FIRE RISK MANAGEMENT GUIDE

PROTECTING CULTURAL
AND NATURAL HERITAGE FROM FIRE

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SHORT SUMMARY

The world's cultural and natural heritage holds untapped potential for fire disaster risk reduction

Today, heritage sites face significant threats from human-induced and natural fire hazards. Climate change has only intensified these risks, causing devastating losses of both World Heritage sites and living heritage as well as widespread environmental damage, leaving communities with long-lasting impacts.

Yet, heritage in all its forms – cultural and natural, tangible and intangible alike – also plays a crucial role in disaster risk reduction and resilience. Traditional ecological knowledge, skills, and practices of bearers and guardians can contribute to the preservation and restoration of the ecosystems and help mitigate fire risks.

Wildfires caused nearly
40%
of global forest loss annually
from 2003 to 2018

An innovative and holistic approach to fire risk management is more pertinent than ever. The emerging standards integrate prevention, mitigation, response and recovery with a strong focus on disaster preparedness and monitoring. As we enter an era where the unexpected is expected, policymakers, site managers and emergency responders must be empowered to tailor mitigation efforts to the unique needs and contexts of diverse heritage sites, harnessing the power of indigenous and local knowledge.

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MANAGEMENT GUIDE

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ACRONYMS

DIG	Disaster Imagination Game
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
ERT	Emergency Response Team
FRMP	Fire Risk Management Plan
GFDRR	Global Facility for Disaster Reduction and Recovery
HVAC	Heating, Ventilation and Air Conditioning
ICCROM	International Centre for the Study of the Preservation and Restoration of Cultural Property
ICOMOS	International Council on Monuments and Sites
OUV	Outstanding Universal Value
PPE	Personal Protective Equipment
R-DMUCH	Institute of Disaster Mitigation for Urban Cultural Heritage (Ritsumeikan University)
UNDRR	United Nations Office for Disaster Risk Reduction
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHC	World Heritage Centre

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PREFACE

How can this guide help manage fire risks?

Globally, cultural and natural heritage[1] are increasingly affected by fires – a situation further exacerbated by climate change. From the Notre Dame Cathedral in Paris to the National Museum of Brazil in Rio de Janeiro, from the Rapa Nui National Park in Chile to the Tombs of the Buganda Kings at Kasubi in Uganda, the negative impacts of fires on local communities, the loss of tangible and intangible heritage, as well as extensive adverse environmental effects – including on vegetation, wildlife, water resources, air quality and biodiversity – are often long-lasting and sometimes permanent. The lack of consistent monitoring, planning and preparedness, coupled with the loss and limited integration of traditional knowledge and practices into fire risk management policies, as well as the limited engagement of local communities, also pose considerable challenges to the management of fire risks for cultural and natural heritage.

Since its inception, UNESCO has been on the frontline of actions to support communities in safeguarding cultural and natural heritage, including in situations of disasters and conflicts. As part of the Organization's efforts to respond to the growing threats and adverse impacts of fire on cultural and natural heritage, UNESCO developed this **Fire Risk Management Guide** to strengthen the capacities of relevant stakeholders in managing fire risks for cultural and natural heritage, but also in leveraging cultural heritage – including living heritage and traditional knowledge – to mitigate fire risks and enhance disaster resilience.

The Guide focuses on presenting the principles, methodology and process to prevent damaging fires and reduce fire-related risks at cultural and natural heritage sites. This Guide does not attempt to be fully comprehensive or exhaustive in identifying all risk reduction measures that may be available given the significant variety and uniqueness of each heritage site – including local, traditional knowledge and community engagement, as well as local emergency response and recovery capabilities and resources. Instead, it provides a helpful framework and examples that can be adapted to different contexts to support stakeholder development of risk-informed, tailored and effective **Fire Risk Management Plans (FRMPs)**.

Who is the target audience?

Primarily, the Guide targets site managers as well as management teams and organizations responsible for the oversight and management of cultural and natural heritage. It will also be useful for other stakeholders – including communities, conservators, government entities, archivists, architects, engineers, emergency responders, contractors and policymakers – to understand the principles, process, challenges and measures available to assist in protecting heritage.

1 This Guide follows the definition of cultural and natural heritage of the UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage, the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, as well as other UNESCO Culture Conventions and instruments. These definitions are included in the Glossary herein. This Guide additionally uses the term 'heritage sites and structures' which includes buildings, structures, ensembles and natural sites that are culturally or historically significant, including those that have Outstanding Universal Value, to a community.

How was this guide developed?

The Guide was developed through detailed research and input from experts in fire and life safety, fire engineering, disaster risk management (DRM), heritage sites and structures, and traditional knowledge and addresses the following questions.

- Why are heritage sites and structures so vulnerable to fires?
- What common themes recur in how these fires start, develop and cause damage, losses and casualties?
- What findings from research into past fires at heritage sites and structures can be applied to address fire risks?
- What process[2] should be followed to develop an Fire Risk Management Plan (FRMP) that more effectively addresses fire hazards and reduces damage, losses and casualties for heritage sites and structures?

Based on the above, the Guide provides an overview of the various types of fires and findings related to why heritage sites and structures are at such risk of fire. Part 1 then provides an overview of developing FRMPs for both heritage sites and structures as the approach is the same. Parts 2 and 3 provide details on applying this approach to reduce risks related to potential structure fires, including during the vulnerable period of restoration/renovation and construction-related work. Part 4 highlights important considerations when applying this approach to reduce wildfire risks. Note in going through this Guide, the concepts are similar for reducing risks related to structure fires and wildfires (e.g., reduce ignition sources, limit combustible materials and provide early detection, notification of occupants and emergency responders) but their implementation may differ. Since the development, implementation, monitoring and updating processes of these plans are similar, they are highlighted together in Part 5.

2 Regarding which process to follow, as with any discipline, risk management, fire protection and fire and life safety rely on first principles and fundamental concepts, including those related to prevention, mitigation, response and recovery from fire. These principles underlie this Guide and have been widely prescribed on a global level, including in various international risk management and fire engineering guides (ISO, 2018; Society of Fire Protection Engineers [SFPE], 2007; Standards Australia, 2009); building codes (International Code Council [ICC], 2024; ICC, 2021; National Fire Protection Association [NFPA], 2021c); standards (Australian Building Codes Board [ABCB], 2005; BSI, 2019; NFPA, 2021b; NFPA, 2021c); fire engineering handbooks (Hurley et al., 2016; NFPA 2023); wildfire codes and guides (CalFire, 2014; New South Wales [NSW], 2019; Victoria State Government [VSG], 2022); and by stakeholders who oversee natural and cultural heritage sites (Baril, 1998; Kidd, 2010; Historic England, 2017; Historic Scotland, 2005; McClean, 2012). These works and many others address the unique needs and challenges of protecting historic sites and structures from fire. The reader is urged to consult applicable citations for further insight as needed.

