homeowners? J. For. 102(5):12–19.

McDaniels, T.; Axelrod, L.J.; Cavanagh, N.S.; Slovic, P. 1997. Perception of ecological risk to water environments. Risk Anal. 17(3):341–352.

McGee, T.; McFarlane, B.; Varghese, J. 2005. Exploration of wildfire risk reduction in communities directly affected by wildfire in 2003. Final report. Public Safety and Emergency Preparedness. Can., Ottawa, ON.

McGee, T.K.; Russell, S. 2003. "It's just a natural way of life…" an investigation of wildfire preparedness in rural Australia. Environ. Hazards 5:1–12.

Monroe, M.C.; Nelson, K.C. 2004. The value of assessing public perceptions: wildland fire and defensible space. Appl. Environ. Educ. Commun. 3:109–117.

Mottus, B. 2002. Duffield wildfire behavior and review of April 24 2001 fire in Parkland County in West-Central Alberta. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

Nelson, K.C.; Monroe, M.C.; Johnson, J.F. 2005. The look of the land: homeowner landscape management and wildfire preparedness in Minnesota and Florida. Soc. Nat. Resour. 18:321–336.

Partners in Protection. 2003. FireSmart. Protecting your community from wildfire. 2nd ed. Edmonton, AB.

Pearce, L. 2003. Disaster management and community planning, and public participation: how to achieve sustainable hazard mitigation. Nat. Hazards 28:211-228.

Russell, L.A.; Goltz, J.D.; Bourque, L.B. 1995. Preparedness and hazard mitigation actions before and after two earthquakes. Environ. Behav. 27(6):744–770.

Savage, I. 1993. Demographic influences on risk perceptions. Risk Anal. 13(4):413–420.

Shindler, B.; Gordon, R. 2005. A practical guide to citizen-agency partnerships. Public outreach strategies for fire and fuel management. Dep. For. Resour., Oregon State Univ., Corvallis, OR.

Shindler, B.; Toman, E. 2003. Fuel reduction strategies in forest communities. A longitudinal analysis of public support. J. For. 101(6):8–15.

SILVIS Lab. 2004. Patterns of change. The Wildland–Urban Interface. Forest Ecology and Management, Univ. Wisconsin-Madison, Madison, WI. Accessed 14 Dec 2005. <http://silvis.forest.wisc.edu/projects.asp>.

Slovic, P. 2000a. Introduction and overview. Pages xxi–xxxvii *in* P. Slovic, ed. The perception of risk. Earthscan Publications, Sterling, VA.

Slovic, P. 2000b. Trust, emotion, sex, politics, and science: surveying the risk-assessment battlefield. Pages 390–412 *in* P. Slovic, ed. The perception of risk. Earthscan Publications, Sterling, VA.

Slovic, P.; Flynn, J.; Layman, M. 2000. Perceived risk, trust, and politics of nuclear waste. Pages 275–284 *in* P. Slovic, ed. The perception of risk. Earthscan Publications, Sterling, VA.

Smith, M.D.; Krannich, R.S. 2000. "Culture clash" revisited: newcomer and longer-term residents' attitudes toward land use, development, and environmental issues in rural communities in the Rocky Mountain west. Rural Sociol. 65(3):396–421.

Steelman, T.A.; Kunkel, G.F. 2004. Effective community responses to wildfire threats: lessons from New Mexico. Soc. Nat. Resour. 17:679–699.

Tàbara, D.; Sauri, D.; Cerdan, R. 2003. Forest fire risk management and public participation in changing socioenvironmental conditions: a case study in a Mediterranean region. Risk Anal. 23(2):249–260.

Vogt, C. 2003. Seasonal and permanent home owners' past experiences and approval of fuel reductions. Pages 63–73 *in* P. Jakes, compiler. Homeowners, communities, and wildfire: science findings from the national fire plan. Proc. 9th Int. Symp. Soc. Resour. Manage., 2–5 June 2002, Bloomington, IN. US Dep. Agric. For. Serv., North Cent. Res. Stn., St. Paul, MN. Gen. Tech. Rep. NC-231.

Vogt, C.; Winter, G.; Fried, J. 2003. Antecedents to attitudes toward prescribed burning, mechanical thinning, and defensible space fuel reduction techniques. Pages 74–83 *in* P. Jakes, compiler. Homeowners, communities, and wildfire: science findings from the national fire plan. Proc. 9th Int. Symp. Soc. Resour. Manage., 2–5 June 2002, Bloomington, IN. US Dep. Agric. For. Serv., North Cent. Res. Stn., St. Paul, MN. Gen. Tech. Rep. NC-231.

Vogt, C.; Winter, G.; Fried, J. 2005. Predicting homeowners' approval of fuel management in the wildland–urban interface using the theory of reasoned action. Soc. Nat. Resour. 18:337–354.

Weber, M.G.; Flannigan, M.D. 1997. Canadian boreal forest ecosystem structure and function in a changing climate: impact of fire regimes. Environ. Rev. 5:145–166.

Whitehead, J.C.; Edwards, B.; Van Willigen, M.; Maiolo, J.R.; Wilson, K.; Smith, K.T. 2000. Heading for higher ground: factors affecting real and hypothetical hurricane evacuation behavior. Environ. Hazards 2:133–142.

Winter, G.; Fried, J.S. 2000. Homeowner perspectives on fire hazard, responsibility and management strategies in the wildland–urban interface. Soc. Nat. Resour. 13:33–49.

Winter, G.; Vogt, C.A.; McCaffrey, S. 2004. Examining social trust in fuels management strategies. J. For. 102(6):8–15.

Winter, P.L. 2003. Californians' opinions on wildland and wilderness fire management. Pages 84–92 *in* P. Jakes, compiler. Homeowners, communities, and wildfire: science findings from the national fire plan. Proc. 9th Int. Symp. Soc. Resour. Manage., 2–5 June 2002, Bloomington, IN. US Dep. Agric. For. Serv., North Cent. Res. Stn., St. Paul, MN. Gen. Tech. Rep. NC-231.

McFarlane, B.L. 2006. Human dimensions of fire management in the wildland–urban interface. Pages 27–34 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

# ANALYSES

# Fire Risk and Population Trends in Canada's Wildland–Urban Interface

**B. Peter**[1], **S. Wang**[1, 2], **T. Mogus**[3], and **B. Wilson**[1]

## Introduction

Wildfire, a natural agent of forest renewal, plays an important role in Canada's forests. The ecological value of wildfire is now widely accepted, but fires also affect forest attributes that are important to society, such as aesthetics, recreation space, water quality, and timber values. Throughout history, humans have attempted to manage wildfires in what is now Canada. Aboriginal people set fires in some parts of Canada to manage vegetation, encourage wildlife habitat, or clear forest areas for living space, and early European settlers used fire to clear farmland, mining sites, and railway corridors (CFS 2004). Contemporary fire management in North America began in the 20th century and has traditionally focused on suppressing wildfires and preventing fires that are caused by humans (Martell 2001).

Recent wildfires that have damaged private homes and property have raised concerns over the level of risk that forest fires pose to communities. Because these wildland–urban interface (WUI) fires can threaten valuable assets and severely disrupt the lives of local residents, they are often accompanied by aggressive firefighting campaigns that draw heavily on public resources. When wildfires cause direct damage to communities, the economic and social costs can be substantial. Many are now concerned about the number of vulnerable communities at the WUI and the possibility that the area vulnerable to interface fire may be increasing.

Quantifying the WUI is challenging because of the need to assess both settlement patterns and patterns of forest structure, topography, and weather that contribute to fire risk. Whereas geographic information systems can be used to make detailed assessments of the WUI (e.g., Stewart et al. 2003), this paper examines the issue at a broader scale, by looking at statistics and trends that are relevant to this important issue. We begin by reviewing statistics on wildfire occurrence and costs in Canada and provide some examples of fires that have had direct effects on communities. We then examine population trends in Canada as a whole and in a set of specific interface communities. Finally, we discuss some implications of these trends and offer suggestions for further research.

## Fire Occurrence in Canada

Fires occur every year in Canada's forests, although the amount of fire (in terms of numbers and area burned) and the associated costs can vary widely. The average area burned in Canada from 1920 to 2004 was 1 592 042 hectares, although in many years less than 1 million hectares are burned (Figure 1). In 1981, 1989, 1994, and 1995 the area burned exceeded 5 million hectares. The most extensive fire year in Canada since 1920 occurred in 1989, when more than 11 000 fires burned a total of 7 559 572 hectares.

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Figure 2 displays the number of fires and area burned since 1990 in terms of suppression response. Relatively few fires receive a limited (modified) response, but these fires account for a large proportion of the area burned. For example, in 2004, only 10.6% of fires received a modified response, although these fires accounted for 81% of the area burned (Johnston 2005).

Van Wagner (1988) analyzed the pattern of fire occurrence in Canada from 1918 to 1986 and concluded that most of the 20th century had been characterized by a downward trend in the annual area burned. This trend appeared to end in the late 1970s, when much more severe fire years began occurring at regular intervals. Podur et al. (2002) confirmed that this trend has continued into the 21st century. The causes may include changing forest conditions or a changing climate. The magnitude of some recent fires has been linked to fuel accumulations resulting from successful fire suppression (Filmon 2004). Global warming has also been cited as a driver of increased fire occurrence (Gillett et al. 2004), and climate change forecasts for many parts of North America predict longer fire seasons and more severe fire weather (IPCC 2001). Determining fire occurrence trends with certainty is difficult, however. Records of fire occurrence in the past may be less reliable, as fires would not have been detected as reliably or extensively as they are today. Furthermore, it is difficult to know whether the trend toward more severe fire years will continue or whether this is simply part of a natural ebb and flow of fire activity. Although climate change is predicted to increase overall fire occurrence, impacts at the local level remain uncertain. Fire occurrence could remain unchanged or even decrease in some locations because of other impacts from climate change, such as increased summer precipitation (Flannigan and Wotton 2001).

## Fire Costs in Canada

The costs associated with fires can include direct suppression costs, lost timber assets, and damage to private property or public infrastructure. The evacuation of communities that are threatened by fire can also result in significant costs, and fires may cause disruptions to highway or rail transport or other economic activity. Smoke may create costs in the form of health effects. Amenity values may be reduced after

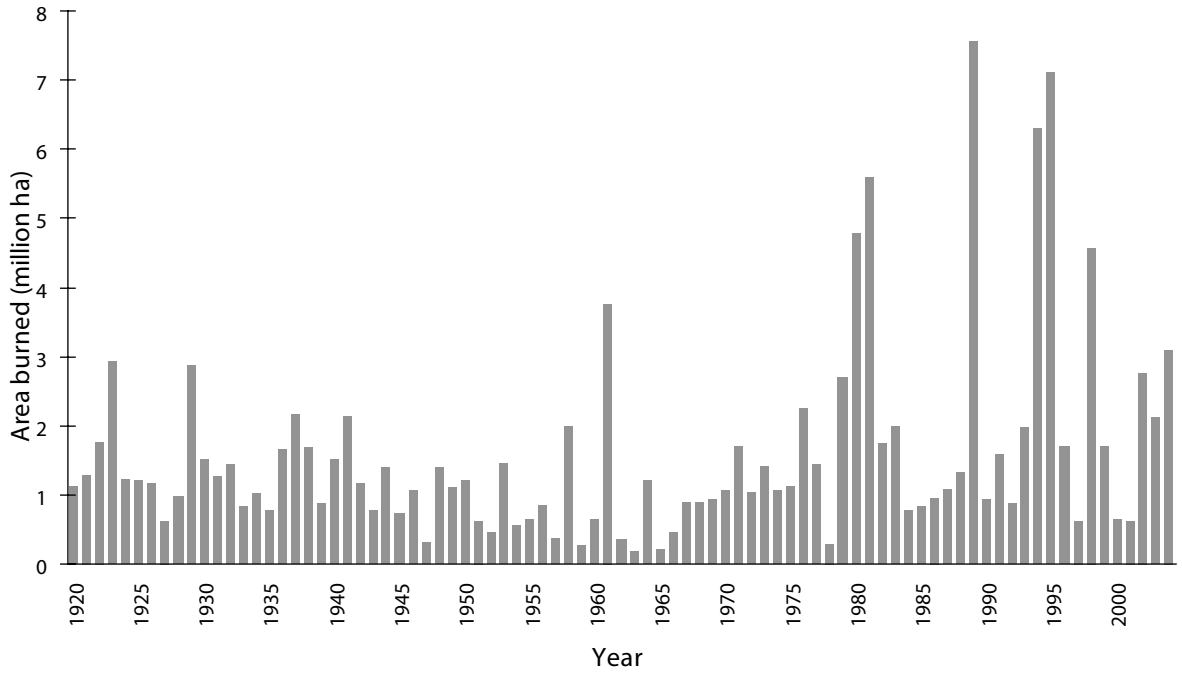


**Figure 1. Area burned in Canada from 1920 to 2004.**

fire, and other forest values such as habitat or carbon storage may be affected. While many of these costs go unrecorded (and in some cases are difficult to quantify), variation in annual fire costs are reflected in the variation in direct firefighting expenditures. From 1990 to 2001, protection expenditures in Canada averaged $417 million (Figure 3). In 1998, fire expenditures were over $800 million, roughly double the average for the period. During the 2003 fire season, fire management costs in Canada approached $1 billion (not shown in Figure 3).

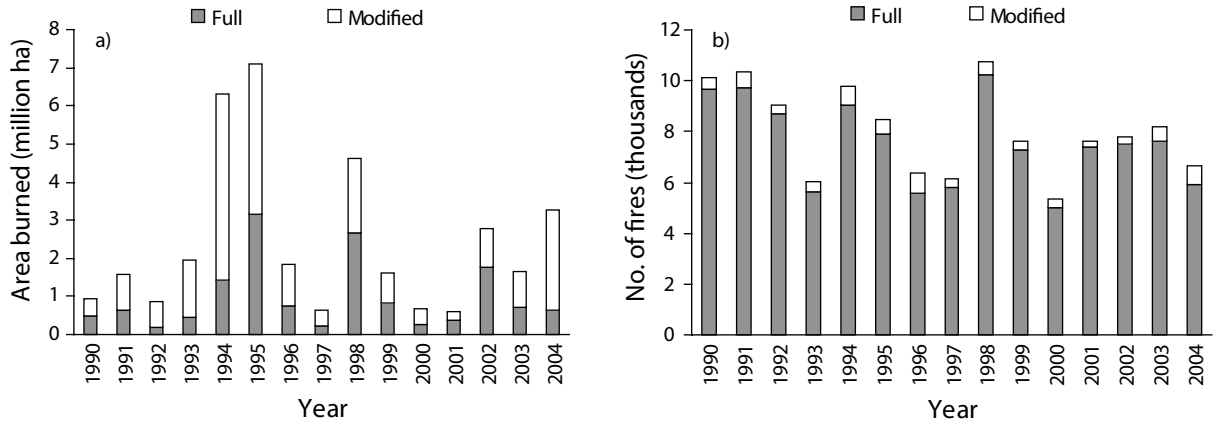


**Figure 2. Area burned (a) and number of fires (b) in Canada by response type.** Full response refers to an attempt to control the fire as soon as possible, consistent with resource availability and values at risk. Modified response refers to an attempt to control the fire in a limited way, such that only isolated values threatened by a fire are protected, or an attempt to monitor a fire until it is extinguished naturally. Sources: Data for 1990–2002 from CCFM (2004); data for 2003–2004 from Johnston (2005).

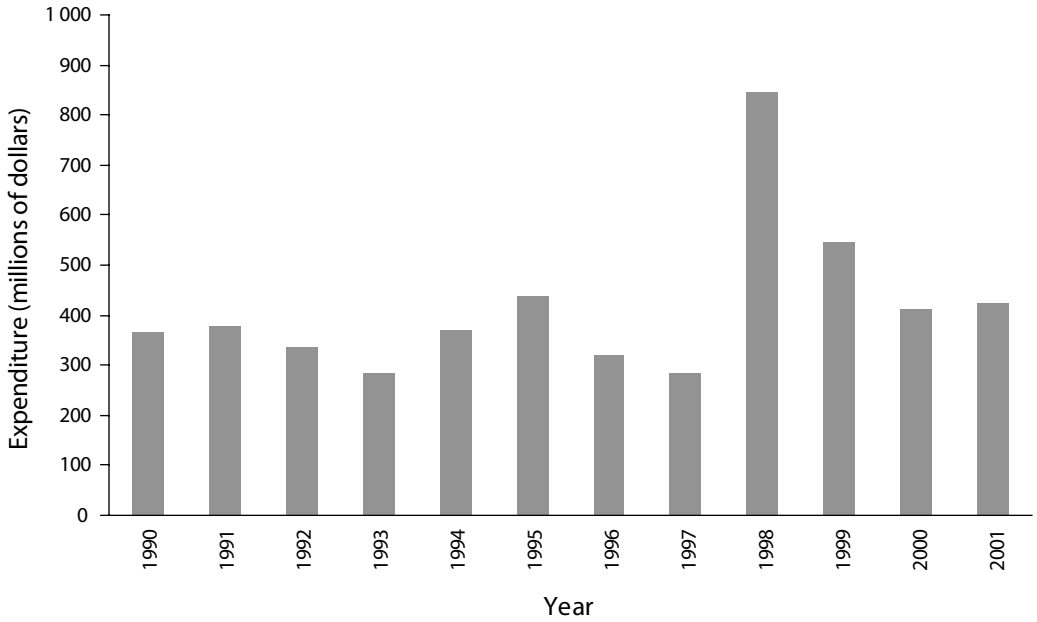


**Figure 3. Protection expenditures in Canada, 1990–2001.** Source: CCFM (2004).

Costs also vary widely from year to year at the provincial level; see Table 1 for an example.

**Table 1. Firefighting budget, area burned and final costs for wildfires in British Columbia**

| Year | Total area (ha) | Total cost ($, millions) | Average cost/ha ($) |
|---|---|---|---|
| 1993 | 5 183 | 25.2 | 4 860 |
| 1994 | 30 310 | 90.9 | 2 999 |
| 1995 | 48 080 | 38.5 | 800 |
| 1996 | 20 669 | 37.1 | 1 794 |
| 1997 | 2 960 | 19 | 6 419 |
| 1998 | 76 574 | 153.9 | 2 009 |
| 1999 | 11 581 | 21.1 | 1 822 |
| 2000 | 17 673 | 52.7 | 2 982 |
| 2001 | 9 677 | 53.8 | 5 560 |
| 2002 | 8 581 | 37.5 | 4 370 |
| 2003 | 264 747 | 371.9 | 1 405 |
| 2004 | 220 468 | 164.6 | 747 |

Source: BCMFR (2004).

Fire suppression costs average $53 million per year in British Columbia, but the 2003 fire season saw a total of $371.9 million spent suppressing fires that burned an area more than 10 times larger than the average for the previous 10 years. As a result of the costly 2003 fire season, the Canadian government is providing funding through the Disaster Financial Assistance Arrangements (DFAA) to help offset some of the expenses borne by the provincial government (PSEPC 2003).

In the 2003 fire season, several wildfires burned through communities in the WUI of British Columbia, resulting in many costs beyond those incurred by provincial fire-suppression crews. Insurance payments totalled approximately $200 million (IBC 2004), and the Red Cross spent over $4.5 million on activities that included direct assistance to displaced residents and community support after the fires (Canadian Red Cross 2004). A local sawmill that provided approximately 200 direct jobs was destroyed in the town of Barriere (Tolko Industries 2003). Individual communities were responsible for many of the cleanup costs, which were estimated to be as high as $6 million in Kelowna (CHBC 2003). The Myra Canyon trestles near Kelowna, a popular recreation area and National Historic Site, were also destroyed in the 2003 fires. Reconstruction of the trestles has been estimated at $13.5 million, with the majority of this funding to come from federal disaster relief funds (PSEPC 2004b).

Other recent fires in Canada have caused significant costs and impacts. In 2001 the Chisholm fire in Alberta resulted in the loss of 10 homes, 1 cabin, and 48 outbuildings, as well as requiring approximately $10 million in direct firefighting costs (CFRC 2001). In 1999, 5 structures were lost at Burwash Landing, Yukon; in 1998, 20 homes were destroyed near Salmon Arm, British Columbia; and in 1995, fires in northern Saskatchewan burned over 160 000 hectares and resulted in the evacuation of 2 500 people (PSEPC 2004a). In 1994, a fire near Penticton destroyed 18 homes (Ko 1995). In 1989, fires in northern Manitoba resulted in the evacuation of approximately 25 000 people from 25 communities (PSEPC 2004a).

Other major WUI events occurred earlier in the century. In 1908, a forest fire engulfed the town of Fernie, British Columbia, leaving roughly 3 000 people homeless (Parminter 1991). Furthermore, forest fires throughout the past century have regularly led to evacuations when property or communities have been threatened. More recently, the 2004 fire season in British Columbia also resulted in an extensive area burned, although many of the fires occurred in more isolated areas of the province's north, and no significant WUI events occurred (BCMFR 2004). Consequently, costs per hectare in 2004 were roughly half of those in 2003. This difference highlights the fact that the cost of fire often has more to do with where fires occur than how much forest actually burns.

## Population Trends at the WUI

Although increases in fire occurrence may lead to an increasing risk, fire has long been a regular occurrence in many of the ecosystems where interface communities exist. The question many are now asking is whether the area vulnerable to interface fire is itself increasing. In other words, are more people now choosing to live in areas adjacent to fire-prone forests? A look at some population statistics and trends provides insights into this issue.

Canada as a whole is becoming increasingly urban. The population of Canada grew by 4% from 1996 to 2001, but the population of rural and small town areas actually declined by 0.4%. Thus, although the rural population has changed very little since 1931 (Figure 4) it has decreased substantially as a proportion of the total population. However, Figure 4 also shows that over the past several decades the number of rural farm residents has decreased, whereas the number of rural non-farm residents has increased. Several underlying trends are likely contributing to this component of rural growth. We have identified and briefly discuss three such trends that have direct implications for the WUI: urban sprawl, demand for recreation property, and growth in isolated communities.

### Urban Sprawl

Urban sprawl has been defined in many ways, but it essentially refers to the notion that along with urban growth come increasing pressures on the surrounding area. Between 1986 and 2001, a 69% increase occurred in the population living in the portion of large urban centres classified as "urban fringe" (small urban areas with less than 10 000 population within a census metropolitan area [CMA] or census agglomeration [CA] that are not contiguous with the urban core of the CMA or CA). This was nearly 3 times the growth in total population for these areas. Although residential expansion is frequently the key driver, city amenities and economic development often follow. This shift can be seen in virtually all CMAs in Canada, where the average number of persons working in suburban municipalities increased by 63% from 1981 to 2001; in contrast, the corresponding increase in urban core workers during the same period was only 8%. In fact, during this period, the Winnipeg CMA experienced a 229% increase in the number of workers in the suburban municipalities and an increase of only 5% in core workers.