INTRODUCTION

What can be learned from past fires?

To effectively protect our cultural heritage sites and structures from fire, it is crucial to first understand the various types of fires. Some fires are beneficial and necessary, while others pose significant risks. Additionally, by studying past fire incidents at these sites, we can gain valuable insights that inform the development of comprehensive Fire Risk Management Plans, ultimately enhancing future protection efforts. This overview lays the foundation for the rest of the Guide.

What are fires?

As this Guide pertains to creating awareness and managing fire-related risks, it is vital to differentiate the three broad categories of fires, namely controlled fires, structure fires, and wildfires.

Controlled Fires

Controlled fires refer to those that are intentionally ignited and carefully managed for various beneficial purposes while minimizing the risk of uncontrolled spread or damage. Controlled fires may also be referred to by other names, including planned, cultural, managed, intentional, contained, or purposeful fires, among others. These fires are an integral and beneficial part of our daily lives, serving a variety of functions such as the following:

- religious and spiritual ceremonies (candles, butter lamps, rituals, cremations)
- cooking and purification of food, water, medicine (stoves, barbecues, grills, open fires)
- generating heat (fireplaces, fire pits, heaters)
- providing light (torches, lanterns, candles)
- artistic and crafting endeavours (firing pottery, blacksmithing, metal casting, glass blowing)
- celebrations (sky lanterns, fireworks, fire breathing)
- landscape modification and agricultural practices (clearing vegetation/debris, controlled burns)
- signalling and communication
- protection and safety (deterring predators, mosquito control, cauterizing wounds)
- transportation (internal combustion engines in vehicles, rockets)
- industrial processes (smelting, forging, heat treating, incineration of waste)
- construction activities (blowtorches, roofing, cutting, welding).

While controlled fires serve numerous valuable purposes, they need to be managed carefully to prevent them from becoming unintentional ignition sources for structure fires and wildfires.

Structure Fires

Structure fires refer to uncontrolled and undesired fires involving human-made structures, including buildings, monuments, vehicles, ships, shelters, aircraft, spacecraft, tunnels, mines, and other human-built environments (National Fire Protection Association [NFPA], 2021).These fires typically involve the burning of not only the contents within the structure, but also the interior finishes, construction elements, and facades if they are combustible materials. Structure fires can originate within a single structure and can rapidly spread to adjacent structures, further increasing the risk and potential for widespread damage and losses.

Wildfires

A wildfire is an uncontrolled fire involving trees, grass and other vegetation (Fitzgerald-McGowan, 2024; National Wildfire Coordinating Group [NWCG], 2006; Northwest Fire Science Consortium [NFSC], 2019). While 'wildfire' is often the more widely used term, various regional and vegetation-specific terms are also used, including:

- bushfire – fires that burn through wild vegetation like woodland, scrubland, grassland or savannahs
- forest fire – often involves coniferous forests or heavily wooded areas
- brush fire – generally refers to fires involving smaller vegetation, such as shrubs and undergrowth
- grass fire and veld fire – fires involving lighter fuels, including savannas, prairies, and grasslands
- peat and heath fire – fires occurring in low-lying vegetation, such as peatlands or heathlands.

To help understand and characterize the behaviour and spread of wildfires, different terms are used to describe which part of the vegetation is burning:

- ground fires – burn and smoulder underground in the duff layer, which consists of dead vegetation, leaves, needles, twigs, and other organic matter and are often challenging to detect and extinguish
- surface fires – burn small trees, shrubs, lichen, moss, and other small vegetation and debris along the forest floor and typically move slowly and with low-intensity flames
- crown fires – involve burning of the forest canopy, including foliage, branches, and moss/lichen on treetops and can spread rapidly, aided by wind, and often jump across treetops
- spotting fires – occur when firebrands, embers, or sparks are carried by the wind, igniting new spot fires beyond the main fire area and causing the fire to spread rapidly
- wildland/urban interface fires – fires in areas where human-made structures and wildlands meet, posing a significant risk to both natural and built environments.

The potential for fires to develop and transition from one category to another underscores the importance of developing a comprehensive understanding of the different categories of fires, their interrelationships, the potential for rapid development and spread and the need to develop tailored, risk-informed fire prevention, mitigation, preparedness and emergency response measures to address these factors comprehensively and effectively.

Why are heritage sites and structures vulnerable to fires?

Cultural and natural heritage sites are often faced with numerous challenges that increase their vulnerability to fires and associated damage. Findings from past fires (Antoniou, 2012; Kidd, 2006; Laurila, 2004; Maxwell, 2007; NFPA 2021b; NFPA 2021c) help to highlight some of the primary vulnerabilities and risks contributing to the occurrence and extent of fires and the related damage and impacts due to these vulnerabilities, as summarized in Table 1.

Table 1. **Fire risk factors, vulnerabilities and implications to cultural and natural heritage**