Urban sprawl is particularly relevant to WUI risks when it leads to greater numbers of people living in

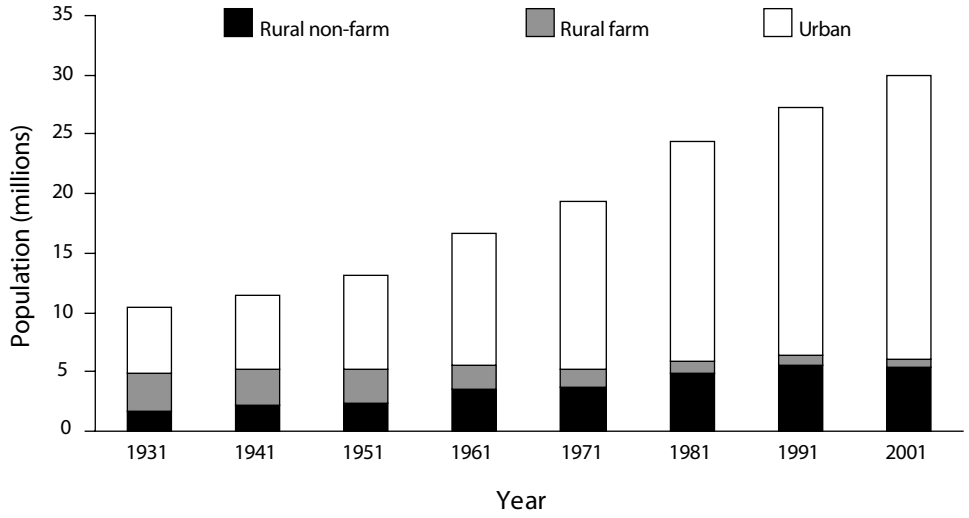


**Figure 4. Rural population levels in Canada, 1931–2001.** Source: Statistics Canada (1986–2001; Leacy 2003). "Urban" refers to areas with minimum population concentrations of 1000 and population density of at least 400/km$^2$, based on the most recent census. All territory outside urban areas is considered rural. Taken together, urban and rural areas cover all of Canada.

rural or semi-rural areas adjacent to cities. In the census of Canada, metropolitan influenced zones identify linkages between urban areas and surrounding census sub-divisions (CSDs) according to their economic ties. Between 1991 and 1996 there was a 28% net increase in the number of strongly influenced CSDs (having greater than 30% of residents commuting to nearby urban centres), and the population living in strongly influenced CSDs increased by 6.7%. From 1996 to 2001 the population in strongly influenced CSDs increased by 3.7%. During this period only Atlantic Canada experienced a declining population in these areas, whereas Alberta's strongly influenced CSD population increased by 12.7%. As reported by Statistics Canada (2001a), "The growth in these areas was mainly the result of people who moved just beyond urban boundaries to live in a more rural setting."

### Demand for Recreation Property

Although statistics on recreation properties are not explicitly detailed in census data, other sources provide some insight into trends in this area. For example, a recent Canada-wide poll (Royal LePage Real Estate Services 2004b) estimated that approximately 10% of Canadians owned recreation properties at the time of the survey. Of these owners, only 17% (i.e., 1.7% of Canadians) planned to sell their properties in the next 2 to 3 years, while 6% of Canadians intended to purchase recreation property in the next 2 to 3 years. Furthermore, it was estimated that during 2004 approximately seven Canadians were searching for a recreation property for every two properties for sale. Excess demand is seen as a major factor in the rising prices of recreation property (Royal LePage Real Estate Services 2004b). In the recent past, factors such as favourable interest rates, high levels of employment, and rising incomes have been cited as important contributors to real estate demand in general (Warren 2005). More specifically, it has been suggested that the baby boomer cohort represents the driving force behind demand for recreation property, as this aging generation looks to retire in "cottage country" (Hiller 2002). Leacy (2003) estimated that in 2002, 13% of Canada's population was over the age of 65, and this figure is projected to increase to 21% over the next 20 years.

### Growth in Isolated Rural Areas

Although most of the growth in the rural population has occurred in the general vicinity of urban centres, some of the most isolated rural areas have also experienced growth. Many of these communities are in Canada's north, and they typically have a strong Aboriginal presence. Statistics Canada (2001a) reported that from 1996 to 2001, "The population of the most remote areas grew 1%. Their rate of natural increase was still high enough to offset any out-migration. The high rate of natural increase may be attributed to the higher birth rate among Aboriginal people." Moreover, although net out-migration was prominent in rural non-reserve areas, Statistics Canada (2001a) reported a small net increase (1.1%) in movement into reserves between 2000 and 2001. It was noted that this was "a continuation of a trend that has been observed since 1981."

During Canada's census, many Aboriginal communities are improperly enumerated, which makes it difficult to assess trends. Accounting for this issue, Southcott (2002b), in a detailed examination of northern Ontario, reported that "of the 285 [CSDs] for which figures exist, the 39 fastest growing were all Aboriginal communities. . . . Overall, the average rate of growth for these communities was 5.9% in Northern Ontario. While this growth rate was slightly less than the 6.1% growth rate for Ontario, it was substantially higher than the 4% growth rate for Canada." Although Ontario was home to the largest Aboriginal population in 2001, INAC (2000) reported that "Population growth [for Aboriginals] is uneven across Canada. The Prairies are experiencing the largest growth, particularly in Manitoba, followed closely by Alberta and Saskatchewan." INAC (2000) also projected that "The on-reserve RI [Registered Indian] population could increase from 407 300 in 2000 to 703 200 in 2021 with an average annual growth rate of approximately 3.5%." Despite the overall trend toward urbanization in Canada, it appears that some isolated rural areas will continue to experience a strong rate of population growth.

## Examples of Local Population Change at the WUI

The population trends highlighted above have direct implications for the WUI. Through the growing appeal of out-of-town living, increased demands for recreation properties, and population growth in some isolated areas, the WUI is continually being redefined. Although quantifying the magnitude of this impact in detail is beyond the scope of this paper, we discuss here a few specific examples (Figure 5).

### Urban Sprawl: Kelowna and Penticton, British Columbia

Two examples from British Columbia, the towns of Kelowna and Penticton, were examined in terms of growth within the city centre and the surrounding area (Figure 6). These towns are both located in the Okanagan Valley, one of the fastest growing regions of Canada.

In each year, growth in the areas adjacent to Kelowna and Penticton either matched or exceeded growth within the city centres. For example, from 1991 to 1996, the population of the city of Kelowna grew by approximately 18%, while that of the surrounding area grew by 31%. From 1996 to 2001, the city of Penticton recorded a slight decrease in population, while the population of the surrounding area grew by approximately 7%. Many of the homes in these areas have been constructed recently. The average proportion of homes in Canada that were built after 1991 is approximately 15% (Statistics Canada

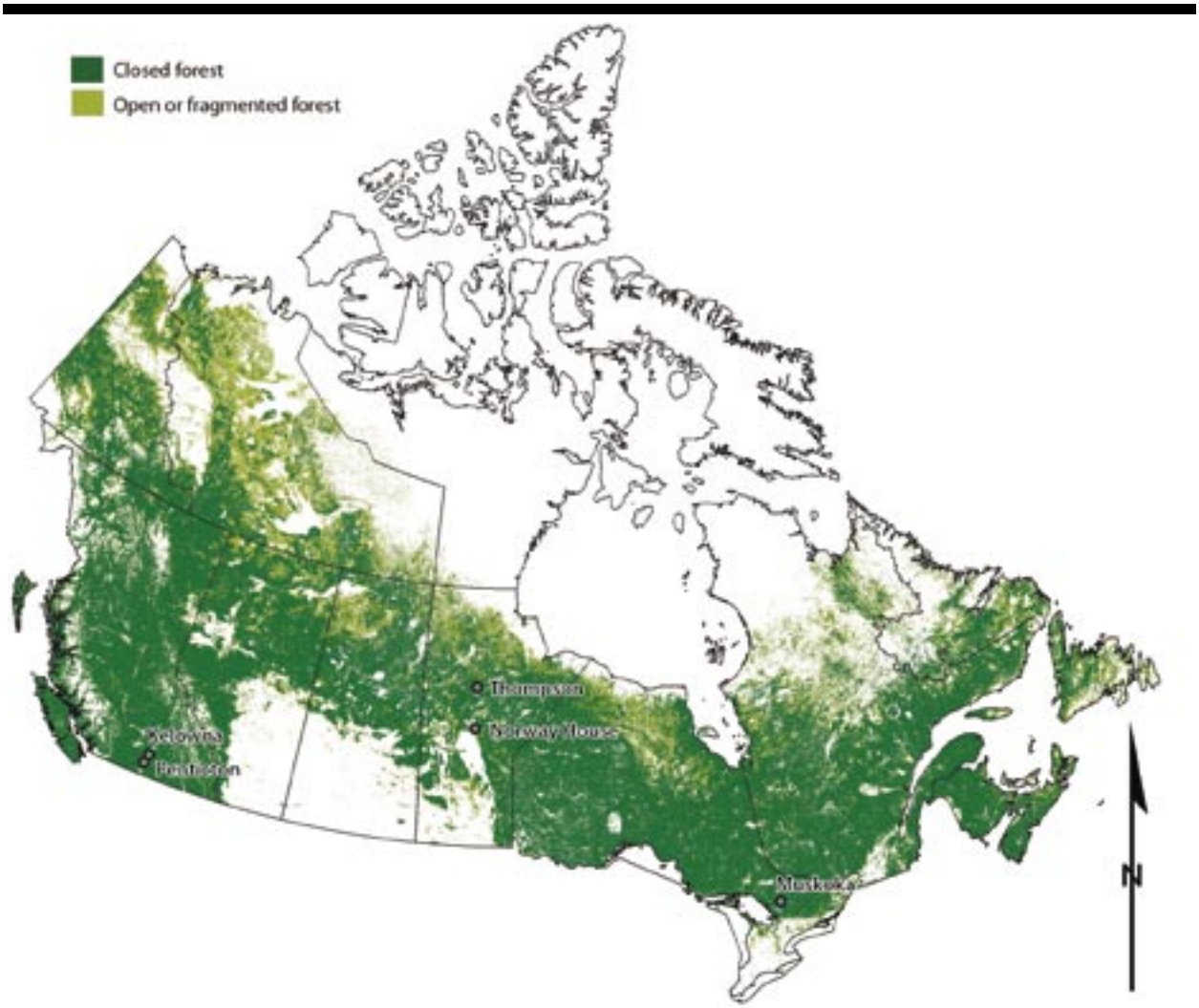


**Figure 5. Location of communities examined in detail.** Forest cover data from FAO (2001).

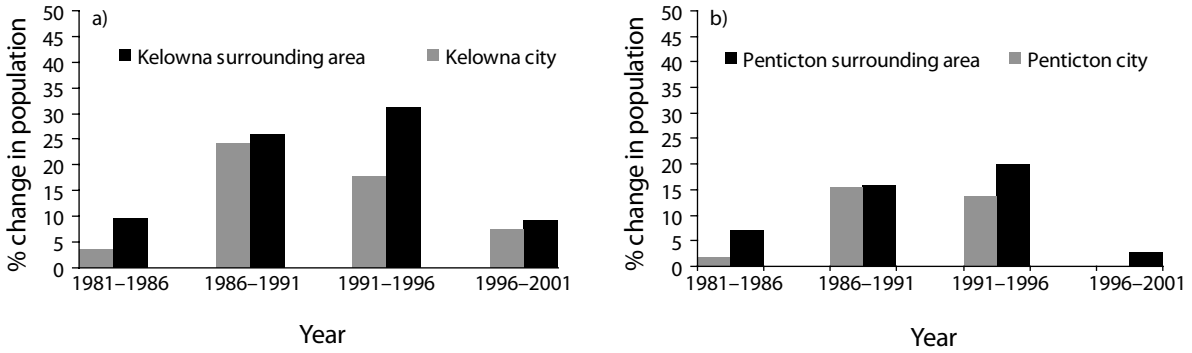


**Figure 6. Percent population growth for Kelowna (a) and Penticton (b).** Source: Statistics Canada (1986–2001). The population of the surrounding area was estimated by subtracting the population of the city centre from the population of the census agglomeration.

2001b). However, the 2001 census showed that over 20% of the homes in the city centres of Penticton and Kelowna were built after 1991, and the proportion was over 30% outside the city centres. The population of these communities is predicted to continue rising, particularly in the Kelowna area. From 2004 to 2031 the populations of the Penticton and Kelowna Local Health Areas are expected to increase by 33% and 56%, respectively (British Columbia Statistics 2004).

A recent report (Alexander et al. 2004) confirmed that urban sprawl is an issue in the Kelowna area, driven in part by the attractiveness and affordability of housing outside the city centre and by geographic factors that make contiguous urban development difficult. The report also acknowledged that the city of Kelowna is taking steps to mitigate sprawl through its official community plan and other initiatives. However, it is expected that the area will face continuing challenges from urban sprawl because of its geography, past land-use decisions, a lack of affordable urban housing, and transportation improvements that may encourage further growth in the surrounding area.

## Recreation Property: Muskoka, Ontario

With its abundant environmental amenities and proximity to several large urban centres, Ontario's Muskoka region is a prime example of cottage country. Southcott (2002a) stated, "The two districts closest to the main metropolitan areas of Ontario, the Muskoka District Municipality and the District of Parry Sound have migration rates that are consistently higher than the average for Northern Ontario and Ontario as a whole." Figure 7 shows the permanent populations of each of the six communities that constitute the Muskoka District Municipality. In the 30-year period from 1971 to 2001, five of these communities experienced considerable growth. Overall, the permanent population of the Muskoka District Municipality expanded by over 60% during this period, and the population is projected to continue increasing (Figure 7).

Another significant factor is that the population in the Muskoka region virtually doubles during the warm summer months. Estimated at 105 972 in 2001, this seasonal influx places additional stress on the landscape, adding to the threat that fires pose to human safety, as well as the risk of human-caused fire. Although a large fire has not threatened the Muskoka region recently, the region does contain fire-prone forests (GVFD 2005), and population trends here are a vivid example of trends that are occurring to various degrees in other regions. For example, interface communities such as Bridgewater, Nova Scotia, and Cranbrook, British Columbia, have been identified as popular locations for recreation property (Royal LePage Real Estate Services 2004a), and growing resort destinations such as Whistler and Radium–Fairmont in British Columbia and the Bow Valley in Alberta have been identified as being subject to the risk of interface fire (RMW 2002; Partners in Protection 2003; Parks Canada 2004).

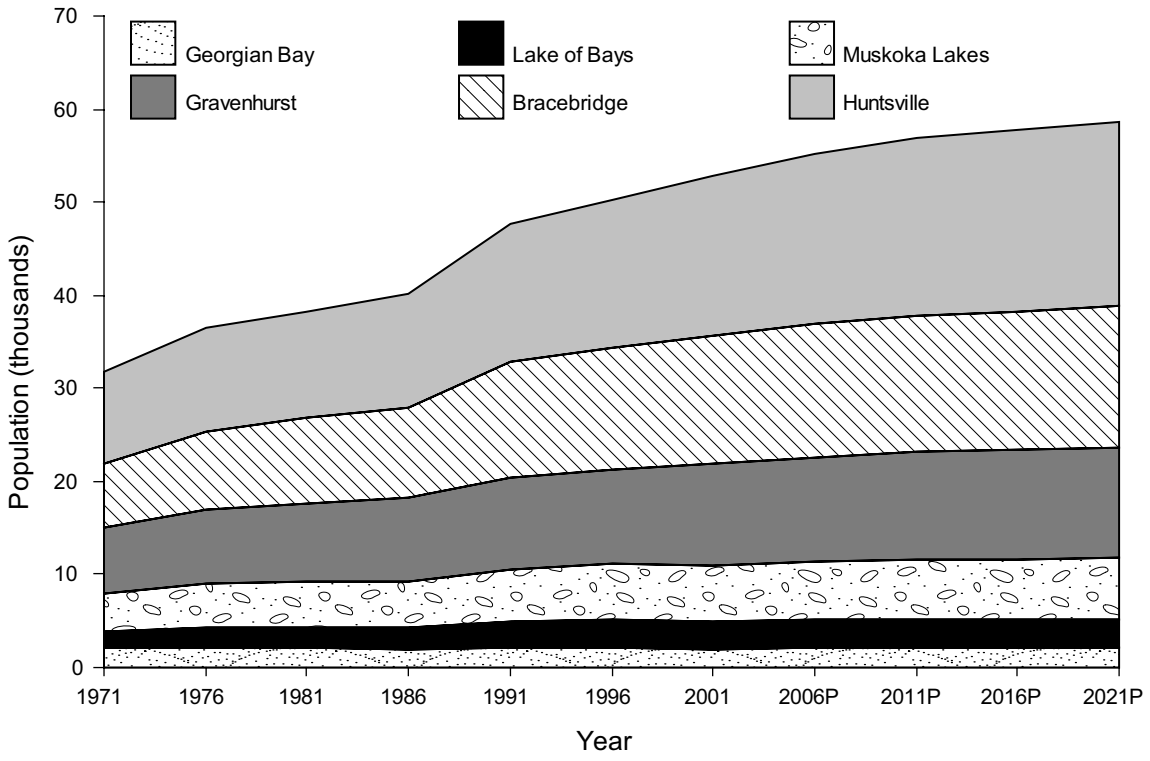


**Figure 7. Population trends in Muskoka District Municipality.** Source: Statistics Canada (1986–2001) and District Municipality of Muskoka (2004). P = projected population.

## Growth in Isolated Communities: Thompson and Norway House, Manitoba

The towns of Thompson and Norway House are located in northern Manitoba (Figure 5). Both communities are home to a significant Aboriginal population. As of 2001, the population of Thompson consisted of approximately 34% Aboriginal residents, while that of Norway House consisted of approximately 98% Aboriginal residents. While Thompson is known as a major commercial and transportation hub in northern Manitoba, the population of Norway House is described as, "...still dependent on the old way of life. Many of the descendents of the fur trappers and fishermen of yesteryear continue to trap and fish today... The traditional thinking of many on Norway House Cree Nation helps to set it apart from other communities in the North." (Province of Manitoba 2005).

Although the population of Thompson is much larger than that of Norway House (Figure 8), Thompson's population has declined by more than 1 000 residents since 1981. In contrast, the population of Norway House has grown by over 2 000 residents, roughly doubling in size. Norway House is an example of a small, isolated community that is nonetheless experiencing rapid growth.

Manitoba's Aboriginal population is expected to continue growing at an annual rate of approximately 1.9% per year (versus 0.3% for the non-Aboriginal population) (Manitoba Bureau of Statistics 1997), indicating that growth in Aboriginal communities like Norway House is likely to continue. A profile of the region confirms this, stating, "The population of Norway House Cree Nation is constantly growing. The largest percentage of the population is in the 0–14 age category which is 39% of the total population. The average age of the population is 24 showing that this is a young, growing community" (Province of Manitoba 2005).

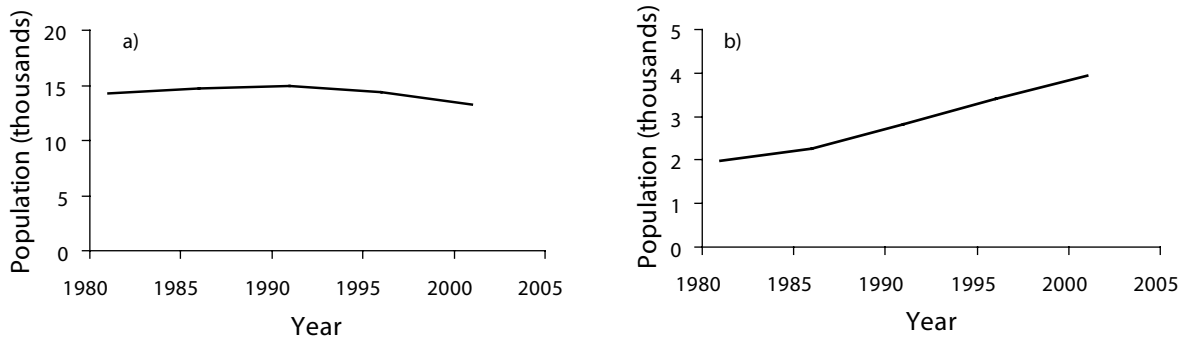


**Figure 8. Populations of (a) Thompson and (b) Norway House, Manitoba, 1981 to 2001.** Source: Statistics Canada (1986–2001).

## Discussion and Conclusions

Although trends in fire occurrence remain difficult to assess, recent damaging fires in Canada have caused many to question whether the area vulnerable to interface fire is itself growing. While Canada as a whole is becoming increasingly urban, populations in some rural areas are increasing. Population trends that affect Canada's WUI include urban expansion into rural areas, increasing demand for recreation properties, and high rates of growth in some isolated communities. A seasonal influx of people to some recreation areas also contributes to the area needing protection. These seasonal surges typically coincide with periods of high fire hazard (warm, dry weather), which affects both the consequences of fire and the risk of human-caused fires. Canada's population is projected to grow steadily and as such, it is expected that these trends will continue.

The key implication of a growing WUI area is that it increases the potential number of fires that need aggressive and costly control efforts. Furthermore, some fires inevitably escape control, and when these occur in the WUI the economic and social costs can be substantial. Some strategies may reduce the vulnerability of these areas, such as the use of flame-resistant building materials or the strategic placement of roads, water supplies or sprinkler systems (Partners in Protection 2003). However, extreme fire conditions may overwhelm these strategies at times, and widespread removal of natural fuels may ultimately be the most effective way to reduce risks in many areas. In some cases this could lead to changes in the aesthetic characteristics that draw people to interface areas in the first place, and an awareness of the risks and mitigation requirements in interface areas may affect the choices people make over whether to live in those areas. The encouragement of safer communities through city bylaws, building codes, and insurance may also have the potential to affect the behaviour of WUI residents. These influences may in turn affect the trends in WUI growth that we have discussed in this paper.

Our study has identified some important trends that affect the WUI issue in Canada, but additional research is required in several areas. More detailed assessments are needed of the extent of the WUI in Canada and the associated level of risk. A better understanding of the effect of fuel treatments and other mitigation strategies on risk reduction is required, and monitoring and assessment of current treatments are also required to determine their costs and long-term effectiveness. The trends we have identified in this paper must be monitored on a continuing basis. Most importantly, however, research and information must be communicated to those making decisions that affect the WUI, including policy-makers, local governments, property developers, insurers, and homeowners. The policy actions and choices of these people will ultimately determine the future growth of the WUI and many of the drivers of interface risks.

## Literature Cited


Alexander, D.; Tomalty, R.; Anielski, M. 2004. BC sprawl report 2004. Smart Growth BC, Vancouver, BC. 79 p.

[BCMFR] British Columbia Ministry of Forests and Range. 2003. Burnt timber provides economic benefits to Ktunaxa [news release on-line]. Victoria, BC. Doc. date 18 Dec 2003. Accessed 26 Oct 2004. <http://www.for.gov.bc.ca/pscripts/pab/newsrel/mofnews.asp?refnum=2004FOR0060%2D001&searchtext=>.

[BCMFR] British Columbia Ministry of Forests and Range. 2004. Average hectares, fires, and dollars [on-line]. Victoria, BC. Accessed 18 Oct 2004. <http://www.for.gov.bc.ca/protect/reports/HistoricalAverages.htm>.

BC Stats. 2004. Population projections — BC and regional [on-line]. Victoria, BC. Accessed 23 Nov 2004. <http://www.bcstats.gov.bc.ca/data/pop/pop/popproj.htm>.

[CCFM] Canadian Council of Forest Ministers. 2004. Compendium of Canadian forestry statistics [on-line]. Ottawa, ON. Accessed 20 Oct 2004. <http://nfdp.ccfm.org/compendium/index_e.php>.

Canadian Red Cross. 2004. Financial summary, August 2004. Red Cross 2003 B.C. Forest Fire Response Fund. [on-line]. Ottawa, ON. Accessed 26 Oct 2004. <http://www.redcross.ca/article.asp?id=010094&tid=079>.

CHBC. 2003. Expensive fire damage [news article on-line]. Okanagan Valley Television, Kelowna, BC. Doc. date 2003 Oct 21. Accessed 26 Oct 2004. <http://www.chbc.com/news/articles_files/7277/news_14_7277.shtml>.

[CFRC] Chisholm Fire Review Committee. 2001. Chisholm Fire Review Committee final report. Submitted to Minister of Alberta Sustainable Resource Development. October 2001. 50 p.

District Municipality of Muskoka. 2004. Permanent population projections 2001–2021. Prepared by Marshall Macklin and Monaghan, Thornhill, ON. 22 p.

[FAO] Food and Agriculture Organization of the United Nations. 2001. Forest Resources Assessment GIS Data. Food and Agriculture Organization of the United Nations, Rome. Accessed 15 Jun 2004. <www.fao.org/forestry/site/8952/en>.

Filmon, G. 2004. Firestorm 2003 provincial review. Province of British Columbia, Victoria, BC. 100 p. Accessed 24 Jan 2006. <http://www.llbc.leg.bc.ca/public/PubDocs/bcdocs/367694/Firestorm_Report.pdf>.

Flannigan, M.; Wotton, B. 2001. Climate, weather and area burned. Pages 527–369 *in* Forest fires: behavior and ecological effects. E.A. Johnson and K. Miyanishi, eds. Academic Press, San Diego, CA.

Gillett, N.; Weaver, A.; Zwiers, F.; Flannigan, M. 2004. Detecting the effect of climate change on Canadian forest fires. Geophys. Res. Lett. Vol. 31, L18211, doi:10.1029/2004GL020876. 4 p.

[GVFD] Gravenhurst Volunteer Fire Department. 2005. Forest fire danger rating [on-line]. Gravenhurst, ON. Accessed 30 Mar 2005. <http://gravenhurst.ca/public/gvfd/FireRatings/>.

Hiller, S. 2002, 13 July. Cottage lust. National Post [Toronto] Article obtained from Century 21 Cottage Country Realty Inc. Accessed 14 Mar 2006. <http://www.algonquin-cottages.com/news_views/nationalpost2.htm>.

[IBC] Insurance Bureau of Canada. 2004. Natural disasters in Canada — facts [on-line]. Toronto, ON. Accessed 26 Oct 2004. <http://www.ibc.ca/ii_natural_foundation_facts.asp>.

[IPCC] Intergovernmental Panel on Climate Change. 2001. Climate change 2001: impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change [on-line]. Cambridge University Press, Cambridge, UK. Accessed 23 Mar 2005. <http://www.grida.no/climate/ipcc_tar/wg2/index.htm>.

[INAC] Indian and Northern Affairs Canada. 2000. Registered Indian population projections for Canada and regions 2000–2021. Ottawa, ON. 16 p.

Johnston, T. 2005. CIFFC Canada report 2004. Canadian Interagency Forest Fire Centre, Winnipeg, MB. 8 p.

Ko, E. 1995, 29 July. Anatomy of a fire. Penticton Herald; Article obtained from the City of Penticton. Accessed 14 Mar 2006. <http://www.penticton.ca/fire/1994/GarnetFire1994.asp>.

Leacy, F. 2003. Historical statistics of Canada [on-line]. Statistics Canada, Ottawa, ON. Accessed 15 Nov 2004. <http://www.statcan.ca/english/freepub/11-516-XIE/sectiona/toc.htm>.

Manitoba Bureau of Statistics. 1997. Manitoba's aboriginal populations projected 1991–2016. Winnipeg, MB. Prepared for the Native Affairs Secretariat, Manitoba Northern Affairs.

Martell, D. 2001. Forest fire management. Pages 527–583 *in* Forest fires: behavior and ecological effects. E.A. Johnson and K. Miyanishi, eds. Academic Press, San Diego, CA.

Parminter, J. 1991. Burning alternatives panel: a review of fire ecology, fire history and prescribed burning in southern British Columbia. Paper presented at the 6th Annual. Fire Management Symposium, Southern Interior Fire Management Committee. 29–30 May 1991, Kelowna, BC. 17 p.

Parks Canada. 2004. Redstreak restoration project [on-line]. Gatineau, QC. Accessed 30 Mar 2005. <http://www.pc.gc.ca/pn-np/bc/kootenay/natcul/natcul21_E.asp>.

Partners in Protection. 2003. FireSmart: protecting your community from wildfire. Edmonton, AB.

Podur, J.; Martell, D.; Knight, K. 2002. Statistical quality control analysis of forest fire activity in Canada. Can. J. For. Res. 32:195–205.

Province of Manitoba. 2005. Northern Regional Profile. Province of Manitoba, Winnipeg, MB. Accessed 28 Oct 2005. <http://www.communityprofiles.mb.ca/cgi-bin/region/index.cgi?id=4&print=1>.

[PSEPC] Public Safety and Emergency Preparedness Canada. 2003. Government of Canada presents $100 million advance payment to British Columbia for forest fires [news release on-line]. Ottawa, ON. Doc. date 25 Oct 2003. Accessed 26 Oct 2004. <http://www.ocipep.gc.ca/info_pro/NewsReleases/NR/2003/NR03-0812_e.asp>.

[PSEPC] Public Safety and Emergency Preparedness Canada. 2004a. Canadian disaster database. Background information: executive summary [on-line]. Ottawa, ON. Accessed 18 Oct 2004. <http://www.ocipep.gc.ca/disaster/bg_info.asp?lang=eng>.

[PSEPC] Public Safety and Emergency Preparedness Canada. 2004b. $13.5 million to re-build Myra Canyon trestles [news release on-line]. Ottawa, ON. Doc. date 26 Aug 2004. Accessed 26 Oct 2004. <http://www.psepc.gc.ca/publications/news/20040826_e.asp>.

[RMW] Resort Municipality of Whistler. 2002. Whistler environmental strategy. Whistler, BC. 137 p.

Royal LePage Real Estate Services. 2004a. Royal LePage recreational property report. Toronto, ON. 29 p.

Royal LePage Real Estate Services. 2004b. Soaring demand pressures average cottage prices up over 10 per cent, year-over-year [press release on-line]. Toronto, ON. Doc. date 17 May 2004. Accessed 29 Mar 2005. <http://www.royallepage.ca/recreational/press-release.htm>.

Southcott, C. 2002a. Mobility and migration in northern Ontario. 2001 Census Res. Pap. Ser. Rep. 4. Northern Ontario Training Boards, North Bay, ON. 33 p.

Southcott, C. 2002b. Population change in northern Ontario: 1996 to 2001. 2001 Census Res. Pap. Ser. Rep. 1. Northern Ontario Training Boards, North Bay, ON. 19 p.

Statistics Canada. 1986–2001. Census of Canada [various years]. Ottawa, ON.

Statistics Canada. 2001a. A profile of the Canadian population: where we live [on-line]. Ottawa, ON. Accessed 27 Oct 2004. <http://geodepot.statcan.ca/Diss/Highlights/Highlights_e.cfm>.

Statistics Canada. 2001b. 2001 census of Canada [on-line]. Ottawa, ON. Accessed 27 Oct 2004. <http://www12.statcan.ca/english/census01/home/index.cfm>.

Stewart, S., V. Radeloff and R. Hammer. 2003. Characteristics and location of the wildland-urban interface in the United States. In: Proceedings of the Second International Wildland Fire Ecology and Fire Management Workshop, 16-20 November 2003. Orlando FL. 6 p.

Tolko Industries. 2003. Tolko confirms loss of Louis Creek sawmill operation [news release on-line]. Vernon, BC. Doc. date 5 Aug 2003. Accessed 26 Oct 2004. <http://www.tolko.com/news/releases/aug5_2003.php>.

Van Wagner, C. 1988. The historical pattern of annual burned area in Canada. For. Chron. 64:182–185.

Warren, A. 2005. Real estate trends. Scotia Economics, Toronto, ON.

Peter, B.; Wang, S.; Mogus, T.; Wilson, B. 2006. Fire risk and population trends in Canada's wildland–urban interface. Pages 37–48 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

# Fire Management in Canada: Vulnerability and Risk Trends

**B.M. Wotton**[1] and **B.J. Stocks**[2]

## Context

Over the past century, the use of Canadian forests for both industrial and recreational purposes has increased dramatically. This shift has resulted in an increase in the incidence of forest fires and a consequent increase in the fire management capability that can be mobilized to address the problem. Provincial and territorial fire management agencies have advanced to the point where state-of-the-art computerized fire management systems are common, and Canada is now recognized as a world leader in many aspects of fire management. Nonetheless, despite considerable progress in the prediction, detection, and early control of fires, Canadian fire management agencies understand that there are physical and economic limits to their ability to further control fire in this country. This, along with a recognition of the ecological desirability of natural fire, has led to the relatively recent acknowledgment that forest fires are an element of the Canadian environment that cannot, and should not, be eliminated. In several regions of the country fire management policies now promote aggressive and intensive protection of high-priority values (e.g., human life and property, communities, recreational areas, and forest industry investments) but permit fires in lower-priority areas (generally northern Canada) to burn naturally while still protecting values at risk.

The increase in fire activity and its impacts in recent decades, despite increased resource availability for fire management, have convinced Canadian fire managers that further reductions in area burned will not be gained without significant financial investment. Yet both common experience and sophisticated models show that increasing expenditures on fire suppression lead to decreasing marginal returns in terms of the number of escaped fires or the area burned in the managed forests of this country. The reality is that about 3% of all fires will escape initial attack and grow large and that these fires account for about 97% of the area burned in Canada. These data, coupled with new and emerging pressures on fire management (public, environmental, and political), indicate that the status quo must change if Canadian fire management agencies are to remain effective in managing fire. The purpose of this discussion paper is to review a number of the emerging pressures on fire management agencies that are beginning (or are soon expected) to influence the way in which fire management is carried out in Canada.

## Major Drivers Increasing Forest Fire Risk and Vulnerability

### Climate Change

It is generally accepted among scientists and a growing proportion of the public that climate change is a reality and that over the next century its effects across Canada will be profound and largely unavoidable. Despite their coarse spatial and temporal resolution, general circulation models (GCMs) provide the best

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means currently available to project future climate, and numerous GCMs have been used extensively to project climate throughout the 21st century. In a variety of studies, fire scientists from the Canadian Forest Service have used GCMs to predict future fire danger conditions across the boreal zone, including Canada. Early studies compared seasonal fire weather severity under a doubled carbon dioxide ($2 \times CO_2$) scenario (representative of the climate around the middle of the 21st century) with current climate records and determined that fire danger conditions would increase significantly with climate warming (Figure 1). In the late 1990s researchers used four current GCMs, along with recent weather data, to evaluate the relative occurrence of extreme fire danger across Canada and Russia; they concluded that a significant increase in both the severity and geographic expanse of severe fire danger conditions would occur in both countries under a warming climate. Higher-resolution regional climate models (RCMs) have been used to confirm projections of elevated fire danger. Other studies using both GCM and RCM outputs have shown that the length of the fire season in Canada would increase by about 30 days under a $2 \times CO_2$ climate and that lightning frequency would also increase substantially.

Recent results using Ontario as a test case showed that both human-caused and lightning-caused fire occurrence would increase by 50%–80% across the province over the 21st century. The increase was predicted to be much greater in the northwest of the province than in the northeast. These fire weather and fire occurrence projections for the year 2040

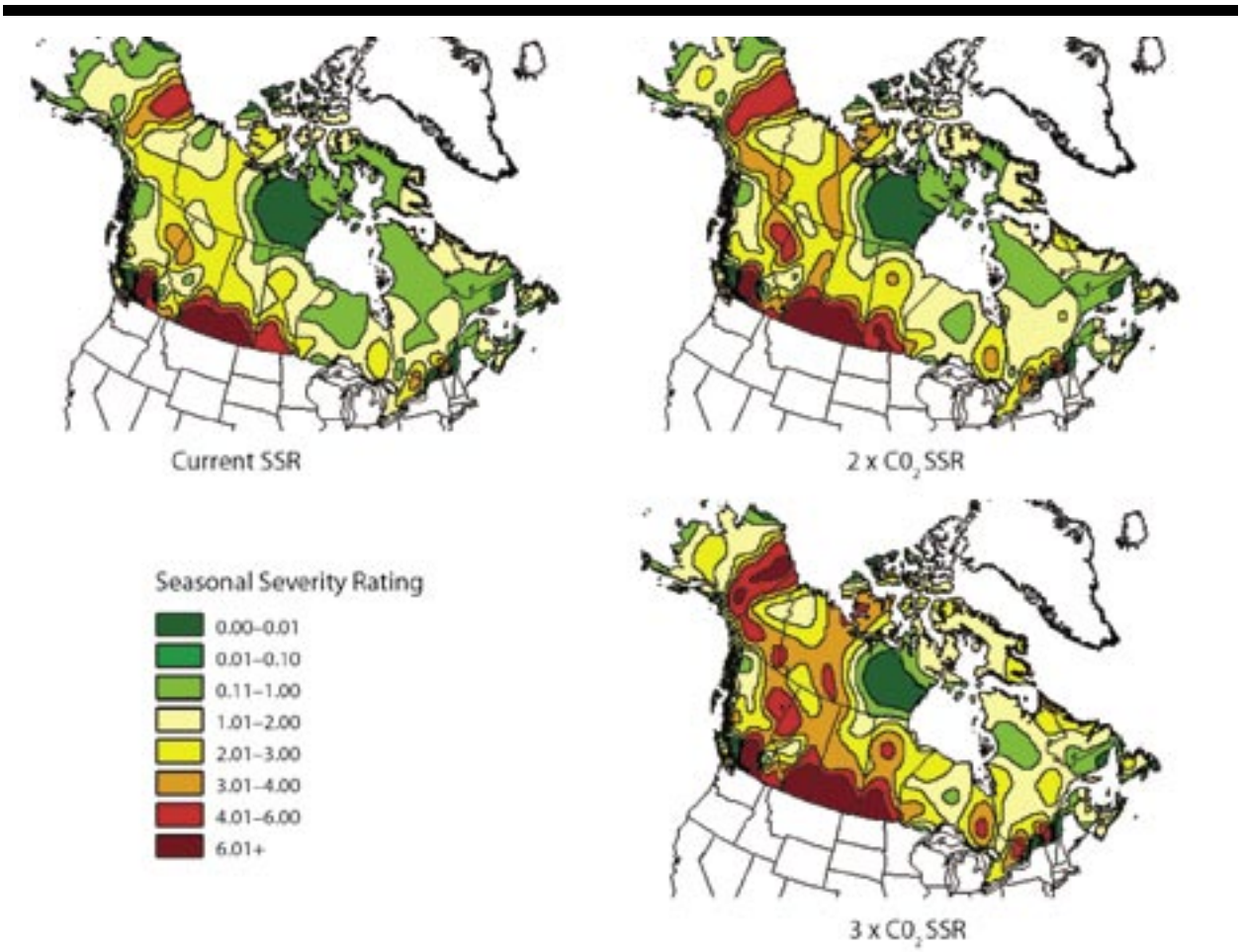


**Figure 1. Average annual seasonal severity rating (SSR) under current conditions and under two future climate scenarios.** The SSR is a summary the severity of the fire weather for an entire fire season. $CO_2$ = carbon dioxide.

(when there will be roughly 2 × $CO_2$, according to the most recent transient GCM models), combined with the province's Level of Protection Analysis System (known as LEOPARDS), showed that the increase in fire occurrence would lead to an increase in suppression costs of just over 15% and an increase in the number of escaped fires in Ontario of almost 30% (Figure 2). Further examination of the impact of changing resource levels in Ontario showed that provincial suppression resources would have to be increased by over 100% above current operational levels to maintain the escaped fire percentage at the current level (Figure 2).

Using models developed from approximately 40 years of historical information about the empirical relationships between fire and weather, in combination with transient GCM scenarios of future fire weather, researchers are now projecting a 75%–120% increase in area burned in Canada by the end of this century. Strong scientific evidence shows that the frequency and strength of mid-tropospheric ridging influence large fire occurrence and area burned in Canada, and new studies are under way to determine the impact of these factors under a changing climate.

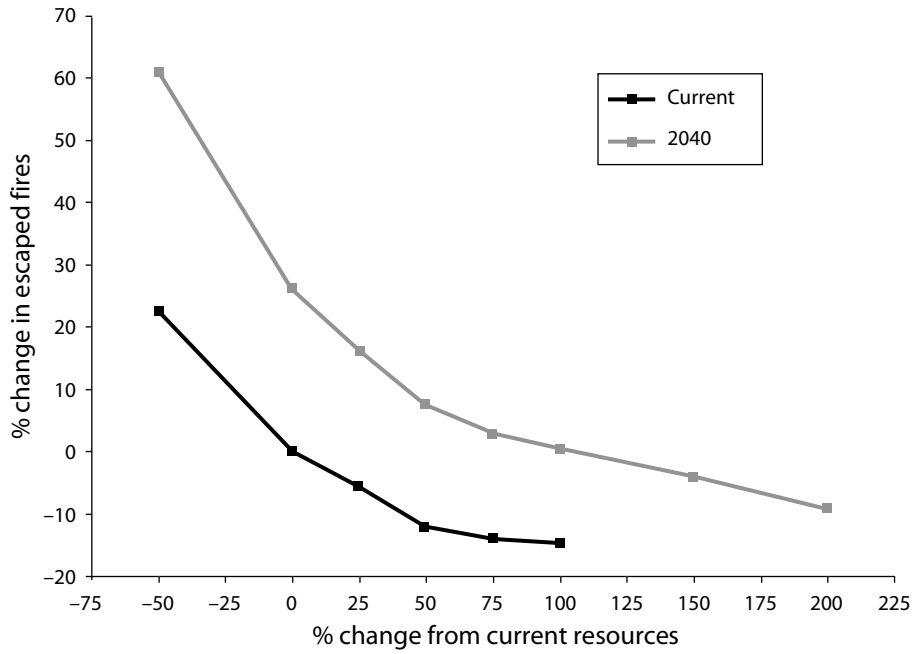


**Figure 2. Percent change in the number of escaped fires (from current level) with changes in resource levels for both current weather and under a climate with doubled atmospheric carbon dioxide climate (the year 2040).**

## Expanding Wildland–Urban Interface

In recent years there has been a large increase in Canada in the number of homes and communities being built in semi-forested environments, mainly on the outskirts of existing communities. This increase is mirrored in the United States, where it is estimated that 60% of new homes are built in the wildland–urban interface (WUI). Living close to the forest has become desirable to many ex-urbanites, and communities in the WUI are growing. Many of these homeowners have little knowledge of wildfire or the need to protect their homes. In addition, very few of these communities have building codes that require residents to build fire-resistant homes or to manage fuels on their property. Provincial and territorial fire management agencies and municipal governments are attempting to institute hazard mitigation programs within and around these communities, but this is a formidable task, given the rate of WUI expansion and the increasing threats of wildfire. Such programs

must consider both the biophysical aspects (e.g., fuel reduction or modification) and the social aspects (e.g., public awareness and involvement) of hazard mitigation.

In addition, communities in northern Canada, which are primarily Aboriginal or associated with resource-extraction industries, need better protection against fire impacts through hazard mitigation. These communities depend on the forest for their livelihood, so even fires that do not affect a town-site directly can affect the future of the community. Evacuations of many northern communities occur almost annually to guard against the direct and indirect (health effects) impacts of fire, and on average a total of about 5500 people per year are evacuated from on average 10 communities. In addition, over the period 1980–2003 an annual average of more than 20 communities (with population totalling about 70 000) are threatened by large wildfires (see Figures 3, 4 and 5). With projected climate change and increased fire activity the need for community protection will expand dramatically, and fire-related evacuations and impacts will increase accordingly.

While protection of "point values" (such as homes and cottages) is not new to fire management agencies, the increased construction of homes in the WUI and the identification of values in the forest itself have added to the demands on those agencies. They must adapt their policies and internal cultures to meet the expanding protection needs of the public while ensuring an effective level of protection for economic values in the managed forest.

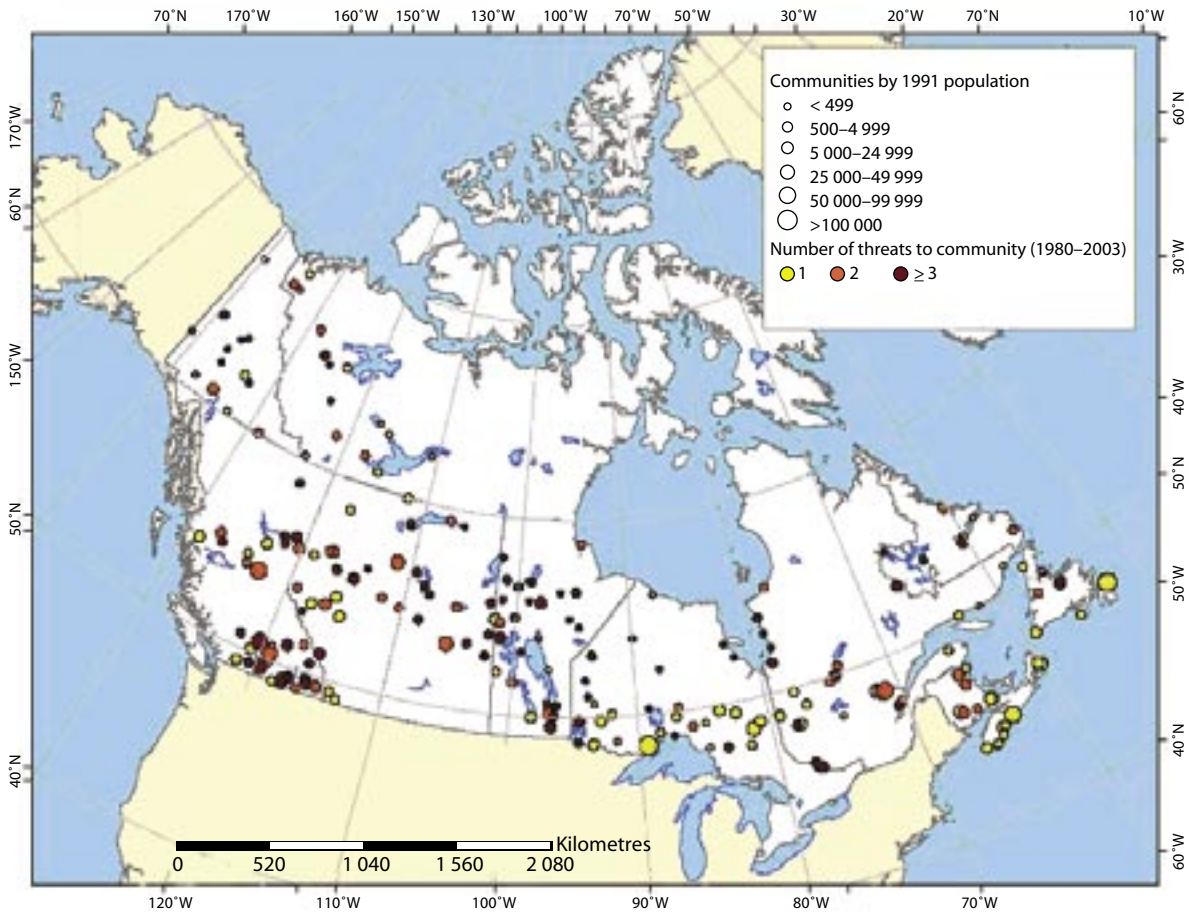


**Figure 3. Location of communities threatened by a large (> 200 hectares) wildfire less than 30 km away over the period from 1980 to 2003.** Data sources: Populated places data provided by Atlas of Canada base map, Populations according to 1991 Canada Census, Forest Fire perimeter data provided by the various Canadian agencies, including provincial and territorial governments, Parks Canada, and the Canada Centre for Remote Sensing.