Fire Risk Factor	Cultural Heritage/Structural Vulnerabilities	Natural Heritage Vulnerabilities	Implications
Lack of FRMP	Limited Fire Risk Assessments and measures in place related to risk reduction, emergency preparedness, evacuation, emergency response and resilient recovery.	Limited Fire Risk Assessments and measures in place related to risk reduction, emergency preparedness, evacuation, emergency response and resilient recovery, including addressing longer-term ecological impacts.	Significant potential damage to structures, contents, sites as well as ecological impacts given limited short- and long-term risk reduction and planning measures in place.
Ignition sources	Numerous ignition sources present, including: • electrical and lighting systems (permanent, temporary) • open flames, candles, incense • smoking, matches, lighters • cooking, hot surfaces • fireplaces, chimneys • appliances (space heaters, furnaces, boilers) • hot works, restoration/construction work • external (lightning, wildfires, adjacent structures, etc.) • intentional (arson, conflict, civil unrest) • other hazards (e.g., earthquakes, explosions).	Numerous ignition sources present including: • utilities (e.g., electrical power lines, lighting, transformers, generators, solar/ wind farms) • open flames (campfires, cooking, grills, outdoor fireplaces, fire pits) • smoking, matches • fireworks, flaming sky lanterns, torches • vehicles (sparks/hot engines from cars, farm equipment, trains) • open burning of fields/vegetation/trees, escaped controlled burns • adjacent sites, structures • natural (e.g., lightning, earthquakes, volcanoes).	Significant types and quantities of ignition sources both inside and outside including intentionally set fires, as well as fires from other events, which may introduce larger ignition sources, and/or ignition in multiple locations.
Combustible materials	Significant quantities of combustible materials exist, including construction, interior finishes, combustible contents – furnishings, archives and storage.	Significant quantities of combustible materials exist, including both living and dead vegetation. Additionally, impacts of climate change including increased droughts, higher temperatures, high winds downing electrical lines and so forth all increase the probability of ignition. Also, several plant species have evolved that promote fire through flammable foliage.	Fast-spreading, longer-lasting fires are created by the presence of significant quantities of combustible materials.
Lack of compartmentation/ fire separations	Fire separations are absent on floors, between floors, within voids and between abutting/adjacent buildings.	Limited fire breaks exist to contain the fire and keep it from spreading further.	Fire, heat and smoke can readily spread on a floor, between floors, in hidden voids, throughout the entire structure, and to/from adjacent structures unimpeded, as well as across natural sites.
Lack of fire detection	Fire detection systems are often not present. If there is a detection system: • smoke detectors are typically not located throughout or outside the structure • systems are often non-operational • no automatic notification of occupants and others.	Fire detection systems are often not present (watchtowers, aerial observations, detection systems, satellite monitoring, etc.).	Significant delays occur in detecting a fire and alerting occupants and emergency responders. For every minute of delay, fire continues to grow and spread exponentially.
Lack of automatic notification of emergency responders	Few detection systems automatically notify emergency responders of a fire and the need to respond.	If present, few systems automatically notify emergency responders of a fire and the need to respond. Fires may start in remote areas at some distance from structures or in adjacent non-managed areas.	Significant delays in notification to emergency responders both on/off site.
Lack of automatic suppression systems	• Systems are typically not provided to automatically suppress fire. • When provided, systems at times are non-operational (e.g., shut valves, not maintained, etc.) • Numerous unfounded misconceptions exist and adversely impact stakeholders' decisions to use such systems.	Automatic systems typically do not exist.	Fires will grow and spread, often beyond the capabilities and resources of emergency responders, and eventually involve significant portions of the structure/site.
Lack of manual suppression systems (e.g., fire extinguishers, standpipes, buckets, etc.)	• Lack of manual systems to assist occupants and emergency responders in early stages of fire suppression operations. • Limited detection and alerting of occupants hinder the initiation of manual suppression while the fire is still small.	• Lack of provision to assist personnel on site and emergency responders in the early stages of fire suppression operations. • Limited detection and alerting of people hinder initiation of manual suppression while the fire is still small.	Small fires that could be extinguished are allowed to grow beyond the capacity of first responders and spread quickly.

Fire Risk Factor	Cultural Heritage/Structural Vulnerabilities	Natural Heritage Vulnerabilities	Implications
Lack of protection of structure/ infrastructure	Structural elements (beams, columns, floors, roofs, facades, steeples, domes, etc.) have a limited fire rating.	Limited protection of: • infrastructure (i.e., pump houses, water storage facilities, roads/trails, etc.) • structures on natural sites.	Premature collapse of structures (floors, roof, facades, domes, steeples, etc.) Inadequate resources available. Wildland fire spread to structures.
Limited incorporation of traditional knowledge, including fire prevention system (prescribed burnings, cultural fire practices and uses, etc.)	No/limited engagement of traditional or indigenous knowledge, including means, methods and materials in development of FRMPs for cultural sites. For example, the construction materials and infrastructure of buildings are not fireproof nor sufficiently resistant to fire to prevent the advance of fire. Constructions or monuments at the rural/urban interface can also benefit from prescribed burns that reduce combustible material in the natural surrounding areas.	No/limited engagement of traditional or indigenous knowledge, including means, methods and materials in development of FRMPs to address wildfires. For example, prescribed burns and mosaic patch burnings (used ancestrally by indigenous peoples to prevent the advance of wildfires and dangerous fires) are only used locally and have not been extended to fire risk reduction policies on a widespread scale.	Inability to understand/incorporate traditional, proven hazard forecasting and identification techniques, vulnerability reduction methods, environmental governance frameworks, and cultural resilience knowledge.
Limited engagement with local communities	No/limited engagement of local communities in development of FRMPs for cultural sites.	No/limited engagement of local communities in development of FRMPs to limit wildfires at natural sites.	Inability to understand and incorporate community-centred strengths including social fabrics, trusted leadership, geographical knowledge, cultural retention, impacting long-term effectiveness and sustainability of plans.
Limited compliance with current codes	Codes typically do not effectively address the unique needs and objectives of limiting fire-related impacts to heritage sites, structures and their contents and collections. Compliance with code requirements is limited.	Although some wildfire codes exist (e.g., NFPA 1140, Australian National Construction Code Standard AS 3959-2009), they are rarely adopted.	Damage and losses often exceed expectations as risk reduction measures do not address unique exposures and vulnerabilities.

Identifying and understanding the numerous similarities and common themes that continue to emerge and cause fires with their resultant damages, losses and casualties, can help further inform the next steps in reducing fire risks and limiting losses.

Fundamental findings to help effectively address fire risks

In reviewing past fires, four fundamental findings emerge that should be understood and addressed to manage fire risks more effectively.

Finding 1. Creating awareness is the first step to preventing fires.

Generating awareness about fire risks among stakeholders – including site managers, communities, emergency responders, heritage professionals (e.g., site managers, conservationists, architects, engineers), visitors and tourists – is essential to inform decision-making and fire risk management planning. Key considerations in this regard include the following.

- Tailored FRMPs are needed to effectively manage risks that recognize the uniqueness of each site.
- Fires can happen anywhere and to any site or structure.
- Time is one of the most critical metrics in responding to fires.
- Misconceptions need to be addressed to limit ongoing losses.
- Emergency responders have limitations that can impact decisions.
- Heritage sites and structures are extremely vulnerable during renovation and construction-related work.
- Low cost, simple, high-impact solutions are available.
- Codes often provide only a minimum level of safety for heritage sites, structures and collections, and may not address objectives.

Finding 2. Engaging communities and incorporating traditional knowledge and practice helps in developing effective and long-term sustainable Fire Risk Management Plans.