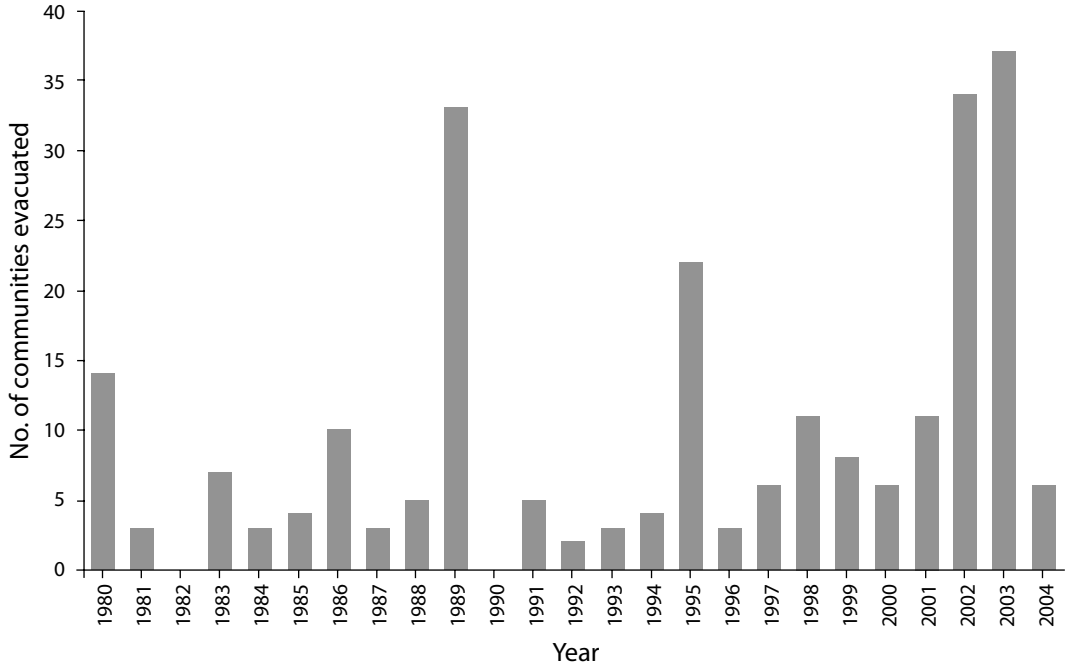


**Figure 4. Number of Canadian communities evacuated because of fire, by year.** (Data from an ongoing analysis provided by P. Bothwell, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta.)

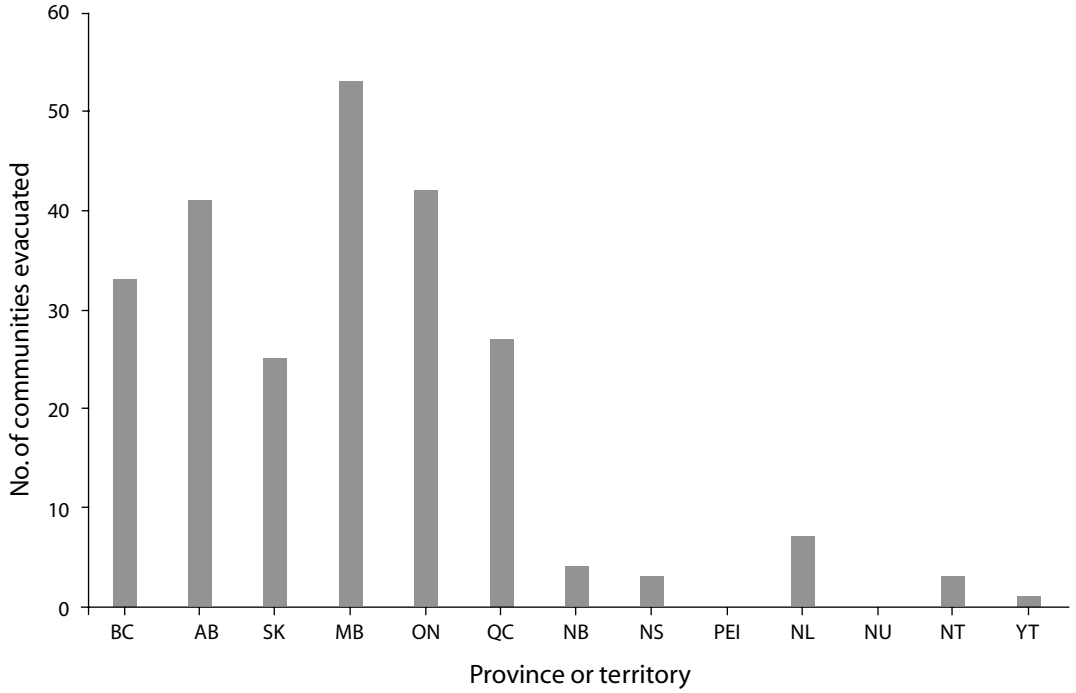


**Figure 5. Number of Canadian communities evacuated because of fire, by province, between 1980 and 2003.** (Data from an ongoing analysis provided by P. Bothwell, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta.)

### Infrastructure for Forest Fire Management

Fire suppression is an expensive business, relying on large investments in expensive equipment (e.g., air tankers) and infrastructure. For suppression activities to remain safe and efficient, aging equipment and infrastructure must be replaced as it reaches the end of its expected lifetime. However, over the past decade or more, fire management agencies, like all other government-funded organizations, have been subject to budget reductions and spending constraints. Such constraints tend to limit an agency's flexibility in planning; they also introduce delays in the replacement of aging equipment and infrastructure. Furthermore, over the past decade, fire management costs have increased and, particularly in the case of WUI fires, these costs are becoming more variable and unpredictable from year to year.

The fire suppression workforce is also aging. The demographic characteristics of Canadian fire managers are changing, and government budgetary restraints have reduced hiring and training activities. Nearly 50% of current permanent fire management staff in Canada is due to retire in the next 10 years. Although on the surface this problem can be solved by hiring more staff, the training path for highly qualified fire managers is lengthy (taking a good part of a person's career), and previous budgetary restraints and the ensuing delays in training have greatly reduced the number of personnel on the training track. As such, some jurisdictions lack qualified personnel to replace retiring fire managers.

### Forest Health and Productivity

The attempted exclusion of fire in many regions of Canada has led to a shift to older age classes or forests in later successional stages. Such shifts could lead to significant changes in wildfire potential and the resultant fire regime, as increasing fuel accumulation will result in fires of higher intensity, consequently increasing the difficulty and decreasing the likelihood of control. Exclusion of fire in many ecosystems also favours the development of major insect infestations (e.g., the mountain pine beetle in western Canada and the eastern spruce budworm in eastern Canada); affected areas can in turn become fertile grounds for large fires fuelled by excessive dead woody material. If suppression activity has resulted in a shift to older forest age classes, the impact on the ecological integrity and sustainability of the ecosystem must be examined, particularly given Canada's commitment to the preservation of ecosystem health through the Convention on Biological Diversity and Sustainable Forest Management (the Montreal Process).

### Competition for Forest Land Base

Canadian forests are now exposed to rising and competing demands on the land base. Forest industries are under pressure to continually increase the wood supply to meet global market demands, even though accessible Canadian forests are almost fully committed. There is growing pressure from environmental groups and the public to set aside and protect more forest areas for recreational activities, biodiversity conservation, and similar purposes. Aboriginal groups require greater access to forest lands for traditional pursuits, including the growing non-timber forest products (NTFP) industry.

This complete commitment of the land base means that when any large fire occurs it has an impact on the values of one or more groups. If a forest company loses part of a management unit to fire, it can, if there is "slack" in the system, move elsewhere to a new harvest block and continue operations. However, if that company does not have room to move, or if the new harvest block is a considerable distance from the originally planned harvest, this loss of local wood supply can affect the community.

### Public Expectations

Public awareness of forest issues, including fire management decisions, has been growing quickly in recent years, partly through the success of public awareness programs but also to a large extent through increased media attention. Protection of the public and property from fire has long been the role of government, and the public continues to expect that their immediate values will be protected: their homes will be saved and their communities safely evacuated if fire threatens their area. In addition, however, there is in Canada a growing emphasis on a civil society, with a greater public role in and responsibility for resource management decision-making. This is particularly true for Aboriginal peoples, forest tenure holders and landowners, and urbanites moving to the WUI, all of whom expect to be consulted before new policies affecting them and the lands around them are

initiated. Fire management agencies must therefore emphasize the inclusion of all stakeholders in policy development and land management decisions, which can mean changes in protection priorities. For this process to succeed, however, it is also critical that stakeholders (and the public in general) correctly understand the capabilities and limitations of fire suppression, and accept the fact that fire must remain a part of the forest environment. Just as Canadians have adapted to living in a northern climate with cold and sometimes harsh winters, they must adapt to living in a fire-prone environment; in the end this is a more economically efficient and environmentally responsible way of living than attempting to exclude fire completely. Across Canada the growing emphasis on public safety and security has made wildland fire an issue for all levels of government (federal, provincial and territorial, and municipal), and they must work closely together to maximize future effectiveness.

## Summary

It seems clear that Canadian forest fire activity is expected to increase as an early result of a trend toward warmer and drier conditions, with potentially significant impacts on wood supply, the forest industry, and industry-dependent communities. This increase in activity should result in shorter fire-return intervals, a shift in age-class distribution toward younger forests, and a decrease in biospheric carbon storage. In turn, these changes will likely result in a positive feedback between fires in boreal ecosystems and climate change, with more carbon being released from boreal ecosystems than is being stored. Supporting this projection, a recent retrospective analysis of carbon fluxes over the past 70 years found that Canadian forests have been a net source of atmospheric carbon since 1980, primarily because of the increasing extent of disturbance (fire and insects). It has also been suggested that fire would be the likely agent for future vegetation shifts in response to climate change.

Any trend toward increased fire activity and impacts will put extreme pressure on Canadian fire management agencies, which will be unlikely to maintain their current level of suppression effectiveness (in terms of limiting area burned to its current levels and protecting values) over the effects of fire. Increases in area burned could have direct effects on wood supply and the competitiveness of the forest industry, along with approximately 300 forest industry-dependent communities in Canada. It may also have an impact on Canada's commitment to carbon sequestration and emissions reduction under the Kyoto Protocol, particularly with increased carbon loss through increased fire severity and the exposure of carbon-rich peatlands to future fire.

We have attempted in this discussion paper to describe several major existing and emerging drivers of fire management change in Canada. This list is by no means exhaustive, but it is meant to highlight some of the factors influencing the effectiveness of fire management both currently and in the future. What is clear is that physical and societal pressures on fire management agencies in this country have already increased. These pressures will necessitate a rethinking of forest and fire management objectives and practices and a reassessment of fire protection priorities if members of the public and their property are to be effectively protected from the impact of unwanted fire.

Wotton, B.M.; Stocks, B.J. 2006. Fire management in Canada: vulnerability and risk trends. Pages 49–55 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

# Canadian Fire Management Infrastructure

**W. Born**[1] and **B.J. Stocks**[2]

## Context

It is becoming apparent that the ability to manage wildland fire in Canada is decreasing, primarily because fire incidence and values needing protection are increasing while suppression effectiveness is near its physical limits. Fire management costs are also increasing, particularly for fires occurring at the wildland–urban interface, and are becoming more variable and unpredictable from year to year. At the same time, fire management agencies are subject to frequent government budget reviews and constraints that restrict their ability to effectively manage wildland fires. In addition, the country's fire suppression infrastructure (aircraft, facilities, and equipment) is declining with age. Perhaps more disturbing, the demographic characteristics of fire management staff in Canada are changing. Government restraints on hiring and buy-out packages are resulting in a preponderance of older employees. Nearly half of the highly trained and experienced permanent fire management staff in Canada is due to retire in the next 10 years, and little is being done to hire and, more importantly, train replacement personnel.

This paper examines in detail the current state of fire management infrastructure and human resources in Canada, focusing on the demographic characteristics and training of personnel and the availability and capacity of aircraft, fireline equipment, decision support systems, and fixed infrastructure. Data for this report were collected by surveying provincial and territorial fire management agencies across Canada; results were provided from 11 of the 12 agencies surveyed. Parks Canada and Nunavut were not surveyed.

## Human Resources: Demographic Characteristics and Training

In this section, we review the demographic characteristics of fire management agency personnel across Canada. In addition, we discuss the ways in which the human resource element, in combination with the changing fire environment, is challenging current training principles and focus.

A survey was sent to each provincial and territorial agency to determine the age of staff members in 6 categories: administrative support personnel, managers, technical staff, tradespeople, professionals, and general labourers. Agencies were also asked to identify their current enrolment in a variety of basic training courses, their capacity in those courses, and reasons why capacity was not met (if such was the case). In addition, agencies were asked to identify their current and anticipated future priorities for training. The results represent 11 of the 12 agencies surveyed.

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## Age of Staff Members and Potential Retirements

In all but one of the agencies (Manitoba being the exception), a large proportion of employees will reach retirement age within the next 10 years. Most agencies calculate eligibility for pension benefits on the basis of years of service plus age; the typical requirement is 80 or 85. Assuming that most staff begin their careers between the ages of 20 and 25, most would be able to retire near the age of 55 after a career of 30–35 years.

The assumptions above yield an estimate of 48.1% or 1 232 of the 2 559 members of the national workforce that may be eligible to retire in the next 10 years (all categories) (Figure 1).

The most critical category is the management group, of whom 72.0% (144 of 200) could retire within the next 10 years (Figure 2). This finding is reasonable, given that senior staff typically fill such positions.

Among the management (Figure 2), technical (Figure 3) and professional (Figure 4) groups, 884 people (out of a total of 14 750 current staff) will be eligible to leave the agencies within the next 10 years. There are only 866 people under the age of 46 currently working in the management, technical, and professional groups who would be available to fill those management, technical and professional vacancies. These retirements (management, technical and professional) will represent a loss of 26 520 years of experience.

## Training

The loss of nearly 50% of existing staff over the next 10 years will create, and may already be creating, a training backlog. In this survey, agencies whose basic fire courses are not operating at full capacity offered three primary reasons: funding shortages, lack of suitable candidates, and lack of qualified instructors. The increasing rate of retirement, and the training that will be required for those promoted within the system or recruited from outside the agencies, will place increased demands on training staff and budgets.

A decrease in the number of qualified candidates is another major issue. Enrolment in forestry degree and diploma programs is decreasing, and graduates have a wide choice of job opportunities. For example, enrolment in the forest technology program at the Northern Alberta Institute of Technology was 75 students 20 years ago, with graduating classes of 30–40 people, and with 10–12 working in wildfire management after graduation. Today, enrolment is down to about 30 people, and only 3 of the current graduating class are considering wildland fire management as a career. At the same time, the legislation governing professional forestry practice in some jurisdictions demands a degree and diploma for any type of career advancement beyond the level of a basic member or leader of a fire-fighting crew.

Today's younger generations are becoming more urbanized, and people are more reluctant to relocate to what may be considered remote communities. Agencies need to learn what motivates the new generation of workers and to refocus their recruitment efforts with these factors in mind. Forestry institutes also need to re-evaluate their recruitment methods and course materials. Recruitment and retention of new staff was a key factor identified at a recent Best Practices Workshop on the Canadian Wildland Fire Strategy, along with the following future critical needs:

- Increased standardization in training.
- National use of expertise in training development. For example, if Ontario crews are the best in water delivery with pumps and hose, that province should be developing the national curriculum for this type of training and, where possible, should be training the trainers in other jurisdictions.
- A national training centre or academy. This need not be a location where all courses are delivered but rather a central clearinghouse for training material, to ensure consistency and to keep training material current and widely available (e.g., by offering interactive CD training).

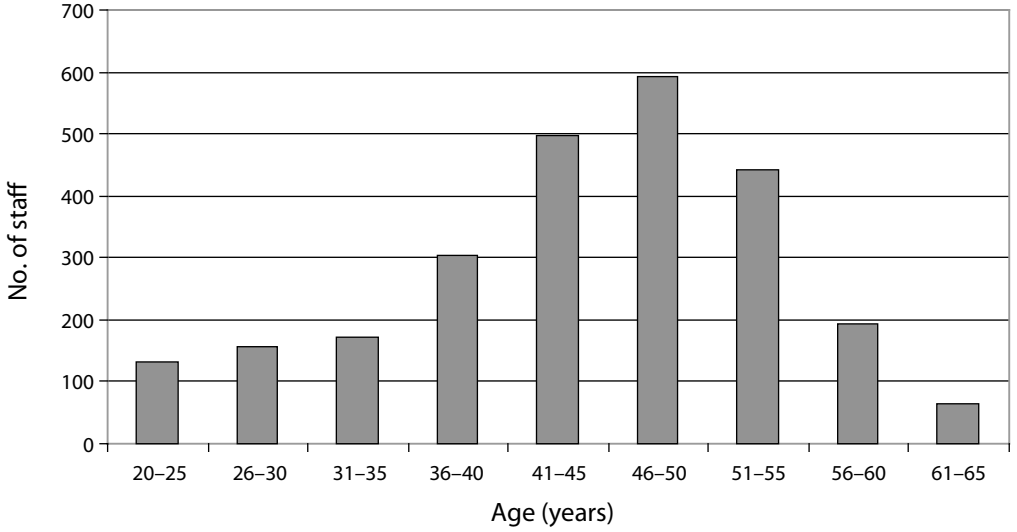


**Figure 1. Age distribution of all staff of Canadian fire management agencies.**

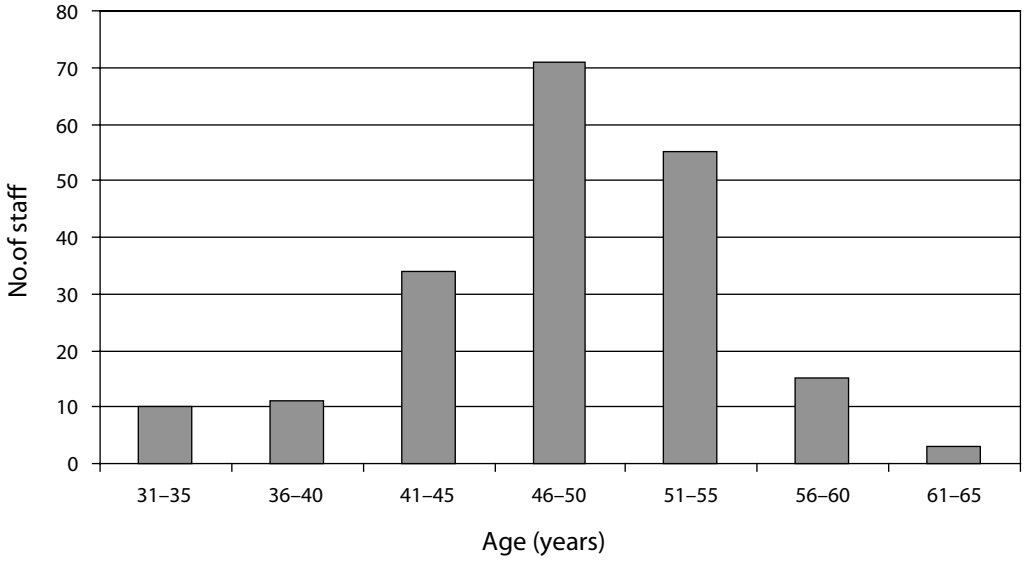


**Figure 2. Age distribution of managers in Canadian fire management agencies.**

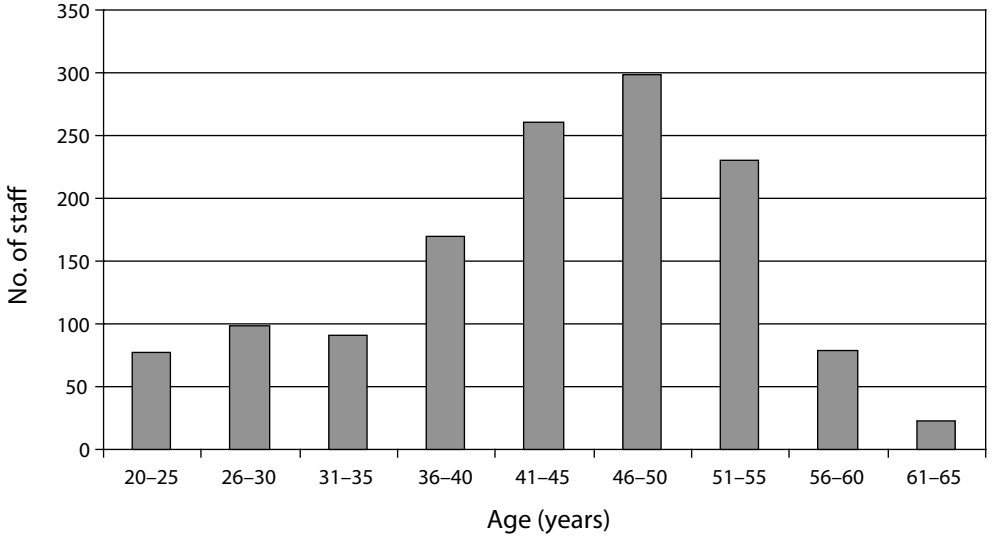


**Figure 3. Age distribution of technical staff in Canadian fire management agencies.**

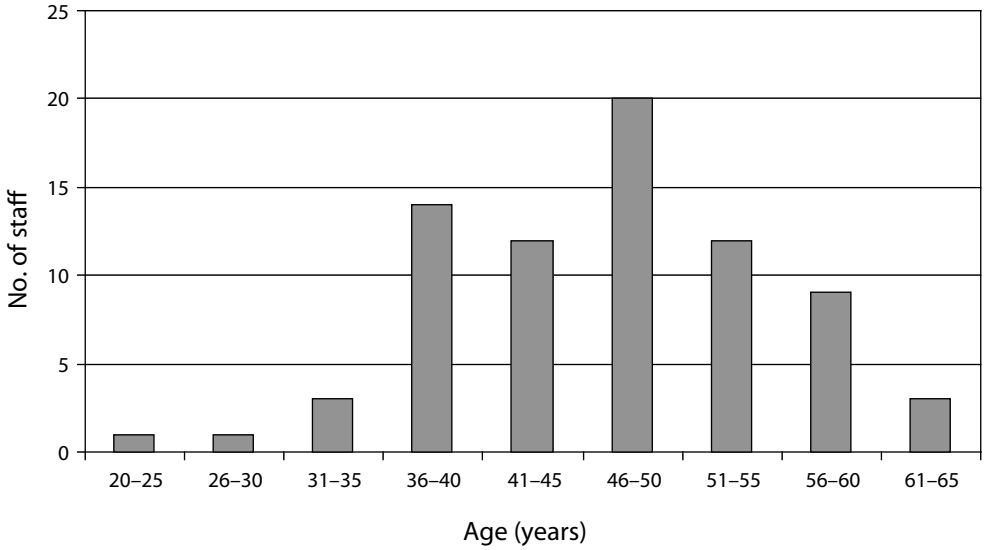


**Figure 4. Age distribution of professional staff in Canadian fire management agencies.**

## Aircraft

Provincial and territorial fire management agencies were asked to identify their respective aviation fleets, either owned or on long-term contract, in the following terms:

- Registration, make, and model of all aircraft
- Age and expected remaining economic life
- Proposed replacement aircraft type (when current aircraft are taken out of service)
- Purpose or role of the aircraft

The 11 agencies that responded had a total of 253 aircraft either owned or on long-term contract, which represents the vast majority of aircraft in the Canadian fixed-wing air tanker fleet.

### Critical Issues

Not unlike the human resource issue, the fleet of aircraft, rotor wing, fixed wing transport and air tankers is aging. As a result, reliability, safety and operating costs are becoming factors impacting agency operational effectiveness and budgets. The delay in renewing the fleet on an ongoing basis will result in the need for a large investment in the near future.

Fleet replacements and new aircraft in development are costly. The investment to renew the current fleet of aircraft could be 10 times the original capital cost of the existing fleet (Table 1).

Aircraft, in particular air tankers, have been the most consistently exchanged resource since the formation of the Canadian Interagency Forest Fire Centre (CIFFC) and the Mutual Aid and Resource Sharing agreement. This consistent ability to exchange and share the resource has enabled provincial and territorial agencies to minimize their fleet size. Reductions in any one agency's fleet will have an overall impact on Canada's aerial suppression capacity.

The existing national medium fleet of Bell 205 and 212 helicopters is at least 25 years old (Figure 5), with an estimated remaining economic life of about 10 years. The average age of the Bell 204 fleet is nearing 40 years. In 2004 an airworthiness directive was issued for the Honeywell Dash 17 turbine engine, which is used in some Bell 205 helicopters. This directive followed the trunnion and mast airworthiness directives that grounded the Bell 204, 205, and 212 helicopters in mid-fire season in 2002. The challenges of fleet maintenance will continue to affect (or diminish) resources.

Although the number of fixed wing transport aircraft operated by the various agencies is low relative to rotor wing and air tanker fleets, it is no less an issue. The existing fleet is experiencing significant and increasing mechanical problems. Engine failures and precautionary engine shut-downs of Single Otter and other fixed-wing transport aircraft are increasing. The majority of these aircraft, 83.3%, are in excess of 30 years old, while 25.0% are over 40 years old (Figure 6).

The primary identified means of replacement for the CL-215 air tanker is through conversion to the CL-215T. However, 12 of the existing Canadian CL-215 aircraft are not eligible for the conversion package because of their age. Existing CL-215 aircraft are being grounded because of increasing maintenance costs.

Future purchases of skimmer, medium, and heavy air tankers will probably require a capital investment of $10 million to $30 million each. Excluding the CL-415s operated in Ontario and Quebec; this represents a capital investment of at least double the investment in the existing fleet.

Half of the air tankers in the Canadian fleet are over 30 years of age and have an expected remaining economic life of 10 years (Figure 7).

Notification has been received from a principle facility performing overhauls of radial piston engines that support for specific engines will be in place for just 7 more years, which could affect such aircraft as the Conair FireCat and the DeHaviland S2F Tracker. Other overhaul facilities have suggested that support available for other engines such as the Pratt and Whitney R2800 is limited and likely to end soon. The last R2800 engine (used for the CL-215, DC6, and B26 air tankers) was produced in the early 1950s.

**Table 1. Current proposals for aircraft renewal by Canadian agencies**

| New aircraft type | Conversion/ purchase/ contract | Aircraft to be replaced | Unit price (M$, Can) | Indication of intended orders | | Potential orders | | Comments[a] |
|---|---|---|---|---|---|---|---|---|
| | | | | No. | Value (M$, Can) | No. | Value (M$, Can) | |
| CL-215T | Conversion | CL-215 | 14.5 | 9 | 130.5 | 11 | 159.5 | |
| AT1002 | Contract | Conair FireCat | 2 | | 0 | 3 | 6 | New aircraft from Air Tractor in Texas. Expected to be in production in 3 years. Other aircraft in the same price range are being assessed. |
| L188 | Contract | DC6 | 5 | | 0 | 1 | 5 | Air Spray is currently the only company operating this aircraft as an air tanker. |
| TC690 | Contract | PA-60-600 (Aerostar) | 1.3 | | 0 | 2 | 2.6 | YT: Bird-dog; use will be restricted unless the Yukon can pave all the airstrips used for forest fire operations. |
| TC690 | Purchase | Cessna 310 | 1.3 | | 0 | 3 | 3.9 | MB: Bird-dog. Fleet is now 24 years old and will require replacement in the next 5–8 years. |
| CV580A | Purchase | S2F (Tracker) | 10 | 4 | 40 | | 0 | CV580 with engines upgraded to D22 from D13. |
| TC690 - 10 (Grand Renaissance) | Purchase | Beech 55 (Baron) | 1.7 | 1 | 1.7 | 2 | 3.4 | SK: Bird-dog. |
| Commander 1000 | Purchase | PA-31-350 (Navajo) | 2 | | 0 | 1 | 2 | SK: Transport. |
| AT802 Amphib | Purchase | DHC6 (Twin Otter) | 2.5 | | 0 | 6 | 15 | ON: Replacement planned in the future. |
| C208 (Caravan) | Purchase | Cessna 337, 206 and 210, DHC 3, TBM-3 | 2.5 | | 0 | 11 | 27.5 | NB: Bird-dog and detection aircraft. MB: Transport aircraft. |
| Unknown 1 | Contract | Rockwell 500S Shrike Commander | 1.3 | | 0 | 7 | 9.1 | ON: Bird-dog, to be replaced in next 12 years. Current aircraft are 28–42 years old. |
| Unknown 2 | Contract | Cessna 337 | 1.5 | | 0 | 14 | 21 | ON: Patrol aircraft to be replaced in 5–15 years; current aircraft are 24–37 years old. |
| Unknown 3 | Purchase | PA31-350 (Navajo) | 1 | | 0 | 1 | 1 | ON: Infrared scanning platform. |
| Unknown 8 | Purchase | DHC2T-27 | 1 | | 0 | 5 | 5 | ON: Current aircraft are 36–38 years old, need replacement in next 10 years. |

**Table 1. Concluded**

| New aircraft type | Conversion/ purchase/ contract | Aircraft to be replaced | Unit price (M$, Can) | Indication of intended orders | | Potential orders | | Comments[a] |
|---|---|---|---|---|---|---|---|---|
| | | | | No. | Value (M$, Can) | No. | Value (M$, Can) | |
| Eclipse (very light jet) | Contract | TC690 (A/B) Turbo Commander | 1.7 | | 0 | 10 | 17 | Conair estimates 6–7 economic years left; replacement with a very light jet. |
| Unknown 10 | Contract | PA60-600 Aerostar | 1.3 | | 0 | 6 | 7.8 | BC, YK: Bird-dog replacement. |
| Unknown 11 | Contract | DHC6 Twin Otter | | | 0 | 1 | 0 | BC: Smoke jumper; replacement in 10 years. |
| CV580 | Contract | Addition to fleet | 4.5 | | | 3 | 13.5 | AB: Fleet additions. |
| Unknown 12 | Contract | DC4 | 4.5 | | 0 | 2 | 9 | NT: No replacement model specified in survey just a cost estimate. |
| AS350B3 | Purchase | AS350B2 | 1.9 | | 0 | 2 | 3.8 | 10-year life remaining, currently 11 years old. |
| AS350B2 | Conversion | AS350BA | 1 | | 0 | 3 | 3 | 10-year life remaining, currently 23 years old. |
| Bell 210 | Contract | Bell 204/205/212 | 3 | | 0 | 19 | 57 | Current medium fleet is 24–40 years old. |
| Bell 407 | Purchase | Bell 206L1 | 1.7 | | 0 | 3 | 5.1 | Required in next 2 years; current aircraft are 24 years old. |
| Total investment | | | | | 172.2 | | 377.2 | |

[a]YT = Yukon Territory, MB = Manitoba, SK = Saskatchewan, ON = Ontario, NB = New Brunswick, BC = British Columbia, AB = Alberta, and NT = Northwest Territories.

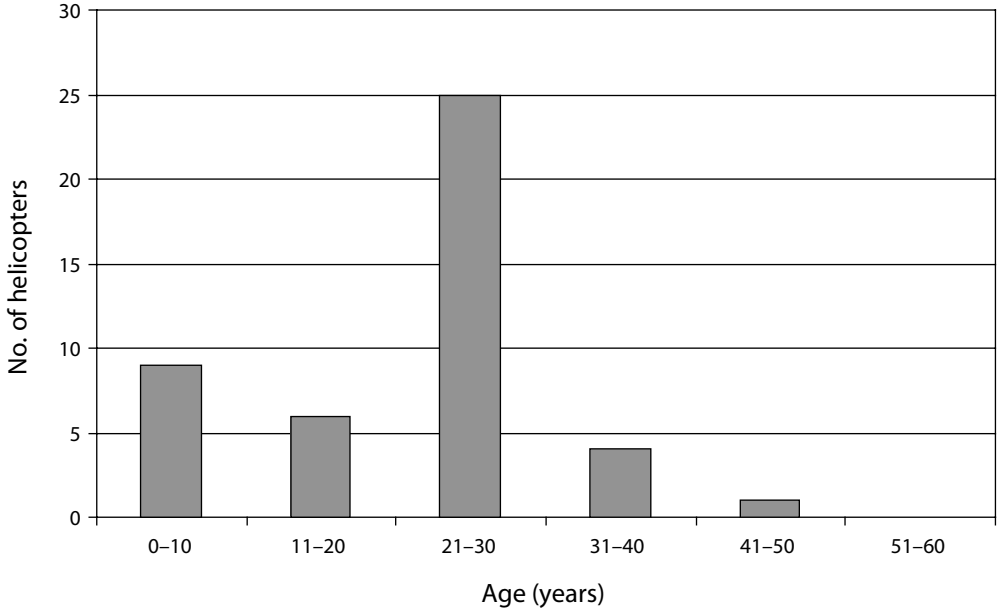


**Figure 5. Age distribution of helicopters used by Canadian fire management agencies.**

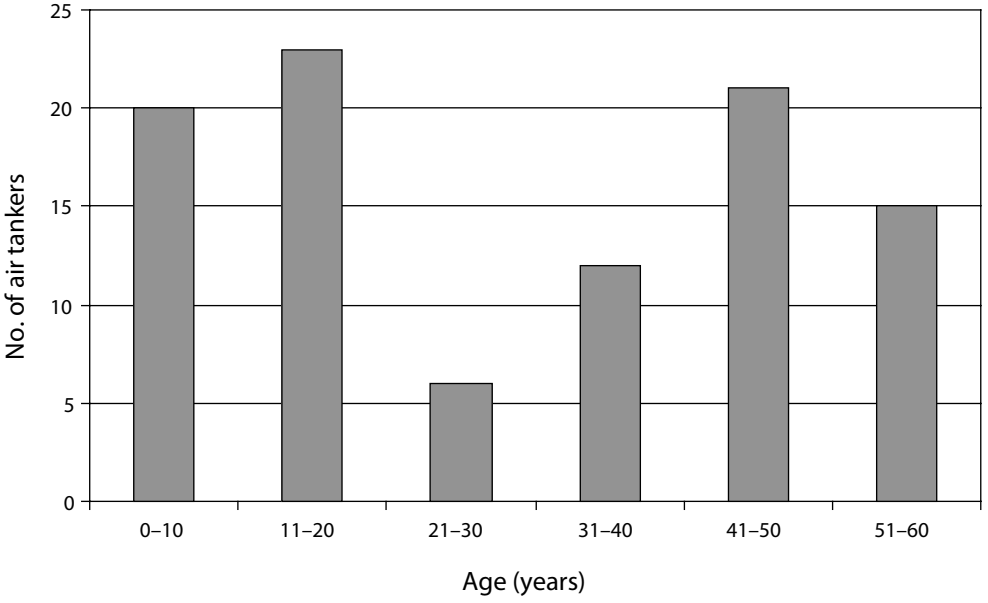


**Figure 6. Age distribution of air transport aircraft used by Canadian fire management agencies.**

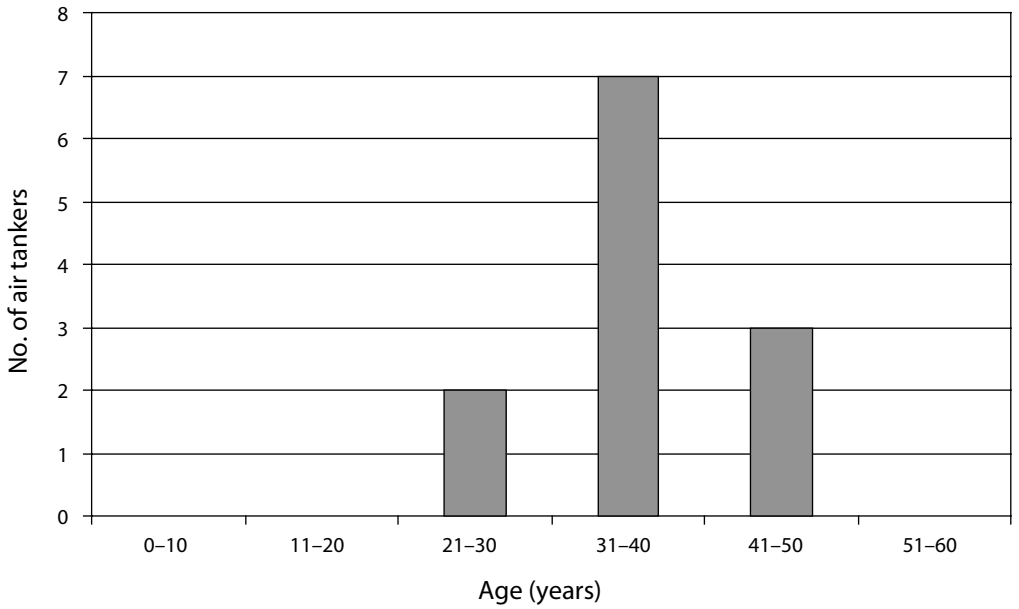


**Figure 7. Age distribution of air tankers used by Canadian fire management agencies.**

## New Developments

Several new air tankers and helicopters are just coming into development or certification.

### *Land-Based Air Tanker*

Cascade Aerospace has recently announced production of the Dash 8 Q400 combi-aircraft, designed for cargo, air tanker, and passenger transport operations. One aircraft is being used in France, and a second was delivered in fall 2005. Air Tractor continues to discuss the launch of the AT1002, a 1000 US gallon, single-engine air tanker. The prototype of this aircraft is under construction in Texas.

### *Skimmer Air Tanker*

Irkut Industries is working with the European Aerospace and Defence group to establish European certification Joint Aviation Authorities and then approval by the Federal Aerospace Administration (US) and Transport Canada of the Beriev BE200 jet-propelled skimmer. However, the company does not expect to have Canadian certification until after 2008. A preliminary review has indicated that the tank design of this air tanker is not consistent in size and may have a negative affect on the drop pattern. In addition, its fuel consumption appears to be significant, which would reduce "over the fire" endurance.

The ShinMaywaa Company in Japan has developed a 4-engine turbo-prop skimmer air tanker. The company will have to overcome export restrictions before marketing this aircraft internationally.

### *Helicopters*

Bell recently announced a program to overhaul ex-military UH 1H helicopters (the military version of the Bell 205A). The overhaul was to have consisted of recertification to a zero time (new) airframe. Unfortunately, the Honeywell Dash 17 engine would have remained as the power plant. This engine uses older turbine technology and has recently been the subject of an airworthiness directive, as described above. Bell should consider using newer turbine technologies, such as newer versions of the Pratt and Whitney PT6 model engine. Recent reports now indicate that the planned overhaul would have been too expensive, and new aircraft will be built instead.

Newer models of the Eurocopter AS350 series continue to be developed and purchased, and upgrade conversions are also under way. In addition some private operators have introduced the Eurocopter EC130 and Augusta 109 aircraft over the past 4 years, although availability is very limited.

## Fireline Equipment

This section examines the current inventories of "basic" fireline equipment available across Canada. In addition, a supplementary review was conducted to determine the age of some equipment technologies currently in use. The Best Practices Workshop identified resource tracking and non-agency equipment availability as priority items that should be reviewed (see page 83 in this volume).

A great deal of work has been done on standardization of equipment in recent years. The efforts of the CIFFC Equipment Working Group and the international partnership that CIFFC has developed with its United States counterparts, have ensured promotion of national and international equipment standards. In addition, the adoption of the standards and equipment-testing practices of the US National Fire Protection Association (NFPA) will ensure the availability of products that perform consistently in the wildland fire environment.

### Current Inventories

The 12 provincial and territorial fire management agencies in Canada were surveyed to determine the "national" inventory of basic fireline equipment (Table 2) available for response to resource-sharing requests or for use in wildland–urban interface fires. Agencies were asked to list their total inventory and the portion of the inventory that could be made available to other agencies on request.

In addition, CIFFC assisted in identifying "critical resources," equipment for which demands had exceeded the Canadian supply at some point. From this review, two items were designated as critical resources: Wajax Mark-3™ pumps and 1.5-inch (3.81 cm) diameter fireline hose. It had already become known that the supply of these resources was depleted, and the requesting agencies had simply stopped asking for them, so the severity of the undersupply could not be determined. The inventory for these items is presented below.

Despite the numbers given above, it is unlikely that more than 2000 pumps and 40 000 lengths of hose are available for export at any given time, since it would be unusual for only one agency to be in need and all others to have the equipment available for export. Instead, two or three agencies typically experience high to extreme fire loads simultaneously. The other factor affecting availability is the location of high forest fire hazard. Ontario has the largest single inventory of pumps and hose, so if eastern Canada is at moderate to high risk of fire, the ability to import equipment from any combination of the western or territorial agencies is limited by the uneven distribution of stocks. In some years, the demand for pumps and hose across Canada has exceeded the supply in North America, particularly if the demand comes from Ontario or Quebec. Both pumps and hose are replaced at an average annual rate of 5%.

### Equipment Development

Significant advances have been made in aircraft retardant tanks, helicopter fixed tanks, and water buckets, yet the standard fire pump (Wajax Mark-3™) has not changed in more than 25 years. This pump, although robust, is heavy and somewhat temperamental. Given recent advances in metal alloys and composite materials, efforts are needed to develop more lightweight equipment, especially pumps.

**Table 2. National pump and hose inventory**

| Item | Total national inventory | Maximum inventory available for export |
|---|---|---|
| Wajax Mark-3™ pumps | 6 323 | 3 390 |
| 1.5-inch (3.81 cm) diameter fireline hose (100 ft. [30.48 m]) length) | 166 903 | 82 990 |

Lightweight pumps are a significant part of the equipment complement of an initial attack crew, yet they are poorly represented in the industry. In the past, the Wajax Mini Mark was seen as the standard lightweight pump, but it is no longer manufactured, and the Wick lightweight pumps tested thus far as replacements have yet to pass NFPA pump standards.

New emission standards for two-cycle engines recently introduced in California and likely to spread across the United States and Canada are forcing other changes in fireline equipment powered with this type of engine. Changes are already evident in other types of equipment that have historically relied on two-cycle engines, such as motorcycles, and that are now moving to more low emission power plants.

## Tracking Systems

Collaborative efforts have led to three systems for inventory and near real-time tracking of aircraft and other mobile resources.

### *Inventory*

Alberta, Ontario, and British Columbia are working together to enhance a common inventory platform. Originally developed in Alberta, the Inventory Management Information System has been shared with both the British Columbia Forest Service (BCFS) and the Ontario Ministry of Natural Resources. Ontario is now enhancing the system with radio-frequency-emitting inventory tags. Initial trials were conducted in 2004; modifications will be required for use with aircraft and for calibration. It is expected that Alberta and the BCFS will start to adopt the radio tags after successful testing in Ontario. This process and a national inventory system were identified as a "best practice" during the Best Practices Workshop.

### *Aircraft Tracking*

The BCFS has been a leader in adopting a real-time aircraft tracking system. The system was originally built as a tracking and dispatch tool for the BCFS air tanker fleet, but its capability has since been expanded. Alberta has adopted the system, modifying the display software but maintaining the same position-collecting software. Recently, Saskatchewan has adopted the BFCS system for use with its air tanker fleet. Other agencies have adopted other tracking systems such as OuterLink, which is used in Ontario.

In the future, efforts will be made to track other mobile resources including casual-hire helicopters, trucks, heavy equipment, and possibly people. The final step will be standardizing a data-sharing format, so that agencies can view the resources of neighbouring agencies and make maximum use of neighbouring resources in border-zone action areas. A data-sharing initiative is already under way between Alberta, British Columbia, and the US Forest Service.

## Resource Availability

The need to identify internally available resources through inventory systems or by tracking systems that display resources graphically are two of three critical elements identified in the Best Practices Workshop. The third critical element was a means of identifying non-agency (e.g., municipality) resource availability.

An example of this capability already exists in the form of WebAir Canada, an online database that permits private operators to post the availability of their aircraft. All Canadian agencies have access to the system to locate required aircraft by type and proximity to specified locations. The system has been seen as beneficial for both the agencies and the aviation industry. Recent additions to the website have included the sharing of company safety audits and the posting of pilot information sheets by the operators.

This system is seen by some as a prototype that could be expanded to include other equipment, from bulldozers to high-volume pumps. It might also be a simple means for municipal fire departments to share inventory information with each other and with wildland fire agencies.

The agencies need more integration of critical inventory items, technological advancements in basic fireline equipment, compatible resource-tracking data, and better systems to determine non-agency resource availability.

## Decision Support Systems

This section examines the issues surrounding the development, support, and use of decision support systems or tools. Weather forecasting and data collection have been included here because weather represents a fundamental input for most decision support systems. Forecasts are the single most relied upon input to preparedness and response decisions, and can lead directly to significant expenditure on resource deployment and risk management decisions.

### Software

Within Natural Resources Canada, the Canadian Forest Service (CFS), in cooperation with the front-line wildland fire agencies in Canada and around the world, has long been a leader in developing decision support systems.

The Canadian Forest Fire Danger Rating System (CFFDRS) (Canadian Forest Service 1987; Stocks et al. 1989) remains the main tool used by most agencies for daily preparedness planning. From this fundamental building block, additional tools have been developed for use by the agencies. These include the Intelligent Fire Management Information System (Lee and Anderson 1989, 1991; Lee et al. 2002; Lee 1990; Lee and Buckley 1992), which has more recently evolved to the Spatial Fire Management System (sFMS) (Englefield et al. 2000); LEOPARDS (a level-of-protection analysis system) (McAlpine and Hirsch 1999); the Wildfire Ignition Probability Prediction system (WIPP) (Lawson et al. 1996; Lawson and Dalrymple 1996); PROMETHEUS (Tymstra 2002; Alexander et al. 2004; see also Remsoft 2001 and PROMETHEUS: The Canadian wildland fire growth model, available from <http://www.firegrowthmodel.com>; and FBP97 (a Fire Behavior Prediction model).

These developments represent a great set of tools for fire managers. However, there is a critical need to ensure that fire management software is continually enhanced with new operating systems and related software. A good example is sFMS. Originally designed by CFS to operate as an add-on to ESRI's ArcView 3.x (ESRI 2003) with spatial analyst, it has served the agencies well. However, no plan was put in place to ensure that sFMS kept in step with the supporting software. ArcView 3.2 (ArcView GIS 1999) is now obsolete, and ERSI's replacement product (ArcGIS version 9.0) (ArcGIS 2004) is not compatible with the current version of sFMS.

The complexity of the programs has also been identified as a problem, especially LEOPARDS and PROMETHEUS. Two solutions are essential to ensure full and effective use of these powerful tools: create simplified version of the programs and ensure proper training and support for analysts who are using them. With regard to the first solution, development of a Leopards II or Leopards-Lite program is strongly supported by many agencies.

### Weather Forecasting

As expenditures on equipment, fuel, aircraft, and human resources continue to increase, the need for accurate short- or medium-range (5 to 10 days) and seasonal forecasts is also increasing. Forecasts beyond 48 hours currently have an accuracy of about 50%, but greater forecast accuracy is imperative: daily preparedness costs can differ by a half million dollars a day between anticipated hot and dry conditions and anticipated wetter conditions. Medium-range forecasts are critical to ensure that adequate resources can be requested and put in place in anticipation of multiple ignition events.

An added complication is that Environment Canada has reduced forecasting services for wildland fire agencies. The department is consolidating its offices and reducing some services or providing them at additional costs to the agencies. The reduction in services has an immediate impact, whereas the consolidation of offices and reduction in forecasters' "local knowledge" will have an impact over the longer term.

To overcome these issues, several strategies have been identified:

- Develop a national forecasting centre or pool of forecasters.
- Identify opportunities to recruit new forecasters who will specialize in fire weather forecasting.
- Invest in the development of better weather modelling for more accurate mid- and long-range forecasts.

## Facilities

This section examines the issues affecting support facilities owned and maintained by Canadian fire management agencies. The provincial and territorial agencies were surveyed to determine the age, maintenance cost, and required critical upgrades of specified facilities. These facilities include fuel cache sheds, kitchens, office buildings, and airstrips and their related structures.

The primary offices identified as being maintained by the government's department of public works were eliminated from this analysis, as the focus here was on facilities owned and maintained by the agencies.

Most buildings owned by fire management agencies were reported as being well within their expected service life. The average reported age was 33 years, although some buildings are over 60 years old.

The agencies identified critical aspects of general facilities that need enhancement and funding, and a fourth is offered for consideration:

- Aircraft support facilities, hangers, runways, air tanker bases, and fuelling systems
- Remote weather networks, including weather stations (to better represent fuel moisture and fire danger) and lightning detection systems (to better assess ignition potential)
- Fixed detection networks (fire lookout towers)
- Compatible radio system and networks

### Aircraft Support Facilities

Upgrades and enhancements to air tanker bases, both to adapt to new air tankers and to ensure that building and environmental control systems meet current industry or legislated standards, were identified as essential by four agencies.