- Local communities possess very extensive and detailed knowledge passed down from generation to generation – including of the local geography, environment, vegetation, wildlife, weather patterns and hazards – as well as lessons learned regarding risk reduction measures.
- Engagement with local communities is critical to understanding local contexts, challenges, objectives, priorities, resources and developing tailored FRMPs.
- Local needs, values, customary laws and norms around cultural and environmental protection should be more effectively integrated into the plans.
- Traditional and indigenous knowledge and resources are important to understand and incorporate into plans as this knowledge has been developed over time and found to be effective. The local community is familiar with its use and implementation to reduce the frequency, severity and duration of fires.
- Engaging communities and incorporating traditional knowledge and practices helps to create a sense of ownership and to reinforce self-reliance and long-term sustainability of the plan.
- Relationships and ties that span borders, languages and cultures help to facilitate regional coordination.

Finding 3. Development and implementation of Fire Risk Management Plans increase resilience.

FRMPs should be developed, implemented, monitored and updated for day-to-day operations and renovation and construction work. Plans should reflect the following key points.

- Be tailored to specific needs, objectives, exposures, vulnerabilities, hazards and capacities of cultural heritage assets.
- Address all phases of fire risk management.
- Be developed closely with qualified fire experts in fire engineering and protecting heritage, including those with expertise in:
  - the different dimensions of fire behaviour and fire science; wildfires; disaster risk management (DRM);
  - socio-environmental impacts of fires; fire prevention/mitigation measures;
  - fire and life safety systems (e.g., detection, alarm, suppression, compartmentation, egress, etc.);
  - the structural behaviour of fire and understanding emergency response;
  - firefighting;
  - fire safety during restoration/construction;
  - vulnerabilities/protection of historic/culturally significant structures/sites;
  - and human behaviour.
- Ensure risk reduction measures are installed, maintained and operational.
- Be reviewed and updated regularly and disseminated appropriately.
- Address applicable regulatory requirements, codes, laws, etc.
- Form the basis of capacity-building, awareness and preparedness activities.

Finding 4. Understanding emergency responders' operations, needs and challenges is essential to avoid misunderstandings and false expectations and to inform risk reduction measures.

Emergency responders have specific protocols and regulatory requirements to follow and resources available to them during emergency events. Knowledge of these and their operations, needs and limitations in each local context is critical to the development of an effective FRMP. These needs and challenges include:

- pre-planning responses to fires with emergency responders
- providing earliest possible notification before the fire is beyond their capacity to control
- understanding the potential limitations of available resources and equipment to fight fires
- knowing the maximum size of fire that local emergency responders can suppress (specific quantities of water can only absorb so much heat to extinguish fires and should not be exceeded)
- ensuring unimpeded, protected access into and throughout the site/structure
- providing appropriate, operational infrastructure (e.g., water supplies, on-site equipment/systems, enclosed access routes, etc.) and
- helping emergency responders understand the value and uniqueness of the heritage site and its structures, contents and collections.

01 Identifying fire risks and developing a **Fire Risk Management Plan**

The following is an overview of the process and fundamental principals involved with identifying fire risks and developing a Fire Risk Management Plan to reduce these risks (ABCB, 2005; ISO, 2018; Meacham and Custer, 1997; NFPA, 2021c; SFPE, 2007).


TADANO

Step 1: Identify scope and details

Relevant information should be gathered regarding identifying the overall scope and associated details, including:

- stakeholders
- scope, background, objectives and goals of assessing fire risks
- characteristics of the site/structure/collections, including
  - heritage values, attributes, significant features, etc.
  - construction, layout, adjacent structures, etc.
  - occupant characteristics
  - resources on site (people, systems, processes)
  - operational characteristics (functions, ceremonies, etc.)
  - infrastructure (water, power, gas)
  - existing fire and life safety features, systems, etc.
  - past fires, existing issues, concerns, limitations
- traditional knowledge, methods, materials (e.g., fire safety, construction, etc.)
- limitations on heritage attributes due to installation of risk reduction measures
- emergency responders (personnel, equipment, resources, location, etc.)
- fire protection resources (equipment distributors, contractors, costs, etc.)
- impacts from weather (temperatures, windstorms, etc.) and climate change
- multi-hazard impacts (e.g., earthquakes, floods, volcanoes)
- schedule, resources, responsibilities, capital
- regulatory requirements (e.g., laws, codes, regulations, etc.).

Step 2: Identify exposures, vulnerabilities, capacities, objectives and hazards

Exposure assessment

An exposure assessment is a process used to develop an inventory of people and assets and how they may be impacted by fire, including from emergency response and recovery activities. Table 2 provides examples of various types of exposures.

Table 2. Examples of exposures

People	Assets	Surrounding factors
Occupants Users Visitors Community, volunteers Emergency responders	Site (extension, land, components, etc.) Structure (building, historic fabric, etc.) Contents (e.g., collections, furnishings, etc.) Infrastructure (facilities, systems, utilities, natural resources, etc.)	Environmental Social Economic Agricultural Sustainability

Fires can affect exposures in several ways (SFPE, 2007), including:

- effects of fire (heat, smoke, flame, carbon monoxide (CO), carbon dioxide (CO2), hydrochloric acid (HCl), hydrogen cyanide (NCN), particles, etc.)
- effects of fire suppression agents – type, discharge/pressures, quantities, duration of exposure, concentrations
- effects of firefighting operations – damage to structure, contents (e.g., broken doors to gain access, holes in roof/ broken windows for ventilation, water pressure).

Fires can also impact people and assets in a variety of ways, including:

- injury, loss of life
- loss of heritage value(s), spirit of place
- loss/damage to site, structure, contents, collections
- loss of livelihood and cultural practices
- economic loss (damage, reconstruction, lost revenue)
- environmental impacts (smoke, water run-off, products of combustion),
- biodiversity and carbon storage.

Vulnerability assessment

Vulnerability assessments identify factors that increase the susceptibility of exposures to the impacts of fire, including impacts during emergency response and recovery phases. This may include, for instance, combustible construction materials (i.e., wood, straw), lack of detection and notification systems to alert occupants and emergency responders, no automatic suppression systems to control the fire while it is small, or lack of fire separations to limit fire spread.

Capacity assessment

Attributes and resources available to increase capacity to address fires and reduce their risk should be identified. A number of risk reduction measures exist to help prevent and mitigate fires, assist in emergency response and strengthen capacity, with each having its own objective to help reduce the impact of fires. These are shown in Table 3 (Marrion and Custer, 2006; SFPE, 2007).