- Alberta has completed upgrades to 5 air tanker bases, has planned an additional 7 upgrades, and is now assessing further base sites that are close to communities and high resource areas. The planned projects vary in size and scope. Their costs have been estimated at $2 million to $10 million each.
- In 2003, British Columbia identified the need to upgrade several air tanker bases. Three bases have been designated as critical, and 7 additional bases need work, although on a less urgent basis.
- Saskatchewan has identified 5 air tanker bases, 3 runways, and several fuels systems as needing upgrades to accommodate planned air tanker upgrades. In addition, a new hanger will be required to house a larger fleet.
- Quebec has recently built one new runway and is developing another new airstrip and air tanker base. Both have been located and constructed to ensure that they can respond and provide adequate protection to northern communities.
- The Yukon is looking for significant upgrades to its air tanker runways. Three of the five airstrips used by the Yukon have a gravel surface, which cannot be used by many of the new air tankers. This limits the Yukon not only in terms of resources that can be borrowed from outside the territory during a heavy fire period but also in terms of the air tankers the territory can contract or acquire in the future.
- Manitoba's land-based, retardant air tanker program is in its early stages. If this program continues to grow, additional development of air tanker bases will be required.

### Weather Networks

As noted above, Environment Canada has reduced its service levels rather than responding to the need for better coverage for fire weather and fire behaviour forecasting. This has lead to agencies developing their own weather networks and reducing their reliance on outside sources of weather data.

Saskatchewan alone is considering the creation of 60 new weather stations. Wherever possible, agencies need to cooperate and pool weather data for forecasting, operational, and historical purposes. As an example Alberta, the Northwest Territories, and several power companies have recently entered into a partnership to enhance the lightning detection system that they jointly use.

### Fixed Detection Networks

Saskatchewan recently experienced catastrophic structural failure of one lookout tower. Thirty-eight lookout towers in the province were subsequently pulled from service and will need to be rebuilt. After this event Alberta undertook a review of their lookout towers, and twelve towers have been rebuilt, with several others are undergoing significant structural repairs as prescribed by an engineering review.

Other agencies have chosen to reduce or shut down their network of lookout towers, using aerial detection and public reporting as the replacement.

### Radio Networks

At least six different (incompatible) radio systems are in use by Canadian fire management agencies. This incompatibility increases the demand on an agency's mobile and handheld radio inventories during very busy seasons. Even if fire-fighting resources are available from other agencies, it may be impossible to effectively integrate them because of a shortage of radio units or incompatibility of this equipment. Even more disturbing is the incompatibility of agency radio systems with rural and municipal radio systems. Given the recognized increase in the number of fires at the wildland–urban interface, there is a pressing need to develop radio systems that are compatible not only between wildland agencies but also with their rural and municipal counterparts.

Another issue for all radio systems is frequency availability. To alleviate this concern, Industry Canada is moving to the use of narrow frequency bands. However, most agency systems and radios will be unable to take advantage of this added flexibility.

A common approach to radio systems would allow more efficient sharing of resources and would enhance the safety of both communities and firefighters. In addition, it would put the agencies in a much more favourable position to negotiate with Industry Canada for an adequate number of radio frequencies (on both the AM and FM frequency bands) designated for their exclusive use.

## Summary

Canadian fire management agencies identified an immediate need for over $60 million worth of critical repair, replacement, or development costs. Overall, the necessary infrastructure components needed to properly equip the agencies represent over $500 million of capital investment over the next 10 years.

## Literature Cited


Alexander, M.E.; Tymstra, C.; Frederick, K.W. 2004. Incorporating breaching and spotting considerations into PROMETHEUS – the Canadian wildland fire growth model. Foothills Model Forest, Hinton, AB. Chisholm/Dogrib Fire Research Initiative Quicknote 6.

ArcGIS. 2004. ArcGIS version 9.0. Environmental Systems Research Institute. Redlands, CA.

ArcView GIS. 1999. ArcView GIS version 3.2. Environmental Systems Research Institute. Redlands, CA.

Born, W.; Fuglem, P.; Hirsch, K.G.; Stocks, B.J.; Taudin-Chabot, P.; Wang, S.; Wotton, B.M. 2006. Canadian Wildland Fire Strategy: summary report of the best practices workshop. Pages 83–85 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

Canadian Forestry Service. 1987. Canadian Forest Fire Danger Rating System¯Users' Guide. Produced by the Canadian Forestry Service Danger Group, Ottawa, ON. Three-ring binder (unnumbered publication).

Englefield, P.; Lee, B.S.; Suddaby, R.M. 2000. Spatial Fire Management System *in* Proc. 20th annual ESRI user conf., Paper #489. Environmental Systems Research Institute, Redlands, CA. Available from <http://www.esri.com/library/userconf/proc00/professional/papers/PAP489/p489.htm>.

(ESRI) Environmental Systems Research Institute. 2003. Search ArcScripts [on-line]. Accessed 14 July 2004. <http://arcscripts.esri.com/>.

Lawson, B.D.; Armitage, O.B.; Dalrymple, G.N. 1996. Wildfire ignition probability predictor (WIPP). R&D Update. Can. For. Serv., Pac. For. Cent., Victoria, BC.

Lawson, B.D.; Dalrymple, G.N. 1996. Probabilities to sustained ignition in lodgepole pine, interior Douglas-fir, and white spruce–subalpine fir forest types. Supplement to Field guide to the Canadian Forest Fire Behavior Prediction (FBP) System. Pac. For. Cent., Can. For. Serv., Victoria, BC. FRDA Handbook 012.

Lee, B.S. 1990. Use of advanced concepts for dispatching fire control resources. Pages 137–147 *in* M.E. Alexander and G.F. Bisgrove, Tech. Coords. The art and science of fire management. Proceedings of the First Interior West Fire Council Annual Meeting and Workshop, Kananaskis Village, AB. 24–27 October 1988. For. Can., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-309.

Lee, B.S.; Alexander, M.E.; Hawkes, B.C.; Lynham, T.J.; Stocks, B.J.; Englefield, P. 2002. Information systems in support of wildland fire management decision making in Canada. Computers and Electronics in Agriculture 37:185–198.

Lee, B.S.; Anderson, K.R. 1989. A spatial analysis approach for forest fire preparedness planning. Pages 339–345 *in* D.C. MacIver, H. Auld, and R. Whitewood, eds., 10th conf. on Fire and forest meteorology. Environ. Can. and For. Can., Ottawa, ON.

Lee, B.S.; Anderson, K.R. 1991. An overview of IFMIS: the intelligent fire management information system. Pages 58–70 *in* H. Grewal, ed. Forestry Canada Modeling Working Group: Proceedings of the 5th Annual Workshop. For. Can., North. For. Cent., Edmonton, AB.

Lee, B.S.; Buckley, D.J. 1992. Forestry Canada applies GIS technology to forest fire management. Earth Observ. Mag. 3(6):44–49.

McAlpine, R.S.; Hirsch, K.G. 1999. An overview of LEOPARDS: the level of protection analysis system. For. Chron. 75(4):615–621.

Remsoft Inc. 2001. Accessed 14 June 2006. <http://www.remsoft.com/docs/products/bbr.brochure.pdf>.

Stocks; B.J.; Lawson, B.D.; Alexander, M.E.; Van Wagner, C.E.; McAlpine, R.S.; Lynham, T.J.; Dubé, D.E. 1989. Canadian Forest Fire Danger Rating System: an overview. For. Chron. 65(6):450–457.

Tymstra, C. 2002. PROMETHEUS – the Canadian wildland fire growth model. Initial Attack 2002 (Spring):8–9.

Born, W.; Stocks, B.J. 2006. Canadian fire management infrastructure. Pages 57–71 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

# From the Other Side of the Ledger: The Industrial Benefits of Wildland Fire Management in Canada

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## Introduction

Although typically thought of in terms of its costs, fire management in Canada is also a source of economic activity and industrial benefits. In Canada, direct costs for wildfire suppression typically range from $400 million to $800 million per year. Costs depend largely on the severity of the fire season, as well as the threat posed to property or other assets. For example, in the 2003 fire season, fires in British Columbia affected extensive areas of forest and several communities in southern BC, resulting in some of the highest firefighting expenditures ever required in the province (BCMFR 2006). At first glance, it would appear that the industrial benefits of fire management could be determined by examining total public expenditures, and the industrial sectors in which those funds are spent. However, the benefits of fire management are widespread and multifaceted, extending beyond those incurred directly during a fire. Economic activity occurs and industrial benefits are created through all four stages of fire management: preparedness, mitigation, response, and recovery. The expenditures resulting from fire management, including those for employment and equipment purchases, support a number of sectors of the Canadian economy and can provide direct benefits to forest-dependent communities. In addition to economic activity, fire protection also helps to support the sustainability of Canada's forest industry. At the same time, benefits flow from the presence of fire on the landscape.

This paper briefly examines a variety of industrial benefits that can be attributed directly and indirectly to fire management in Canada. It is divided into four main sections: fire-fighting equipment and infrastructure, fire-fighting employment, benefits and costs of fuel reduction and risk abatement, and other benefits from fire and fire management. For the purposes of this discussion, fire management is defined as managing fire on a given landscape, specifically, carrying out prescribed fires, thinning forests, and deciding which fires to fight and which to let burn. Benefits from some of these activities clearly depend on one's perspective. While government spending on fire management can benefit the sectors in which money is spent, these activities may be financed through taxes that are a cost to other sectors or the overall economy. Considering the wide range of economic, social and ecological benefits that Canada's forest endowment helps to generate, fire management can also be thought of as a cost associated with the overall business of managing forests for multiple benefits. However, estimating the total industrial benefit or the net benefits of fire management is beyond the scope of this paper. Instead, the principal objective is to offer a different perspective on an aspect of the forest industry that is traditionally understood simply in terms of costs.

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## Fire-Fighting Equipment and Infrastructure

A substantial network of infrastructure and equipment exists to support Canada's wildfire management programs. The total dollar value of equipment, supply caches, repeater networks, air tanker bases, and other infrastructure is likely in the hundreds of millions of dollars (P. Fuglem, BC Ministry of Forests and Range, electronic mail, 29 April 2005). Canada has a fleet of more than 50 CL-215 and CL-415 water bombers, as well as several land-based air tankers (CIFFC 2005). Bombardier Inc. (formerly Canadair) of Montréal, Quebec, manufactures the CL-215/CL-415. The CL-215 was produced from 1969 to 1989, and 125 aircraft were sold for use in Canada and abroad. Production of the CL-415 began in the 1990s, and as of 2001, 17 aircraft were in use in Canada and 36 abroad (Bombardier Inc. 2005). In 1998, the province of Ontario purchased 9 CL-415s at a total cost of $225 million (including training and maintenance). This expense was offset through an agreement whereby Bombardier would buy back the existing CL-215 fleet and conduct the final CL-415 assembly in Ontario, creating approximately 50 local jobs (MNR 1998). Table 1 shows the total number of CL-215 and CL-415s in use as of 2001.

Canadian companies are involved in the manufacture of other aircraft used in fire management, such as the Convair CV580, which is modified for use as a water bomber by Kelowna Flightcraft and Conair Group Inc. in British Columbia. Although much of the water bomber fleet is owned and operated by provincial fire agencies, some private companies (particularly in the west) make water bombers and spotter planes available on a contract basis e.g., Flying Tankers Inc. and Conair Group Inc. in British Columbia; Air Spray Ltd. in Alberta; and Forest Protection Ltd. in New Brunswick. Helicopters are also used extensively for patrols; for transporting crews; for delivering water, retardant, or other supplies; and for igniting controlled burns.

In 2004, fixed-wing water bombers logged approximately 6 000 hours of flying time in Canada, and rotary-wing water bombers (helicopters) logged over 18 000 hours of flying time (calculated from tabular data obtained from D. Bokovay, Canadian Interagency Forest Fire Centre, electronic mail, 11 April 2005). It is worth noting that the latter statistic does not include time for transporting crews to and from fires, time for daily patrols, or time when helicopters are on standby, which can accumulate to a significant amount of time and cost.

Canada's current inventory of other forest fire equipment is summarized in Table 2. Many of the items mentioned there are manufactured in Canada. For example, fire-line hose, relay tanks and power pumps are manufactured by Wildfire Equipment Inc. (formerly Wajax) in Lachine, Quebec. Fire suppression involves other equipment such as Caterpillars and backhoes for constructing fireguards and pickup trucks for transporting crews and equipment. Fuel for vehicles and equipment is also required, as is food and other basic supplies for crews. Workers require appropriate personal gear, including clothing, gloves, hard hats, and boots.

Fire fighting also involves the use of technologically sophisticated equipment such as two-way radios, global positioning systems (GPS), digital cameras, and personal computers. Various types of computer software, such as geographic information systems (GIS) are used to record spatial fire data, and specialized computer models have been developed in Canada to provide decision support to fire managers.

**Table 1. Bombardier Inc. amphibious aircraft in service in November 2001**

| Location | CL-215 | CL-215T | CL-415 | Total |
|---|---|---|---|---|
| Alberta | 6 | 0 | 0 | 6 |
| Manitoba | 7 | 0 | 0 | 7 |
| Newfoundland | 6 | 0 | 0 | 6 |
| Northwest Territories | 4 | 0 | 0 | 4 |
| Ontario | 0 | 0 | 9 | 9 |
| Quebec | 4 | 2 | 8 | 14 |
| Saskatchewan | 6 | 0 | 0 | 6 |
| Canada (total) | 33 | 2 | 17 | 52 |
| United States | 3 | 0 | 0 | 3 |
| France | 0 | 0 | 11 | 11 |
| Greece | 14 | 0 | 8 | 22 |
| Italy | 2 | 0 | 14 | 16 |
| Spain | 7 | 15 | 0 | 22 |
| Croatia | 2 | 0 | 3 | 5 |
| Thailand | 1 | 0 | 0 | 1 |
| Total | 62 | 17 | 53 | 132 |

Source: Bombardier Inc. (2005).

**Table 2. Fire-fighting equipment used in Canada**

| Equipment type | Total quantity |
|---|---|
| Power pumps | 10 737 |
| Fire line hose (30 metre lengths) | 221 242 |
| Burn-out devices (e.g., drip torches and heli-torches) | 2 724 |
| Portable weather kits | 134 |
| Relay tanks | 3 222 |
| Sprinklers | 8 873 |
| Aircraft fuelling kits | 56 |
| Infrared units | 86 |
| Hand tools (e.g., Pulaski axes, chainsaws, backpack pumps) | 84 634 |
| Communication equipment (e.g., radios, repeaters) | 7 009 |
| Tents | 7 738 |
| Mess kits | 4 292 |
| Mobile camp trailers | 125 |
| Portable helipads | 10 |

Source: CIFFC (2004).

## Fire-Fighting Employment

Wildland fire fighting employs thousands of people in Canada. The work is typically seasonal, in accordance with the wildfire season. One estimate of the number of people directly employed in fighting forest fires in 2004 in each province is shown in Figure 1.

Other specialists and support staff are employed to manage fire operations, maintain equipment, and provide administrative support. It is estimated that fire management in British Columbia directly employs approximately 1 260 people (1 035 of which are seasonal), as well as providing contract work for several thousand additional firefighters and emergency crews (P. Fuglem, BC Ministry of Forests and Range, electronic mail, 29 April 2005). Also in British Columbia, approximately 360 aboriginal people obtain seasonal employment in BC's Native Unit Crew program, and there are 12 full-time positions for aboriginals in the Native Fire Prevention Technician program (MOFR 2005).

Many firefighters are hired in small, forest-dependent communities where well-paid jobs are scarce. For example, Fort Chipewyan, Alberta has a sub-office of Alberta Forest Protection with two full-time staff. During the fire season (May-September) the office typically hires ten or more employees from the local community (an eight person crew along with several support staff), and during severe fire seasons additional emergency firefighters and support staff are hired (Bauer, K. Alberta Forest Protection, telephone conversation on 22 February 2006). These jobs make an important contribution to the incomes of local residents in this isolated area. Wages for firefighters are also well above the minimum wage. An entry-level firefighter hired by the province of Ontario earns approximately $17 per hour (MNR 2003), and pay for experienced firefighters can be higher.

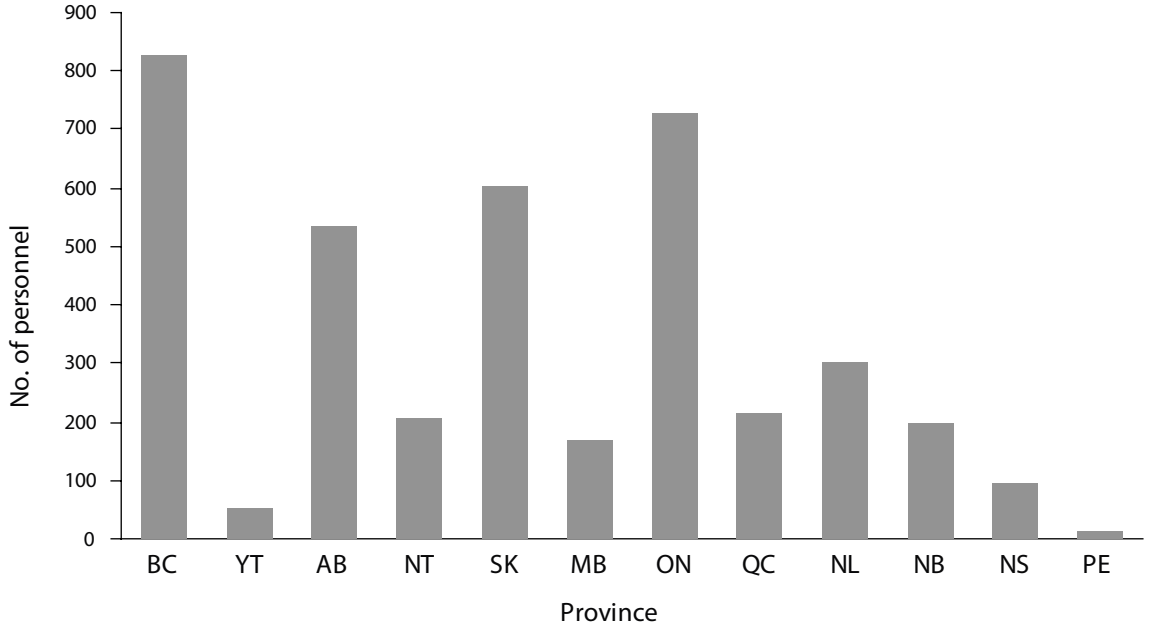


**Figure 1. Fire-fighting employment in Canada.** Note: Estimates do not include Parks Canada employees. Nunavut is not included due to the absence of a wildland fire management agency in the territory. Source: CIFFC (2004).

## Benefits and Costs Associated with Fuel Reduction and Risk Abatement

Risk abatement activities, such as fuel modification, prescribed burning, and fireguard construction, may also provide periodic employment and economic benefits. As for other areas of fire management, the benefits and costs of these activities can be complex. A project such as stand-level fuel modification would have costs associated with planning, management, labour, and equipment needed to carry out the treatment. The costs might also include other impacts, such as disruptions to commercial recreation activity or short-term effects on water or air quality (e.g., because of smoke). Direct benefits could include revenue from merchantable trees harvested during the treatment, as well as any other resource improvements, such as improvements in grazing potential. The benefits of successful treatments might also include reduced suppression costs in the event of a fire, reduced potential for fire occurrence, or reduced likelihood of a highly catastrophic fire threatening property or human safety. If the stand is part of a commercial forest, fuel treatments may result in a greater probability of a profitable timber harvest in the future.

Nonmarket benefits could include aesthetic improvements and a return to more ecologically appropriate forest conditions. The skills and training obtained by workers may also represent a significant benefit. For example, Human Resources and Skills Development Canada and BC's Regional District of Central Okanagan are providing funding for fuel modification treatments in the Okanagan. The project has provided employment and training for 15 previously unemployed people (Seymour 2004).

Many of these costs and benefits can be extremely difficult to quantify, and even the direct cost of treatments can vary widely. Some of the factors that influence the net cost of fuel treatments include revenue from the sale of timber, the quantity of unmerchantable stems that must be treated, terrain conditions, transportation requirements, and the availability of skilled labour. Anderson (2004) documented costs for a variety of fuel treatments in the East Kootenays in British Columbia. Total costs for planning and treatments on 2 728 hectares averaged $214 per hectare, although the costs ranged from as little as $53 per hectare in some areas to over $400 per hectare in others. Prescribed burning in Canada's national parks costs an average of $80 per hectare though costs can range from as little as $10 per hectare to over $1 000 per hectare (Parks Canada 2004). In the United States, over 5 million hectares of forest has undergone fuel reduction and restoration treatments since 2000 (HFI 2005), and the USDA Forest Service (2004b) reported that fuel treatment programs had an average cost of US$420 per hectare in 2004. The USDA Forest Service (2005) also estimated that gross costs of fuel treatments under the US National Fire Plan could vary from approximately US$85 to US$2 500 per hectare.

## Other Benefits from Wildland Fire and Fire Management

In addition to the obvious benefits from ensuring human safety and protecting property, wildland fire management helps to maintain the sustainability of Canada's forest industry. By controlling fires that threaten valuable timber or plantations, fire management aims to prevent catastrophic fires from compromising future harvesting opportunities and helps to ensure the continued existence of local forest industries and employment.

Managing wildfires in Canada also promotes investment in research and development. In fact, Canada is a leader in forest fire research. Research and investment involves various fields of study, including weather forecasting, GIS mapping, operational research, technology for suppression equipment, and fire behaviour. Some of the expertise and technology developed in Canada has been exported abroad or has attracted overseas funding. The Canadian Forest Service's Canadian Forest Fire Danger Rating System and Spatial Fire Management System have been adapted for use in several other countries, including Mexico, Indonesia, Malaysia, and New Zealand (CFS 2003). BC's Real-time Emergency Management via Satellite (REMSAT) project, funded by the European Space Agency, uses satellite-based communication, GPS, and imaging to provide advanced decision support to BC fire managers. Fire crews from abroad train in Canada, and Canadian fire management experts are regularly invited to speak at international conferences and to provide tours to visiting fire managers.

Wildfire leads to economic impacts in other areas. Although the impact may be negative in terms of damage to timber inventories and property, other industrial activities may occur after fires have been extinguished, and some positive benefits can occur from the impact of fire itself. Restoration activities may be undertaken after wildfires, including salvage logging, tree planting, and rehabilitation of disturbed soil. Wood that has been burned by a low-intensity fire has multiple uses, particularly for the pulp and paper industry (Watson and Potter 2004). In some areas wildlife habitat may be improved, including habitat for species that commercial tourism operators and guide outfitters rely on (Loomis et al. 2002). Growing conditions for wild mushrooms may also be enhanced by fire, providing opportunities for commercial mushroom harvesters. Canada's morel mushroom harvest comes mainly from western Canada (particularly the Yukon); harvesters seek out recently burned areas, where growing conditions are favourable for morels (Wurtz et al. 2005). Wills and Lipsey (1999) estimated that the combined BC and Yukon harvest can range from as little as 10 000 kilograms of mushrooms in a poor year to as much as 225 000 kilograms in a good year. Pickers receive an average of $3 per pound ($6.61per kilogram), and exporters sell morels overseas for $18 to $22 per pound ($39.67 to $48.48 per kilogram) (Wills and Lipsey 1999). These figures suggest that the morel industry in western Canada could be worth between $400 000 and $10 million in any given year.

## Conclusions

In this paper, we have detailed various industrial benefits and economic activity resulting from wildfire and fire management. Understanding these benefits is important for stakeholders and policymakers who are helping to shape the future of fire management in Canada. While some of these benefits may not provide a basis in themselves for spending additional public funds on fire management, the benefits to industries, workers and local economies are an important impact from program expenditures. Benefits from the presence of fire in our forests must also be considered if money is to be spent influencing fire occurrence. Although the protection of lives and property will remain essential, there are benefits from ensuring that fire continues to play its natural role in forest ecosystems.