Table 3. Risk reduction measures and objectives

Risk reduction measures	Objective(s)
Ignition sources	Limit the probability that ignition will occur.
Combustible materials	Limit the growth, spread, intensity and duration of a fire.
Compartmentation	Reduce the spread of fire from the area of origin to the rest of the site/structures.
Fire detection	Detect the fire automatically while its extent is still small.
Alarm/notification	Provide early notification to occupants and emergency responders of a fire.
Egress system	Allow occupants to safely evacuate during tenable conditions.
Structural fire resistance	Limit the probability that the structure may collapse.
Fire suppression (automatic)	Provide automatic suppression/control of a fire while its extent is still small.
Fire suppression(manual)	Provide manual suppression resources (i.e., standpipes, extinguishers, water supplies, lakes, rivers, etc.)
Smoke minimization	Provide safe spaces to limit exposure to smoke inhalation.

Fire safety objectives

Fire safety objectives need to be developed to help identify and quantify maximum acceptable, or tolerable, damage and loss limits. This includes losses due to the fire (heat, smoke, flame, etc.) and firefighting efforts (suppression agents, firefighting activities, etc.). Fire safety objectives are typically defined in relation to protecting the following: people (occupants, emergency responders); property (site, structure, assets, contents, collections); environment (air quality, water quality, wildlife, erosion, biodiversity); heritage values; limiting the interruption of operations; and maintaining continuity of mission (ability to serve the community). Once these are defined, then thresholds that quantify acceptable losses or damage are defined. For instance, for a painting, one may define the maximum temperature and how long it could be exposed to that heightened temperature before it begins to damage the painting. When mitigation measures are developed, they can then be checked to determine if they will keep the temperatures below that threshold, or not, to prevent damage. (Meacham and Custer, 1997; NFPA, 2021c; SFPE, 2007).

Hazard identification

Ignition sources internal and external to the site and structure should be identified. Section 2.1 contains details related to this assessment process, including the identification of ignition sources and combustible materials. Various tools such as failure modes and effects analysis, hazard and operability studies, statistics, and historical data are available to help identify and reduce the number of possible fire scenarios. These can be used to identify fires that may have a higher probability and/or frequency of occurring, higher consequences and/or affect more people and assets (Meacham and Custer, 1997).

Step 3: Develop fire scenarios

Fire scenarios describe the sequence and timing of events to help understand the development and progression of the fire, as well as responses being undertaken in parallel, including by occupants, emergency responders, collection removal teams and others (ABCB, 2005; NFPA, 2021c; SFPE, 2007). Fire scenarios identify key components on a time basis to allow for comparison in order to assess if risk reduction measures can achieve the intended fire safety objectives. For instance, can occupants leave safely while conditions are still tenable? How much time will it take to remove the collections? How large will the fire be when emergency responders arrive? What impact does the change in wind direction have on fire spread? The risk assessment in Step 2 is used to help develop fire scenarios. Table 4 provides examples of items that may be incorporated into fire scenarios for the varying components (SFPE, 2007).

Table 4. Examples of fire scenario components

Component	Fire scenario description
Fire	Ignition, growth, spread on floor, smoke production, spread to adjacent floors (inside) and areas (outside), severity, duration, extinguishment, etc.
Occupants	Detection, notification, assessment, travel time to exit, queuing time, travel to safe area, etc.
Emergency responders	Detection, notification, response, site access, situation assessment, initiate search/ rescue, equipment set-up, entry to structure, initiate suppression, ventilation activities, extinguishment, overhaul, etc.
Collections removal	Detection, notification, set-up, removal from mounting/case/enclosure, travel to safe area, return, etc.

Fire scenarios should be specific to the site/structure and consider the following factors:

- ***Changes in use/functionality*** – varying ignition sources and combustible materials may be introduced over time (e.g., ceremonies, holidays, etc.).
- ***Time/day*** – fires in specific occupancies may vary depending on time and day of the week.
- ***Time of year*** – temperatures, humidity, winds, moisture content in vegetation, water levels, etc.
- ***Intentional fires*** – fires may be set by arsonists and during times of conflict and civil unrest. These may include larger and/or multiple ignition sources.
- ***Location*** – ignition sources may be internal and external to the site/structure.
- ***Multi-hazard assessments*** – fires can start as a result of other hazard events (e.g., earthquakes, volcanoes, explosions, etc.). Additionally, these may adversely impact fire risk reduction measures (i.e., breaks in water supply pipes, blockage of emergency access roads, etc.)

Step 4: Assess fire scenarios

Fire scenarios are assessed to determine whether the fire safety objectives will be achieved through the existing or proposed risk reduction and capacity building measures. Several different assessment methods can be used. These range from qualitative methods that may be based on the perceptions of experts, to semi-quantitative and quantitative methods that involve deterministic or scenario analyses, probabilistic risk analyses and/or historical analyses, including computer modelling of fire behaviour, structural response and evacuation. Selecting which method(s) to use often depends on the available resources and the significance of the risk.

As part of the evaluation process, it is beneficial to assess the following to help determine whether the risk reduction measures achieve the intended objectives (Meacham and Custer, 1997; NFPA, 2021c; SFPE, 2007):

- the nature of the hazards (e.g., heat, smoke, products of combustion, etc.)
- time until untenable conditions reached (e.g., temperature, CO, visibility, etc.)
- activation time of fire detection and suppression systems, where present
- time to evacuate the occupants and collections
- time for emergency responders to be notified, arrive on site, set up, begin suppression operations and extinguish the fire
- impacts of varying suppression agents on contents, interior finishes, etc.
- impacts of preceding events on performance of risk reduction measures (e.g., power outage to fire alarm/broken sprinkler pipes from earthquake, etc.)
- impacts of fires on secondary hazards such as smoke production, hillslope erosion, and mudslide risk
- uncertainties and variabilities in assumptions, including safety factors
- level of redundancy should risk reduction measure(s) fail to perform.

Understanding the interrelationships and interdependencies between these risk reduction components is important as they all need to function together during a fire (e.g., sprinkler system operates and in turn activates the fire alarm which notifies occupants to evacuate and releases doors on automatic door closers, shuts down mechanical ventilation systems and notifies local emergency responders).

The level of uncertainty or level of confidence in the assumptions and analysis should be understood, including impacts due to potential changes that can occur over time. In addition, fire behaviour – how a fire may behave and spread – is not an exact science. Once the uncertainty or confidence level for each assumption or calculation has been determined, additional assessments can be made (Meacham and Custer, 1997).