We have examined employment, equipment used, supplies purchased, and infrastructure necessary for fire management; however, more research is required to quantify the value of these items and how often they are purchased. This descriptive analysis provides evidence of the industrial benefits associated with fire management in Canada, but a more comprehensive analysis is needed for a complete understanding of these benefits.

## Literature Cited

Anderson, G. 2004. Applying large-scale treatments in BC — the costs and methods in doing so [presentation]. BC Wildfire Conf. 2004: Wildland Urban Interface Fire in the New Era, Whistler, British Columbia, 11–13 May 2004.

[BCMFR] BC Ministry of Forests and Range. 2006. Average Hectares, Fires, and Dollars. BC Ministry of Forests and Range Protection Branch, Victoria, BC. Accessed 24 Feb 2006 <http://www.for.gov.bc.ca/protect/reports/HistoricalAverages.htm>.

[BCMFR] BC Ministry of Forests and Range. 2005. Employment Equity. BC Ministry of Forests and Range Protection Branch, Victoria, BC. Accessed 17 Feb 2006. <http://www.for.gov.bc.ca/protect/firefighter/equity.htm>.

Bombardier Inc. 2005. Amphibious aircraft status report [on-line]. Bombardier Inc., Montréal, QC. Accessed 7 April 2005. <http://www.bombardier.com>. (Note: located under Bombardier Aerospace - Amphibious Aircraft - Bombardier 415 - Status Report).

[CFS] Canadian Forest Service. 2003. Fighting wildland fire with technology [on-line]. Nat. Resour. Can., Ottawa, ON. Accessed 25 May 2005. <http://cwfis.cfs.nrcan.gc.ca/pdf/fighting_fire.pdf>.

[CFS] Canadian Forest Service. 2004b. The state of Canada's forests 2003–2004 [report on-line]. Nat. Resour. Can., Ottawa, ON. Accessed 20 Sep 2005. <http://www.nrcan.gc.ca/cfs-scf/national/what-quoi/sof/sof04/index_e.html>.

[CIFFC] Canadian Interagency Forest Fire Centre. 2004. CIFFC resource catalogue. Winnipeg, MB. 5 p.

[CIFFC] Canadian Interagency Forest Fire Centre. n.d. CIFFC overview [on-line]. Winnipeg, MB. Accessed 7 Apr 2005. <http://www.ciffc.ca/about.htm>.

[HFI] Healthy Forests Initiative. 2005. Healthy forests report [on-line]. Washington, DC. Accessed 27 Jun 2005. <http://www.healthyforests.gov/projects/progress_report.html>.

Loomis, J.; Griffin, D.; Wu, E.; González-Cabán, A. 2002. Estimating the economic value of big game habitat production from prescribed fire using a time series approach. J. For. Econ. 8(2):119–129.

[MNR] Ministry of Natural Resources. 1998. MNR to replace aging waterbombers [news release on-line]. Toronto, ON. Accessed 8 Apr 2005. <http://www.mnr.gov.on.ca/MNR/csb/news/apr2nr98.html>.

[MNR] Ministry of Natural Resources. 2003. Forest fire jobs and careers: overview [on-line]. Toronto, ON. Accessed 6 Apr 2005. <http://affm.mnr.gov.on.ca/spectrasites/viewers/showArticle.cfm?objectid=5B5B8331-1BBE-431F-BEDC33674F008725&method=DISPLAYFULLNOBARNOTITLE&id=5B5B8331-1BBE-431F-BEDC33674F008725&siteid=>.

Parks Canada. 2005. Fire in Canada's national parks [on-line]. Gatineau, QC. Accessed 24 Jun 2005. <http://www.pc.gc.ca/progs/np-pn/ecosystem/ecosystem5_E.asp>.

Seymour, R. 2004, 3 Feb. Work aims to avoid another big blaze [on-line]. Kelowna Daily Courier. Accessed 21 Feb 2006. <http://photos.kelownadailycourier.ca/archive/2004/02/03/stories/5484_full.php4?latest_date=2004/02/03>.

US Department of Agriculture Forest Service. 2005. A strategic assessment of forest biomass and fuel reduction treatments in western states. US Dep. Agric., For. Serv., Rocky Mtn. Res. Stn., Fort Collins, CO. Gen. Tech. Rep. RMRS-GTR-149. 17 p.

US Department of Agriculture Forest Service. 2004b [update 17 Dec. 2004]. Quick facts: fire and fuels [on-line]. Washington, DC. Accessed 27 Jun 2005. <http://www.fs.fed.us/projects/four-threats/facts/fire-fuels.shtml>.

Watson, P.; Potter, S. 2004 Burned wood in the pulp and paper industry: a literature review. For. Chron. 80(4):473–477.

Wills, R.M.; Lipsey, R.G. 1999. An economic strategy to develop non-timber forest products and services in British Columbia. Forest Renewal BC Project PA97538-ORE Final report. Cognetics International Research Inc.,Bowen Island, BC. 117 p.

Wurtz, T.; Wiita, A.; Weber, N.; Pilz, D. 2005. Harvesting morels after wildfire in Alaska. US Dep.Agric., For. Serv., Pacific Northwest Res. Stn,, Portland, OR. Res. Note. PNW-RN-546. 31 p.

Peter, B.; DesRoches, C.T.; Mogus, T.; Wang, S.; Wilson, B. 2006. From the other side of the ledger: the industrial benefits of wildland fire management in Canada Pages 73–79 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

# PERSPECTIVES

# Canadian Wildland Fire Strategy: Summary Report of the Best Practices Workshop

## Compiled by Canadian Wildland Fire Strategy Core Team[1]

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## Introduction

The development of the Canadian Wildland Fire Strategy (CWFS), an initiative of the Canadian Council of Forest Ministers, included a two-day workshop in Winnipeg, Manitoba, on 9 and 10 December 2004. The objective of the workshop was to identify a wide range of innovative policies, strategies, and practices that could be considered and implemented by the public and private sectors over the next 10 to 20 years to increase public safety, enhance forest health and protection, and foster new business models for sharing risk and increasing economic efficiency.

The more than 60 invited workshop participants represented a wide range disciplines, including land and resource planning; social sciences; disaster management; fire operations, management, and research; and forest management and research. Most of the provinces and territories with significant forest areas were represented, as were key federal departments and the private sector (e.g., the forest and insurance industries). The participants (Appendix 1), who also included subject area experts from the United States, Mexico, and Australia, were selected or nominated by their respective organizations on the basis of their analytical and creative "out-of-the-box" thinking abilities.

## Goals

The workshop had the following primary goals:

1. Review the current situation for wildland fire management in Canada and around the world in 5 key areas: policy, infrastructure (including human resources), vulnerability and risk trends, economics and institutional arrangements, and science.
2. Specify and evaluate present and potential best practices that can be used to deal with current and emerging realities facing wildland fire management in Canada.
3. Identify opportunities, challenges, and key actions associated with implementing selected best practices across Canada.

## Format

Before the workshop, each participant submitted a minimum of one best practice that had been implemented by his or her organization (or, in some cases, a worst practice to be avoided in the future). Each submission included a description of the project, its impacts, who was responsible for its implementation, and suggested steps that would be needed to implement the practice on a Canada-wide

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basis. All of the case studies, which can be viewed at ftp://ftp.nofc.cfs.nrcan.gc.ca/pub/fire/CWFS/BP-Casestudies, were made available to participants before the workshop and served as a starting point for small-group discussions.

The workshop itself consisted of three phases over the two days. The first phase consisted of presentations to establish the context (e.g., status, issues, and challenges) of fire and fire management both in Canada and in other parts of the world. During the second phase, facilitated focus groups brainstormed, synthesized, and rated best practices pertaining to five essential aspects of wildland fire management. Finally, each group developed and presented a work plan describing how one of the group's most significant best practices could be implemented.

## Presentations—Setting the Context

During the opening session, the moderator, Peter Fuglem, challenged participants to identify best practices for wildland fire management in Canada by moving beyond traditional approaches and thinking "outside the fire triangle". The scope, rationale, and status of the CWFS was presented by Kelvin Hirsch. An environment scan of current practices, issues, and trends in wildland fire management was presented by members of the CWFS Core Team. This presentation focused on five key areas: policy, infrastructure (including human resources), vulnerability and risk trends, economics and institutional arrangements, and science. There were also three presentations on wildland fire management in other jurisdictions:

- H. Cortner outlined the need for and potential impacts (including implications for wildland fire management) of a shift to ecosystem-based forest management in the United States;
- P. Moore discussed contrasting views of wildland fire management (prevention, suppression, and use) in northern and southern Australia; and
- T. Hoffman described issues related to the wildland–urban interface in California, the challenges that have been overcome, and those that require further work.

Finally, the Honourable Gary Filmon, former premier of Manitoba, spoke about his review of the 2003 fire season in British Columbia, emphasizing the impact of the fires on people's lives, and then discussed the associated recommendations.

These presentations emphasized several common themes.

- Fire plays a valuable role in many ecosystems and is required to maintain their health and biodiversity, although urban stakeholders generally do not recognize this need.
- Aggressive suppression of wildfire is increasing the risk of large catastrophic fires in some, but probably not all, ecosystems.
- Urban dwellers and the media expect governments (local, provincial/territorial, and federal) to fight all wildland fires, regardless of the values at risk or the ecological benefits of fire.
- It is physically impossible to control all wildfires, regardless of the amount of suppression resources available. In Canada, the United States, and Australia, about 97% of all wildfires fires are contained, but 3% escape, and these account for more than 95% of the area burned.
- Mitigation and prevention (e.g., building codes, land use planning, fuel management, and public involvement) often represent a more economically efficient and effective means of protecting communities and selected timber areas than response and suppression activities.

## Development of Best Practices

Each participant chose to participate in one of five focus groups.

1. Integrating fire and land/resource management
2. Mitigation in the wildland–urban interface
3. Community capacity and resilience
4. Fire suppression and operations
5. Managing the business of wildland fire

Each group brainstormed actual or potential best practices under the specified theme, assessed their viability in terms of degree of impact and likelihood of implementation, and estimated the relative cost of implementing the practice. Using these criteria, each group selected one best practice for further development and provided details concerning responsibility for implementation, opportunities, challenges, targets and measures, and critical actions.

## Results

The broad range of ideas and opportunities generated by each of the focus groups was condensed into a few key recommendations pertaining to the best practices viewed as most significant by that group.

### *Integrating fire and land/resource management*

Actively consider fire in long-term planning related to lands, resources, and forest management through both top–down guidance and bottom–up input and insights to strongly imbed the realities of wildland fire and its management into strategic and operational planning.

### *Mitigation in the wildland–urban interface*

Identify, engage, empower, and support all stakeholders in the creation of FireSmart communities. Build on the known FireSmart brand, which includes developing a Partners in Protection type organization at a national level. Establish and provide long-term funding for grassroots FireSmart committees and initiatives (such as fuel management activities and alternative community design and home construction).

### *Community capacity and resilience*

Build partnerships at the community level for reducing the risk of wildland fire. Establish local, multisectoral committees that would make risk management decisions for the community and implement actions to mitigate risks. Enhance communications to increase awareness of wildland fire issues (e.g., benefits of prescribed fires, level of risk reduction associated with managing the fuels within and around homes). Establish pilot communities in various regions of Canada that could serve as demonstration and learning tools.

### *Fire suppression and operations*

Increase, or at a minimum maintain, fire-suppression capacity within jurisdictions and increase interagency sharing of resources. The primary focus must be on ensuring an adequate number of well-trained personnel within all components of response organizations in the immediate future. An adequate supply of modern air tankers and equipment is also required over the next decade.

### *Managing the business of wildland fire*

Increase cooperation among all entities connected with and responsible for wildland fire management. This would require a strategic facilitating organization, a Canadian wildland fire information hub, an implementation group for setting and monitoring firefighting standards established through the Canadian Wildland Fire Strategy, and common messaging to the public and professionals. Cooperation could be increased through creation of a new organization or expansion of an existing organization such as the Canadian Interagency Forest Fire Centre.

The complete set of ideas and related input generated at the Best Practices Workshop were synthesized by the CWFS Core Team and presented to the CWFS Assistant Deputy Ministers Task Group of the Canadian Council of Forest Ministers and were used extensively in establishing the proposed vision, desired future state, actions, and potential programs that have since been documented in the CWFS Declaration and Vision (CCFM 2006a, b).

## Acknowledgements

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## Literature Cited

[CCFM] Canadian Council of Forest Ministers. 2006a. Canadian wildland fire strategy: a vision for an innovative and integrated approach to managing the risks. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

[CCFM] Canadian Council of Forest Ministers. 2006b. Canadian wildland fire strategy declaration. Can. Counc. For Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

Born, W.; Fuglem, P.; Hirsch, K.G.; Stocks, B.J.; Taudin-Chabot, P.; Wang, S.; Wotton, B.M. 2006. Canadian Wildland Fire Strategy: summary report of the best practices workshop. Pages 83–85 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

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# The History of Forest Fire Science and Technology in Canada and Emerging Issues Relevant to the Canadian Wildland Fire Strategy

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## Introduction

This discussion paper describes the history and current status of Canadian science and technology research in support of fire management and some of the products of that research that are used by fire management agencies today. It is not meant as a definitive discussion of Canadian fire science as a whole and explores only a few areas of fire research in any depth. In addition to providing some background on research products that have had a direct bearing on fire management in Canada, both past and present, the paper highlights several emerging areas of research critical to effective fire management in the future, in the hope that they can be addressed under the new Canadian Wildland Fire Strategy (CWFS).

## Context and History of Fire Research in Canada

Although various provincial and territorial fire management organizations and some universities have fire research programs, the federal government's research program, initiated in 1925, has represented by far the strongest, broadest, and most continuous commitment to forest fire research in Canada. Despite residing in a number of federal departments and sectors over the past eight decades and having experienced many fluctuations in resource strength, the federal fire research program, which is now based in the Canadian Forest Service (CFS) sector of Natural Resources Canada, has produced many innovative products of immediate practical value to fire management agencies in Canada and abroad.

Early Canadian forest fire researchers began investigations into the relationship between weather and forest flammability, working primarily in Ottawa and the Petawawa Forest Experiment Station in Ontario and expanding a network of field experiment stations into western and Atlantic Canada in the 1930s. Fire danger studies, including the conduct of numerous small-scale test fires, resulted in the development of a national system of fire hazard rating, which has survived many metamorphoses to form a part of the current Canadian system of fire danger rating. Fire hazard research was a primary thrust of research performed at that time, but fire suppression research was also carried out, with the development of fire-retardant chemicals and specifications and performance-testing procedures for portable fire pumps and accessories. In the mid-1960s, federal regional laboratories were established across Canada (in New Brunswick, Newfoundland, Quebec, Ontario, Alberta, and British Columbia) to provide continuous contact with provincial forest management agencies and to expand the capability to address their concerns and requirements. Fire research programs were developed at these centres to augment continuing research at Petawawa, and the Forest Fire Research Institute was established in Ottawa. This development represented the zenith of the federal

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fire research program in Canada, with substantial fire research activity in the areas of fire danger rating, fire behaviour modelling, fire occurrence and behaviour prediction, fire ecology, and computerized fire management systems. From this peak period, the level of Canadian fire research has declined steadily, as has federal forestry research in general, consistent with declining funding support. Closure of the Forest Fire Research Institute in 1979 was followed by the closing of the Petawawa National Forestry Institute in 1995 and the reassignment of a diminishing number of fire researchers to regional establishments. Through all of these changes, the fire researchers continued to adjust, forming strong collaborative alliances with management agencies, universities, and international partners to address emerging fire research issues, particularly in the areas of fire behaviour prediction, climate change impacts, and carbon budgets.

A significant but lesser volume of fire research has come from Canadian universities in recent decades, often in collaboration with federal and provincial agencies, particularly in the areas of fire management systems, fire ecology, fire occurrence prediction, fire danger rating, and physical fire modelling. Most notable have been the fire research activities at the University of Toronto and Lakehead University in Ontario, Université Laval and the Université du Québec à Montréal in Quebec, Brandon University in Manitoba, the University of New Brunswick, the University of Alberta, and the University of British Columbia.

Although forest fire research in Canada has addressed virtually all aspects of fire science and fire management over the past 80 years, two areas of fire research have proven most significant and are particularly relevant today—the Canadian Forest Fire Danger Rating System and various fire management systems. Over the past 15 years, as climate change has become a reality, Canadian fire scientists have devoted considerable effort to projecting future Canadian fire regimes under changing climate conditions. Progress in these three critical programs is described in some detail in the following sections.

## Major CFS Fire Research Programs

### Canadian Forest Fire Danger Rating System

The Canadian Forest Fire Danger Rating System (CFFDRS), implemented in the 1970s and 1980s, represents the culmination of several decades of continuous research. Since the initiation of fire danger research in 1925, five different fire danger rating systems have been developed, with increasing sophistication and applicability across the country. The approach has been to build upon previous danger rating systems in an evolutionary fashion and to make extensive use of field experiments (including test fires at various scales) and empirical analysis.

The CFFDRS incorporates both the Canadian Forest Fire Weather Index (FWI) System and the Canadian Forest Fire Behavior Prediction (FBP) System. The FWI System, which provides qualitative numerical ratings of relative fire potential based solely on weather observations, has been in use throughout Canada since 1970. The FBP System, which was developed from data gathered through major experimental burning programs and wildfire documentation in major fuel types across Canada, makes quantitative predictions of fire behaviour characteristics such as rate of spread, fuel consumption, and frontal fire intensity. Introduced in 1989, the FBP System represents many years of effort and extensive field programs involving numerous researchers and fire management agencies. These agencies use the CFFDRS in both planning and operational fire suppression activities, to predict the number and location of fires, to organize detection patrols, and to preposition resources in anticipation of fire activity. The CFFDRS is used universally across Canada and has recently been introduced in parts of the United States, in the United Kingdom, and in New Zealand. Although it is difficult to place a dollar value on the cost-effectiveness of a fire danger rating system, a 1987–1988 review by the federal government determined that at least $750 million in benefits could be attributed to the use of the CFFDRS for the period from 1971 to 1982. Research is already under way to develop the next generation of fire behaviour and fire occurrence prediction models for Canada. This work

involves extensive international and cross-disciplinary collaboration, particularly with fire researchers from the United States and Russia. The International Crown Fire Modelling Experiment, carried out in the late 1990s in Canada's Northwest Territories, is a prime example of the future collaborative nature of forest fire research.

## Forest Fire Management Systems

Computer-based fire management systems have been used in Canada since the early 1970s. At present, all Canadian fire management agencies use these computerized systems in their operational fire management programs. Most of these systems have been designed and developed by the CFS to operate on mini-computers and personal computers. In the early 1990s the CFS began using geographic information systems as an enabling technology for constructing fire management information systems. These efforts culminated in the development of the Spatial Fire Management System (sFMS), which can operate as a stand-alone system or be integrated into existing systems and which was designed to support a range of fire management functions, from policy formulation to decision support related to fire suppression. The sFMS is used primarily with current weather data and short-term forecasts to generate hourly or daily maps of fire weather, fire danger, fire behaviour, ignition probability, and attack time. Distributed on the Internet, these maps are used by Canadian fire managers to assist in decision-making regarding initial attack response, alertness levels, and distribution of resources.

Through the years, in both academia and the CFS, prediction models for forest fire occurrence have been developed for both human-caused and lightning-caused fires. These models have been tested from time to time within specific fire management agencies, but only British Columbia has adopted such a prediction system as part of its daily fire management operations. Ontario is in the process of adopting models of lightning fire ignition to aid fire managers in planning for daily fire activity.

Cellular fire growth models have been in development within the CFS since the early 1970s. These models initially used very early fire behaviour models (which later evolved into the FBP System) and a cellular, nearest-neighbour approach to fire spread. This research culminated in the WILDFIRE growth model developed by the CFS in the mid-1990s. Over the past several years, provincial agencies and the CFS have partnered in a major initiative to develop a wildfire growth model based on the propagation of elliptical wave fronts. This has led to PROMETHEUS, a Windows-based, spatially explicit model for projecting fire growth on complex landscapes.

## Climate Change and Forest Fire Regimes

Growing concern since the late 1980s over the probability of significant climate change during the 21st century, caused by increasing atmospheric concentrations of greenhouse gases, led to a major research initiative, primarily by CFS scientists, to evaluate and project the impacts of climate change on Canadian forests. Forest fires, the major natural disturbance regime in Canadian forests, are likely to be affected both early and significantly by any trend toward a warming and more unpredictable climate, and research into the impacts of climate change on fire was initiated within the CFS fire research program. Over the past 15 years, numerous studies have been conducted, often in collaboration with scientists from other federal departments, universities, and other countries.

Despite their coarse spatial and temporal resolution, general circulation models (GCMs) provide the best means currently available to project future climate, and numerous GCMs have been used extensively to project climate through the 21st century. In a variety of studies, CFS fire scientists have used GCMs to predict future fire danger conditions across the boreal zone, including Canada. Early studies compared seasonal fire weather severity under a $2 \times CO_2$ climate with current climate records and determined that fire danger conditions would increase significantly with climate warming. Higher-resolution regional climate models, although limited in geographic scope, have confirmed these projections of elevated fire danger conditions. Other studies have shown that the duration of the fire season in Canada would increase by 30 days under a $2 \times CO_2$ climate, and that the frequency of lightning would also increase substantially. In the late 1990s researchers used four current GCMs, along with recent weather data, to evaluate the relative occurrence of extreme fire danger across Canada and

Russia; they showed that there would be a significant increase in both the severity and the geographic extent of severe fire danger conditions in both countries under a warming climate. Moving beyond these projections of future fire danger, recent studies have shown a direct increase in the occurrence of forest fires (both human-caused and lightning-caused) so far during the 21st century in Canada. Using a database of large forest fires that have occurred in Canada since 1960, in combination with transient GCM outputs, researchers are now projecting a 75–120% increase in area burned in Canada by the end of this century. Strong scientific evidence now shows that Pacific sea surface temperatures and the frequency and strength of mid-tropospheric ridging have a major influence on the occurrence of and area burned by large fires in Canada, and new studies are under way to determine the impact of these major drivers under a changing climate.

In summary, increased Canadian forest fire activity is expected to be an early and significant result of a trend toward warmer and drier conditions, with potentially significant impacts on wood supply, the forest industry, and industry-dependent communities. These changes should result in shorter fire return intervals, a shift in age-class distribution toward younger forests, and a decrease in biospheric carbon storage. These effects are in turn expected to result in a positive feedback loop between fires in boreal ecosystems and climate change, with more carbon being released from boreal ecosystems than is being stored. Reinforcing this point, a recent retrospective analysis of carbon fluxes in the Canadian forest sector over the past 70 years found that Canadian forests have been a net source of atmospheric carbon since 1980, primarily because of increasing disturbance regimes (both fire and insects). It has also been suggested that fire would be the likely agent for future shifts in vegetation in response to climate change.

## Major Science and Technology Gaps and Research Requirements

Much has been accomplished in forest fire research in Canada over the past 8 decades, and a large number of research products have been applied directly by fire management agencies to better manage fire in this country. However, there are a number of science gaps and research needs that must be addressed if Canada is to continue its progress toward adequately addressing emerging issues and vulnerabilities. Some of the major initiatives required to build efficient business practices are discussed in this section.

This discussion represents a summary of the needs, in terms of both science and decision support systems, that were mentioned during initial discussions with individual fire managers and researchers. It is not intended as a definitive list of science program areas for the CWFS.