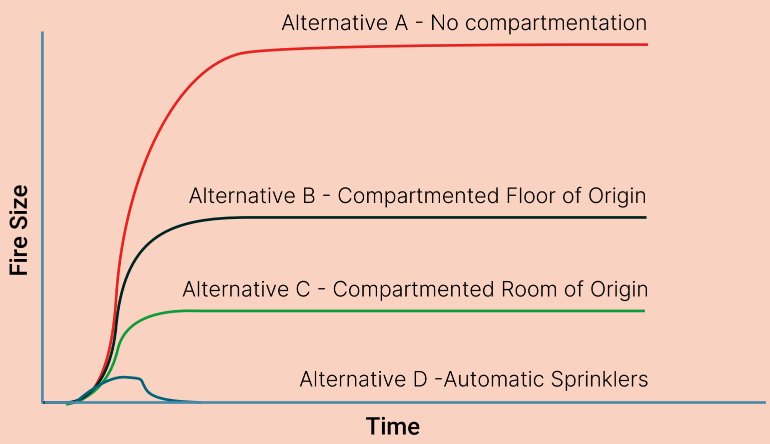
If the risk reduction measures are shown to not appropriately achieve the fire safety objectives (i.e., minimal damage limits too low to be achieved), then alternative measures should be developed, and/or adjustments made to fire safety objectives and reassessments undertaken.

Step 5: Identify/assess alternative risk reduction measures *(if needed)*

Developing risk reduction alternatives

If fire safety objectives are not being achieved, several alternative risk reduction measures may be available. It is important to evaluate the impact each alternative may have on mitigating the event, along with the costs and resources required, to determine which alternative may be most adequate and effective in reducing risk and meeting objectives. A cost-benefit analysis can assist here. Figure 1 provides an example of the potential relative differences in fire size versus time for (a) no compartmentation, (b) a compartmented floor, (c) a compartmented room and (d) automatic sprinklers. Such an analysis enables comparison of these alternatives against the effects of fire size, duration, impact on the structure, contents and potential duration of water from the emergency responders. However, depending on the structure, some alternatives may not be available. For example, in sacred places and sites, it is not possible to compartment a large open space.

Figure 1. Assessing alternatives and impacts on fire size



Considerations in developing risk reduction alternatives

The following factors may be worth considering when evaluating risk reduction alternatives(Marrion, 2016):

- addressing permanent (e.g., electrical) and temporary (e.g., candles) ignition sources, including intentional fires
- embracing traditional knowledge systems, materials and people
- engaging with the local community in all phases of fire risk management
- minimizing the impact to heritage values, aesthetics, etc.
- using existing inherent features (e.g., fire resistance of a thick wooden door)
- limiting the impact on functionality/use of spaces (maintain ceremonies, functions, etc.)
- assessing the reliability, serviceability and resilience of equipment and systems, particularly at the time of the fire
- the local availability of equipment, companies and personnel to maintain risk reduction measures as viable, long-term, sustainable solutions.
- impacts of climate change (e.g., high winds, dry spells, reduced water availability, etc).

Developing alternatives to help address common challenges

When developing alternative risk reduction measures, it is important to identify the challenges and objectives to be achieved, as more than one alternative may exist to address them. Possible alternatives include the following:

Limited water supplies. Consideration could be given to using sprinkler or water mist systems that require significantly less water than required by emergency responders. These can be used in conjunction with compartmentation to reduce fire spread, smoke detection and automatic notification for earlier manual suppression while the fire is still small, and limiting combustible materials to reduce fire size, growth rate and duration, thereby reducing the amount of water needed to suppress these fires.

Limited egress width/reducing evacuation time. Since a key objective in evacuation is to ensure occupants evacuate safely and quickly, a timed egress assessment can help identify measures to reduce egress time during tenable conditions. Measures may include smoke detectors to provide early detection of a fire, automatic evacuation notification for occupants, fire separating exit routes to keep paths tenable, fire wardens trained in crowd management to direct occupants to evacuate, clearly defined exit paths with maps and drawings showing exit routes, and lighting of exit paths and measures to reduce the fire hazard and thereby increase the time to untenable conditions (e.g. sprinklers, reduction in combustible materials, etc.). Outdoors, egress considerations should also include the availability of multiple roads and routes to simultaneously allow evacuation in the event of fires, while enabling emergency personnel to access the site to manage the fire and associated risks. In all cases, egress plans should include redundancies.

Limited access to all sides of the site/structure, or a single access road. Multiple access routes to a site/structure, as well as access around the site/structure, can help firefighting efforts. Challenges include narrow streets, single access roads or access to only one side. Consideration should be given to providing automatic sprinklers to suppress/extinguish the fire, fire hydrants around the site/structure, water monitor nozzles that are fixed in place and readily available on inaccessible sides, early detection and notification to expedite the response of emergency responders, reduction in combustible materials and compartmentation to help limit the size of the fire. At remote sites, where water access is limited, consideration should be given to providing sand or soil stations or locating water storage sites at key locations.

Fast fire growth rate. Risk reduction measures help reduce the growth and spread of the fire, as well as identify measures to detect, notify, respond and suppress the fire. It is critical to factor in time and to reduce the time from detection until final suppression as much as possible. When not limited by fuel, oxygen or space, fires grow exponentially; for every doubling of time, the fire will grow by a factor of four.

Figure 2. Fire growth versus time

Step 6: Develop a Fire Risk Management Plan

Once risk reduction measures to effectively address fire safety objectives have been identified, they should be integrated into the overall risk assessment and incorporated into the development of the Fire Risk Management Plan (FRMP). These include measures to be implemented for analysis, risk reduction, preparedness, the emergency response and recovery phases, as well as equipment and installation specifications. Design criteria for systems should be clearly detailed (e.g., spacing/location of smoke detectors, water flow rates/pressures/quantities for suppression, etc.).

The documentation should also include assumptions, a sensitivity analysis, calculation methods and limitations of the plans, risk reduction measures and identify any specific factors or changes that would initiate a re-evaluation or re-design. These might include change of occupancy, use, operations, occupants, layout, fuel loading or other hazards, as well as any renovation or construction-related work (NFPA, 2021b; NFPA 2021c; SFPE, 2007).

02 Considerations to reduce risks related to fire at cultural heritage sites and structures

When developing risk reduction measures for **Fire Risk Management**, it is necessary to examine the specific stages that occur before, during and after an event. Each of these stages will inform decision-making about the required risk reduction measures.

The before stage involves risk assessment and the development of (1) **risk reduction** and (2) **emergency preparedness** measures. The during stage refers to (3) **emergency response** and is initiated when a fire occurs. The after stage consists of activities post-fire for (4) **recovery, rehabilitation and building back better**, which include damage assessment, treatment, stabilization and conservation (International Organization for Standardization [ISO], 2018; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2010; UNESCO, 2014).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2.1 Fire risk reduction

Fire prevention and mitigation measures help limit risk by reducing the probability of ignition, restricting fire growth and mitigating the effects of fire. This section provides an overview of various measures to help reduce risks (Historic England, 2017; Kidd, 1995; NFPA 2021c; SFPE, 2007).

2.1.1 Limiting ignition sources

Understanding and minimizing the chance for a fire to start is the first and most effective measure to reduce fire risks.

Identifying potential ignition sources

Table 5 presents some of the more common ignition sources to heritage sites and structures (Kidd, 2010; Maxwell, 2007; Neves et al., 2003; NFPA 2021b; Ronken, 2020).

Table 5. Examples of ignition sources

Ignition sources		

• Electrical
• Lights (high intensity, exposed bulbs, exhibit lights, temporary lights, holiday decorations)
• Cooking, grills, stoves, barbecues
• Hot surfaces (appliances, equipment, boiler, space heaters, chimneys, hot plates)
• Open flames
  ◦ candles, incense, butter lamps, lighters, oil lamps
  ◦ fireplaces, chimneys
  ◦ appliances (stoves)
  ◦ heating equipment (gas boilers, water heaters)
• Incendiary, intentional, arson
	• Adjacent permanent structures
	• Adjacent temporary structures (tents, canopies, trailers)
	• Explosives, munitions
	• Blasting agents, flares
	• Smoking/disposal (cigarette, cigar, pipe)
	• Lighters, matches
	• Hot works
	  ◦ Open flame (stripping, paint removal, roofing)
	  ◦ Grinding
	  ◦ Welding/cutting
	  ◦ Brazing, soldering
	• Spontaneous combustion (linseed oil rags) and chemical reactions
		• Wildfires (flames , hot sparks, flying embers and firebrands)
		• Open burning in fields
		• Dumpsters, rubbish
		• Hot/smouldering material (embers, ash, coal, flying embers, sparks)
		• Fireworks, sparklers
		• Sky lanterns, sky candles, fire balloons, model rockets
		• Flame/torch/lantern
		• Vehicles (cars, trucks, trains)
		• Lightning
		• Fires following earthquakes, volcanoes, blasts, other events

Figure 3. Ignition sources exist throughout historic sites and structures.
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The intention is not to disallow controlled fires but to identify and manage them appropriately and limit the ways they may trigger an uncontrolled fire.

To identify potential ignition sources and make informed decisions regarding their management, consider the following important factors:

- probability of ignition from each potential ignition source
- potential ignition sources from other events (earthquake, volcanoes, etc.)
- potential intentional fires (arson, time of conflict, civil unrest, etc.)
- low probability, high consequence ignition sources (explosions)
- permanent and temporary ignition sources (candles, space heaters, etc.)
- time of day, day of week (late night when unoccupied, religious days, etc.)
- external ignition sources (lightning, adjacent structure, fireworks, etc.).

What parts of electrical systems can start fires?

Electrical systems are one of the more frequent ignition sources. Potential ways in which they can start fires include

- extension cords used to connect high-power appliances (air conditioners, space heaters, heavy equipment)
- equipment overheating (overloaded, under ventilated, etc.)
- use of non-approved, non-listed equipment unacceptable in a jurisdiction
- old wiring and disintegrating insulation exposing energized conductors
- inadequate connections including the use of electrical tape, wire nuts, etc.
- rodents chewing through wiring
- running power cords under rugs where insulation wears thin over time
- inadequate repairs to damaged wiring
- use of numerous interconnected extension cords
- overloaded outlet strips with multiple connected pieces of electrical equipment
- circuit panels – overloaded, fuses rated too low to accommodate electrical load
- motors and generators generating high temperatures, overheating
- electrical arcing, transient spikes
- abandoned wire and electrical equipment with power still provided
- light bulb wattage exceeding capacity of light fixture.

Sources: Engel, 2024; Kidd, 2010

Figure 4. Ignition sources exist both inside and outside of historic structures.

Reducing ignition sources

Once potential ignition sources have been identified, the following measures can be considered to reduce the possibility of associated fires (Marrion, 2016; NFPA, 2021b; NFPA, 2021c; SFPE, 2007).

A) Remove/Reduce

Consider removing ignition sources and related activities (smoking, cooking, hot works, fireworks, sky lanterns etc.). If ignition sources cannot be totally removed, consider reducing their quantity or potential to cause a fire (reduce quantities of high temperature lights, extinguish flames when unoccupied, reduce quantities of open flames, etc.).

B) Relocate/Isolate

Potential ignition sources can be relocated to areas where they may be less prone to cause ignition including away from combustible materials, are easier to monitor and/or are more readily accessible to emergency responders. For instance, butter lamps could be relocated to one room at ground level, or to an external, detached structure to avoid the presence of open flames in numerous locations throughout a structure. External ignition sources should be relocated away from the site or structure to reduce exposure (relocate rubbish containers, temporary structures, work trailers, vehicles, etc.).

C) Repair/Upgrade/Replace

Potential ignition sources can be assessed, repaired and/or replaced such as replacing high wattage lightbulbs with low wattage/low temperature lightbulbs and requesting a qualified electrician to assess electrical and lighting systems, including replacing temporary electrical and lighting systems with permanent installations.

D) Provide/Install

Implement measures to reduce ignition potential (lightning arrestors, chimney screens, etc.).

E) Maintain

Equipment, systems and other parts of the site or structure can be maintained to limit ignition (electrical equipment, chimneys, heating and cooking equipment, lightning arrestors, etc.).

F) Regulate

Ignition sources that need to remain in place can be regulated through procedures, training and enforcement to help reduce their potential to cause a fire (use of candles only in specific locations, initiating hot work permits, managing exterior burning, etc.).

G) Separate/Isolate Ignition Sources from Combustibles

Ignition sources (lighting, open flames, fireplaces, hot surfaces, etc.) can be separated from combustible materials to limit direct contact and reduce the possibility of ignition due to close proximity.

H) Identifying Alternate Measures while Retaining Functionality

Ascertain why some potential ignition sources may be present, such as space heaters, in order to develop alternative measures and ask questions including the following.

- Why is there smoking in rooms? Can a designated smoking room or area be created?
- Why are people cooking in rooms? Would a communal kitchen reduce this?
- Why do so many rooms have space heaters? Can central heating be upgraded?

Figure 5. Regulations can be implemented to help limit potential ignition sources.

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Figure 6. Mitigation measures, such as encasing open flames in protective enclosures, can help limit uncontrolled fires.

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Prevention and mitigation measures

Prevention and mitigation measures can help appropriately address challenges presented by ignition sources to help achieve fire safety objectives. These may include security measures to limit arson, detection systems to detect smoke early, lightning protection systems and other measures.