### National Decision Support System

To effectively address an escalating fire situation in Canada, a centralized facility that can collect, assimilate, and redistribute critical fire information in a timely manner is a necessity. At present, the country's central facility (the Canadian Interagency Forest Fire Centre [CIFFC]) coordinates the movement of resources across the country and internationally, but it does not have a mandate to *influence* the movement of resources. A facility such as the CIFFC could perhaps be expanded to house a comprehensive national decision support system that would monitor real-time information about critical fire management parameters in a spatially explicit manner. This information could then be shared quickly with all Canadian fire management agencies, facilitating cost-effective sharing of resources across borders, a practice that is steadily increasing. Research requirements to address this issue include the following:

- Develop an enhanced version of the Canadian Wildland Fire Information System (CWFIS) to use input data of much higher resolution from all agencies, in near-real time, to give a spatially explicit picture of the forest fire situation across Canada at any given time. The enhanced CWFIS would include information about, among other things, current and expected fire danger and fire behaviour conditions, maps of current problem fires (incorporating satellite data) and values-at-risk, resource levels across Canada, and expected fire occurrence.
- Improve the capability to anticipate and detect fires through the creation of better occurrence prediction models for lightning- and human-caused fires, more accurate medium- to long-range weather

forecasting, and the expanded use of satellites in detecting and monitoring fires, particularly in remote regions of the country.

- Create a research program, with a dedicated team of modellers, to develop a series of regional (provincial and territorial) level-of-protection models to evaluate the likely success and effectiveness of various resource deployment options at a regional scale. This would provide a means for better resource-sharing and for quantitative evaluation of best business practices.

### Analysis of Escaped and Large Fires

In Canada, as in many countries, fire management agencies attempt to detect and suppress all fires as quickly as possible, since their overall effectiveness diminishes as a fire grows in size. Even so, large amounts of money and effort are expended in attempting to suppress large fires, usually with limited success. Fire management agencies need information that will justify limiting suppression activities for large fires, except when major values-at-risk must be protected. Such information could be used in long-term strategic analyses to assist in rationalizing response tactics on a regional basis (including the definition of "modified" suppression zones). Research requirements to address this issue include the following:

- Create models to evaluate the cost-effectiveness of tactics for suppression of large fires, including the rates at which effective firelines can be established and the use of indirect suppression tactics, such as burning-out operations.
- Evaluate fire behaviour, resource application, and rates of success and failure using case studies of large fires that have occurred across Canada.
- Evaluate the longer-term effects of fire suppression on fuel connectivity, on a resulting shift to older age-class distributions, and on forest health and management in general.

### Biophysical Aspects of Hazard Mitigation around Communities

The 2003 fire season caused extensive housing and infrastructure damage in many communities in British Columbia. Although this was not the first time that values at the wildland–urban interface (WUI) had been lost due to wildfires, it was by far the most extensive loss to date in Canada and attracted considerable attention, primarily because of the value of the homes and property destroyed in highly populated areas. However, fires have been threatening communities in northern Canada for many years. Although these incidents attract little public notice, evacuations of some northern communities, for both public safety and health reasons (related to smoke hazards), occur annually. In western and central Canada (from British Columbia to Quebec) more than 200 communities have been evacuated over the past 25 years. To date, very little research has been conducted to address the threat to communities and ways to mitigate that threat, but such research is urgently required to justify proposed fuels modification programs and possible suppression alternatives (e.g., using resources to directly protect values in communities rather than fighting fires in the forest). Research requirements to address this issue include the following:

- Define what constitutes the WUI in Canada and develop a reliable database on the extent and vulnerability of communities in forested areas, including smaller northern communities.
- Determine (using models and case studies) how fire in the WUI enters communities and burns within them.
- Evaluate the physical effectiveness of fuels modification programs (e.g., thinning, pruning, clearing of fireguards) in halting fire spread or reducing fire intensity to a manageable level. This will require modelling to develop first approximations, followed by a scientifically sound and replicated experimental burning program.

### Social Aspects of Hazard Mitigation around Communities

As human communities expand further into the WUI, the traditional response from fire management agencies has been to stress an engineering solution, which may involve creating defensible space (e.g., modifying fuels, clearing fireguards) or directly protecting property (e.g., installing sprinkler systems, using fire-resistant building materials). This approach ignores the psychological, social, cultural, and political factors that influence the willingness of people (both individual homeowners and communities as a whole) to support and engage in risk-reduction activities,

but these factors must be considered if proactive management in the WUI is to be successful. Very little is known about the perceptions of Canadian property owners and communities with respect to the threat of wildfire, their preferences for mitigation measures, or their willingness to use mitigation and preparedness measures. There is also little understanding of the individual and sociocultural factors that influence such responses or the role of municipal governments and other relevant agencies in influencing responses at the individual and community levels. Although often overlooked when discussing WUI issues, aboriginal communities in Canada frequently experience the impacts of wildfire and may require unique approaches to mitigation. Research requirements to address the social aspects of hazard mitigation include the following:

- Define, identify, and map the WUI in Canada, and identify the societal trends and changes that influence the growth of the WUI, so that the future magnitude of the WUI can be estimated.
- Map current and future wildfire threat in Canada, so that areas and communities can be prioritized in terms of risk.
- Test social science models and processes developed elsewhere (e.g., the United States and Australia) with respect to their applicability in Canada.
- Conduct case studies on recent, current, and future wildfires that threaten the WUI and its communities to identify perceptions of risk, awareness of and engagement in mitigation and preparedness activities, and obstacles to and incentives for undertaking mitigation. The attitudes, perceptions, and beliefs of homeowners and communities about wildfire, fire management, and mitigation, particularly in terms of perceived responsibilities, should also be assessed.
- Investigate approaches, models, and processes to reduce risk in aboriginal communities that incorporate the role of traditional knowledge related to fire and resource use and the subsistence use of forests.

## Climate Change

After many years of uncertainty, Canadian governments and the public at large generally agree that climate change is a growing reality and that impacts on the natural resource base in this country will be enormous. Over the past 15 years, Canadian scientists have been at the forefront of efforts to project climate change impacts so that useful adaptation strategies can be developed for this country. During this period, fire scientists have been increasing their efforts to project the impacts of climate change on future forest fire regimes in this country, and the results indicate that future fire problems will go well beyond the current capacity of fire management. These include increases in fire weather severity and fire danger across larger regions of the country, coupled with projected increases in fire occurrence (particularly lightning-caused fires) and severity, and substantial increases in area burned. In addition to direct economic impacts on the Canadian forest industry and forest-dependent communities, these changes would result in a net loss of terrestrial carbon to the atmosphere, with significant implications for the carbon budget. Research requirements to address this issue include the following:

- Investigate the major drivers of large fire activity in Canada (e.g., Pacific sea surface temperatures, tropospheric ridging) to determine if they are predictable and if they can be used in seasonal forecasting. Also determine how these major drivers and their influences are likely to be altered by a changing climate.
- Model the impact that climate change will have on the ability of Canadian fire management agencies to manage fire. This will include modelling fire occurrence and behaviour to determine whether the fire suppression threshold will be exceeded more often, which would result in more escaped fires and larger areas burned. The most current climate models, as they are developed and improved, should be used in these analyses.
- Model the impact that increased fire severity and the drying of peatlands will have on terrestrial carbon loss from Canadian forests and the potential implications for the Kyoto Protocol and subsequent climate change treaties.

## Conclusions

This background paper has briefly summarized the historical role of federal fire research programs in developing research products to support the various jurisdictions responsible for fire management across Canada. Over the past eight decades, through many organizational changes and fluctuations in resource strength, the fire research program of Canada's federal forest service has produced numerous innovative products of practical value to fire and forest management in Canada and abroad. Fire research in Canada has largely followed the empirical method, primarily through extensive field observation and measurement programs, although theory has been linked with field results where possible. Successive generations of researchers have expanded and built upon the progress of their predecessors as new information and technologies have become available, which has led to a strong sense of continuity. There has always been a large degree of cohesion and collaboration within the Canadian fire research community, despite the variety in disciplines and locations. This approach, combined with a close working relationship with operational fire managers across Canada, has been fundamental to the success of the program.

However, the past two decades have seen a steady decline in forest fire research capacity within the CFS. This decline has accelerated in recent years because of government-wide cutbacks in internal science and technology funding, to the point where the capacity to address major research requirements may not exist. The decline has been partially offset by a growth in research capacity within fire management agencies and universities, but the latter has not been sufficient to meet current or future needs. Fire research scientists in Canada continue to address issues as they arise but are increasingly forced to seek alternative funding sources, often through the development of multidisciplinary proposals that may deal with fire as only part of a larger national or international issue (e.g., climate change, carbon budgets, atmospheric chemistry).

The reduction in fire research capacity is occurring at a time when Canadian wildlands are increasingly vulnerable to wildland fire. This background paper has identified five major areas where additional research is urgently required if Canada is to deal effectively with these emerging vulnerabilities. The list presented here is not exhaustive, and other research efforts are needed to address the whole spectrum of fire management activities in Canada. However, it should be clear to even the most casual observer that enhancement of fire research capacity is essential if new and innovative approaches are to be generated.

The CWFS presents an opportunity to revitalize the fire science and technology program in this country, through a shared commitment among all levels of government. This will require an influx of funding and research capacity, but also the vision to establish research priorities. Perhaps a joint funding program could be created, with contributions from federal, provincial, territorial, and municipal governments. Such a funding program would present the opportunity to refocus and expand fire research in Canada. Beyond the initial perspectives that have been presented in this paper, a logical next step would be to consult with CFS fire scientists, science and technology experts from all Canadian fire management agencies, and academic institutions conducting research in subject areas relevant to the CWFS (e.g., fire management systems, fire ecology, social sciences) to determine how science can contribute to achieving the goals of the CWFS and what form a new a research program might take and to set priorities among the fire research issues to be addressed. This consultation process will begin soon, and the results will be synthesized in a future document that will serve, in part, as a basis for the science and innovation program within the CWFS. The evolution of a Canadian fire management program that adequately anticipates and addresses emerging needs is strongly dependent on a revitalized and effective program of scientific and technological innovation.

Stocks, B.J.; Wotton, B.M. 2006. The history of forest fire science and technology in Canada and emerging issues relevant to the Canadian Wildland Fire Strategy. Pages 89-95 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.

# Firewise: a Canadian Perspective

**P. Bothwell**[1]

## Introduction

To understand how the American Firewise program functions, it is necessary to piece together some background on the nature of the wildfire business in the United States. My relatively brief analysis of the Firewise program led immediately to some general conclusions. First, the Firewise program has undergone extensive development and, despite common perception, is directly linked to and strongly dependent on the United States National Fire Plan (NFP). Second, the nature of the wildland–urban interface (WUI) in the United States is fundamentally different from that in Canada, particularly from the perspective of land management and administration. Finally, the purpose of Firewise is similar to that of Canadian organizations such as Alberta's Partners in Protection, except it is much more ambitious. This final point is particularly interesting given that both Firewise and Partners in Protection have been exceptionally successful but for quite different reasons. Their success may indicate that both programs have merits that should be carefully considered in the event that a national WUI program is established in Canada.

## Firewise: a Brief History

The roots of the Firewise program were established after the 1985 fire season, when more than 1 400 homes were lost in California and Florida (National Wildland/Urban Interface Fire Program 2003). The National Fire Protection Association (NFPA) and the US Department of Agriculture Forest Service (USFS) hosted a conference in 1986 that brought together many of the WUI stakeholders in Quincy, Massachusetts. After the conference, participants signed an agreement that led to the National Wildland–Urban Interface Fire Protection Initiative. The initiative focused mainly on delivering information through conferences, workshops, publications, and other media to educate stakeholders and the general public and to increase firefighter safety. The initiative quickly grew to develop programs and tools for specific "disciplines" operating in the WUI, including architects, landscapers, and builders.

Following several other dramatic fire years (Table 1), the initiative gained momentum and evolved to become the National Wildland/Urban Interface Fire Program. A formal working team called the National Wildfire Coordinating Group (NWCG) was given the responsibility of administering the program. The NWCG is composed of the USFS, the National Association of State Foresters, the NFPA, the Department of the Interior and its land management agencies (including the Bureau of Land Management, the National Park Service, the Bureau of Indian Affairs, and the US Fish and Wildlife Service), the US Fire Administration, the National Emergency Management Association, the National Association of State Fire Marshals, and the International Association of Fire Chiefs. These agencies led the development of an educational website for the dissemination of WUI information. This website is one of the key pieces of today's Firewise program.

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**Table 1. Insurance industry payouts associated with severe fire years in the wildland–urban interface in the United States[a]**

| Year | Location | Total insurance claims (US$, millions) |
|---|---|---|
| 1980 | Southern California | 111 |
| 1982 | Southern California | 26 |
| 1985 | Florida | 50 |
| 1990 | Southern California | 327 |
| 1991 | Northern California | 1 997 |
| 1993 | Southern California | 794 |

[a]Adapted from National Wildland/Urban Interface Fire Program (n.d.) *Firewise Communities* DVD, Disc 1.

## Firewise Today

The Firewise program has gained significant momentum throughout the United States, particularly since 2000, when the NFP was introduced. Firewise is still administered by the NWCG, but its member agencies appear to be limited to the USFS, the Department of the Interior (the Bureau of Land Management, the National Park Service, the Bureau of Indian Affairs, and the US Fish and Wildlife Service), the National Association of State Foresters, and the NFPA. These agencies form the network that allows Firewise activities to be promoted, administered, and delivered on federal lands, state lands, and private property. Such comprehensive coverage is, of course, vital to the success of the program (in the United States, about 30% of land is under federal jurisdiction, about 10% is under state jurisdiction, and about 60% is privately owned).

What exactly is Firewise? Firewise is a program through which the NWCG strives to communicate, both to the public and to key stakeholders, ways to make homes, communities, and firefighters safer from wildfire. Toward this end, the NWCG has started two key activities:

- Educational tools: From its inception, the Firewise program has developed educational tools and materials. The main vehicle for education is through the Firewise website (www.Firewise.org). The vast majority of Firewise videos, books, pamphlets, and other educational materials are free and can be ordered directly from the website. The material available ranges from advice on assessment and mitigation of homes and landscaping to firefighter cross-training and safety materials. The website offers access to hard copies and videos as well as on-line and interactive materials. All materials promoted through the Firewise program have been approved by the NWCG.
- Firewise Communities program: The Firewise Communities program was started in 2000 as a method of communicating Firewise concepts to the public. Federal and state employees put on workshops to make susceptible communities aware of the risks and dangers associated with the WUI. The Firewise Communities program quickly evolved to become a community recognition program and provided significant funding opportunities through the establishment of the NFP. Today, approximately 40 communities throughout the United States are recognized as Firewise communities.

## The Keys to Success

Firewise has been successful in raising awareness and improving preparedness in the communities where it has been implemented. The primary strength of the program has been its delivery effectiveness. Whereas Alberta's Partners in Protection (1999) has prepared a comprehensive manual entitled *FireSmart: Protecting Your Community from Wildfire*, the Firewise program has developed a variety of tools, but they are not all available in one place. This is probably not a disadvantage, since many diverse stakeholders are involved in WUI management and mitigation. For example, a homeowner does not need to learn about firefighter training or city planning but does need to learn about hazard assessment and strategies for mitigating home flammability. This is not to say that the comprehensive guide of Partners in Protection is not valuable, only that it includes more information than many people require and is therefore somewhat inefficient and potentially less cost-effective.

The Firewise program excels at the development of technologically advanced educational and planning products. The public, technicians, and professionals have free access to hundreds of tools in many different formats. Educational materials and information are available on-line, as video (VHS and in some cases DVD), on CD-ROM, or in print, and often in more than one language (English and Spanish). This variety of formats could easily be overlooked but is very important. For example, school educators are constantly looking for educational materials that combine skill sets, and the Firewise materials meet this criterion. Using some of the on-line tools, a teacher can educate students about Firewise concepts while teaching computer skills. This can be an invaluable combination that likely results in the material being used by a larger proportion of the population. Examples of successful public education campaigns focused on school-aged children are numerous (e.g., Smokey Bear [Dods 2002]).

The Firewise Communities program has proven instrumental in putting mitigation strategies into practice throughout the United States. The strength of the program is the community recognition element, whereby a community is acknowledged and advertised as being a Firewise community. This recognition provides a benefit not only to the community, but also to the Firewise program through advertisement and through visibility of products and activities. The process for becoming a Firewise community, outlined below, is simple and can be achieved with relative ease (see also http://www.firewise.org/usa/):

1. The community contacts the Firewise program.
2. The community organizes a site visit from Firewise officials and local fire department officials.
3. The community establishes a formal Firewise Board composed of local stakeholders and interested parties.
4. A WUI expert performs an assessment of the area of interest.
5. The Firewise Board develops a Firewise plan and implementation strategy.
6. Once the community meets the basic criteria for Firewise planning and implementation, it can apply for status as a Firewise community and the associated community recognition benefits.

What are the incentives for a community to seek recognition as a Firewise community? In addition to recognition as a Firewise community and the associated advertisement of the community's efforts, participation in the Firewise program allows direct access to government funding, primarily through the NFP. This funding can be significant and provides an effective means of completing work that many private landowners and community associations could not otherwise afford.

## The National Fire Plan

The Firewise program is separate from the NFP, but its success is strongly attributable to the NFP in many ways. Firewise existed long before the NFP was initiated in August 2000. The NFP was developed after the tragic fire season of 2000, and it has provided a new framework and tremendous financial support for responding to wildfires and their impacts on communities, while ensuring that future wildfire damage is minimized. The NFP was developed and is funded by the federal government and is implemented by federal agencies (specifically the US Department of Agriculture Forest Service and the Department of the Interior). The NFP focuses on five key points (see http://www.fireplan.gov/):

- Firefighting: The NFP has provided funding to increase federal suppression resources, including staff and capital. In addition, an aggressive training program is being funded and administered.
- Rehabilitation: The NFP has provided significant funding for rehabilitation and restoration of areas affected by recent severe wildfires. These efforts are focused on reforestation, habitat restoration, control of invasive species, and establishment of desired vegetation.
- Reduction of hazardous fuels: The NFP has significant funding available for long-term fuel reduction and maintenance for the purpose of reducing the risks to people, communities, and natural resources that are associated with wildfire. Particular attention is focused on the WUI. Fuel reduction is achieved through prescribed fire, thinning, application of herbicide, and grazing.

- Community assistance: The NFP provides monetary resources to local and volunteer fire departments, community education programs, and community projects for fire protection planning.
- Accountability: The NFP provides a vehicle, the Wildland Fire Leadership Council, to oversee, coordinate, and monitor all activities, programs, and expenditures associated with the NFP.

Clearly, the NFP was established to meet many of the goals and objectives that the Firewise program is also trying to achieve. The two programs are complementary, the NFP providing the financial means to achieve these goals and objectives and the Firewise program providing the framework and administration. In the end, the success of both programs depends at least in part on their coexistence. Firewise gives the public and established Firewise communities much easier access to federal funding available through the NFP. Conversely, the NFP supplies this funding and thereby makes the Firewise Communities program much more attractive and achievable.

NFP funding is available to Firewise communities primarily for reduction of hazardous fuels and community assistance, as outlined above. Access to this funding, especially for community assistance, is initiated once the community involves Firewise officials in their proposal to attain "Firewise communities" status. Federal agencies and associations administer the Firewise program, and the Firewise officials (usually state foresters) oversee access to NFP funding and help ensure that the money delivers results at the community level, thus leading to effective mitigation efforts in the WUI.

## National Fire Plan Achievements

The NFP reported the following achievements associated with the WUI during the 2002 fiscal year (US Department of Agriculture, US Department of the Interior 2003; all funding reported in US dollars).

- Treated 2.26 million acres (about 915 000 hectares) of federal land and adjacent lands for reduction of hazardous fuels including:
  - 385 000 acres (about 156 000 hectares) treated mechanically
  - 1.78 million acres (about 721 000 hectares) treated with prescribed burns
  - 973 687 acres (about 394 000 hectares) treated in the WUI
- Passed the Healthy Forests Initiative, with the goals of streamlining environmental assessment processes and improving regulatory processes to reduce decision times and "hold-ups" associated with treating hazardous fuels.
- Provided $51 million of community assistance through the State Fire Assistance Program, matched by recipients dollar for dollar.
  - Funded 11 400 education and mitigation campaigns
  - Funded 400 community plans
  - Funded 2 686 hazard mitigation projects
  - Trained 13 000 firefighters
- Funded 19 national-level workshops and approximately 60 state and local workshops over 2 years through the Firewise Communities program.
  - National-level workshops attended by over 1 800 people from more than 600 communities
  - State and local workshops attended by over 4 500 people from more than 1 000 communities
  - Recognition of 11 communities as Firewise communities
- Provided $80 million of community assistance through the Rural Fire Assistance Program, matched by recipients at a rate of 10%. This funding was spread over 1 568 fire departments.
- Provided $10.4 million of community assistance through the Volunteer Fire Assistance Program, matched by recipients dollar for dollar.
  - Funding spread over 3 781 volunteer fire departments serving 5 900 communities
  - Funding used for organizing, training, and equipping volunteer fire departments
  - Trained 16 830 volunteer fire fighters and purchased $2.7 million worth of personal protective equipment

## Conclusions

The US Firewise program has made substantial operational progress at the community level over the past few years. This success is directly attributable to the significant funding that has been made available for these initiatives through the NFP. Although not all of the funding associated with the NFP goes directly to WUI mitigation and solutions, a significant proportion does. What is particularly interesting is the fact that the Firewise program and the NFP are two separate federal initiatives that use one another to greatly increase the overall efficiency of each individual program. In other words, neither the Firewise program nor the NFP would be nearly as effective as it is without the other.

Alberta's Partners in Protection has also been effective, but without significant funding. Firewise and Partners in Protection are attempting to achieve similar results, but their approaches are quite different. One could argue that the success of Partners in Protection is based on one comprehensive resource (FireSmart) that has proven to be an invaluable education tool. Partners in Protection attempts to convince public officials, industry representatives, and the general public to make a difference in their respective communities and to undertake the initiative themselves. In contrast, the Firewise strategy seems to involve linking interested parties to the dollars needed for large-scale work with relatively low level of interest among communities. It seems that both strategies are working well in their respective contexts.

Nonetheless, it could be argued that Partners in Protection is reaching the limits of its effectiveness, given the level of funding this program currently receives. Many Canadian provinces have hesitated to develop a formal strategy for dealing with the WUI, and the Canadian federal government seems uncertain of its role. The federal government in the United States has taken the opposite approach and has indicated its commitment to WUI issues through allocation of significant funding. This federal position is not limited to federal lands, but instead provides a strong incentive (funding) for other stakeholders to develop strategies as well.

Canada has a larger forest resource than the United States, a greater annual area burned, and a much smaller yet more geographically dispersed population. As a result, management of the WUI in Canada will likely have to continue with less funding than is available in the United States, despite the existence of similar risks. The many reasons for this difference in levels of funding include differences in resource management jurisdiction, fuel types, fire behaviour, and economic constraints. Given limited resources, it is absolutely vital that a unique, efficient, and effective national WUI strategy be developed and implemented for Canada.

## Literature Cited

Dods, R.R. 2002. The death of Smokey Bear: the ecodisaster myth and forest management practices in prehistoric North America. World Archaeol. 33:475–487.

National Wildland/Urban Interface Fire Program. n.d. Firewise communities: making sensible choices in the wildland/urban interface. Natl. Wildland/Urban Interface Program. Quincy, MA. DVD: Disc 1 & 2.

National Wildland/Urban Interface Fire Program. 2003. Firewise communities workshop participant workbook: making sensible choices in the wildland/urban interface. 2nd ed. Firewise Communities, Quincy, MA. 30 pp.

US Department of Agriculture and US Department of the Interior. 2003. National Fire Plan: FY 2002 performance report [on-line]. <http://www.fireplan.gov/resources/NationalFirePlan2002Reports.htm>

Partners in Protection. 2003. FireSmart – protecting your community from wildfire. Second edition. 164 pp.

Bothwell, P. 2006. Firewise: a Canadian perspective. Pages 97–101 *in* K.G. Hirsch and P. Fuglem, Technical Coordinators. Canadian Wildland Fire Strategy: background syntheses, analyses, and perspectives. Can. Counc. For. Minist., Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, AB.