2.1.2 Reducing combustible materials and the rapid growth, spread and duration of fires

Combustible materials exist both inside and outside of heritage structures and sites. The presence of combustible materials can result in fast fire growth and limit the time available to respond effectively. Table 6 lists some common combustible materials.

Table 6. Common combustible materials

Internal		External
Combustible construction/finishes*	**Combustible contents**	
• Structural elements (beams, columns) • Roofs, walls, ceilings, floors (wood, lath, reeds, straw, grass, etc) • Interior finishes • Curtains, drapes, decorations • Wall hangings (tapestries, Thangkas)	• Books, archives, artwork • Exhibits, display cases • Furniture, chairs, tables • Storage, rubbish • Flammable/combustible liquids and gases • Wiring insulation	• Vegetation, trees, grass • Adjacent structures • Construction materials • Vehicles • Storage • Rubbish

Recommendations to control and manage combustible materials are presented below (Kidd, 2010; Maxwell, 2007).

Identifying combustible materials and their behaviour during fire

An inventory should be made of combustible materials both internal and external throughout the site or structure (type, location, quantity, if needed on site, etc.). The fire behaviour of each of these materials should be understood. For instance, how fast a fire grows and spreads is dependent on the fuel, heat release capacity and configuration. Wood logs, kindling and sawdust are all produced from trees, but have different ignition and potential fire and explosion characteristics. Fire growth also depends on proximity to other combustible materials. For instance, furniture located throughout a room will burn differently than all furniture stored together in one area.

Common findings regarding combustible materials at heritage sites and structures

- Large quantities of combustible material contribute significantly to the spread and duration of fires.
- Combustible materials can be present both inside and outside the structure or site.
- Temporary combustible materials can contribute to the rapid growth, spread and duration of fires.
- Back-of-house areas are prone to storage that accumulates over the years.
- Flammable/combustible liquids are often stored out in the open, rather than in appropriate fire-related enclosures.
- Spaces and rooms where combustible materials are present typically have limited mitigation measures.
- Time is critical as fires grow exponentially. Controlling the type and quantity of combustible materials is critical to slowing fire development and in aiding emergency responders to suppress fires.
- Products of combustion (HCl, HCN and soot) vary according to the material that is burning, and can have short and/or long-term impacts on materials, artwork, finishes, etc.

Figure 7. Construction materials often include significant quantities of combustible materials.
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How do fires develop and spread?

Ignition. Lighter, thinner, less dense materials (e.g., paper, kindling) ignite more readily, while larger, thicker materials (e.g., logs, beams) take time to ignite. Combustible materials in proximity provide radiative feedback between them, raising temperatures quickly and enhancing fire growth. The process is like starting a fire in a fireplace by igniting newspaper, which then ignites kindling which in turn ignites larger logs placed close together.

Fire growth rate. Fires typically grow at exponential rates, growing by a factor of four with each doubling of time. The type of material is an important factor. Plastics and flammable/combustible liquid fires grow faster and release significantly more heat, smoke and toxic products.

Fire spread. Fires will spread if combustible materials are near each other, sufficient oxygen is present, and no mitigation measures have been taken to stop the spread such as suppression measures.

Fire size and duration. Fire size is dependent on fuel type, quantity and how it is spread out. Fuel quantity also contributes to length of the fire. Some fires burn for minutes, while others burn for days.

Extinguishment. Fires extinguish due to lack of fuel or oxygen, or the application of sufficient extinguishing agents. The latter may require significant resources, including significant quantities of water once a fire has exceeded a certain size .

Sources: Hurley, 2016; NFPA, 2023

Reducing the risk of combustible materials

A) Remove/Reduce

Combustible materials that are not specifically needed on site should be reduced in amount or removed off site. Reducing the quantity of materials will have a beneficial impact on the spread and duration of any fire.

B) Regulate/Prohibit

Combustible materials that need to remain on site should be regulated to reduce their quantities and ensure appropriate storage. Procedures, training programmes and monitoring should be developed to help reduce the potential risk of storing large quantities of combustible materials on site.

C) Relocate/Isolate

If combustible materials remain, they should be relocated to areas where they are less prone to fire, their accumulation is easier to monitor, and they are more readily accessible for emergency responders to extinguish. This could include relocating combustible materials from a high attic space to a protected compartment space on the ground floor away from critical items. For combustible materials located outside (vegetation, rubbish, vehicles, temporary structures, etc.), consider their relocation away from the structure to reduce exposure risks. Storing combustible materials within metal structures or structures surrounded by non-combustible surfaces such as gravel, concrete or soil can reduce the risk of any fire spreading to other areas.

D) Treating Materials to Reduce Combustibility

There may be opportunities to use a fire-retardant treatment in specific areas where this may not create adverse impacts on the materials on which it is applied. These treatments tend to make materials harder to ignite and slower to burn. However, they do not make materials ignition-resistant or flameproof. The impact of these treatments on the flammability of materials should be fully understood, as well as the potential short- and long-term impacts on various materials (e.g., impacts on aesthetics, colour, finishes, structural integrity over time, duration before re-application is required and costs).

Figure 8. Combustible materials may readily accumulate over time.
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Acquiring knowledge for risk reduction measures

Knowledge of the types of materials present on the site, and their quantities and locations, is crucial to determining the relevant risk reduction measures to appropriately address fire safety objectives (e.g., storage of combustible materials in fire-rated rooms, providing flammable/combustible liquid storage cabinets, and presence of sprinklers including to protect concealed combustible spaces).

Community engagement – ignition sources and combustible materials

Community engagement is crucial to limit fire risks. For each of the following groups, actions can be taken to reduce the threat posed by ignition sources and combustible materials.

The ***local community and neighbours*** can establish programmes to increase awareness about the importance and value of tangible and intangible heritage property to the community, the challenges it poses, and how the community can contribute to reducing risks and protecting the site/structure. Specific actions include:

- limiting/eliminating the use of fireworks and sky lanterns
- requiring vegetation burning permits (ensuring controlled burns, proper weather, emergency responders aware/on-site)
- instituting a no smoking policy, or having proper receptacles in place to dispose of smoking materials
- ensuring the safe and proper use of campfires, cooking materials, fire pits and barbecues, and that they are extinguished once used
- parking of vehicles, buses, etc. away from structures
- installing flame arrestors/screens on chimneys (to prevent risks from sparks and embers)
- limiting fires during restoration or construction work, including in adjacent sites/structures.

Tourist agencies can assist with eliminating/reducing ignition sources during site visits, including by:

- enforcing no-smoking policies within tour groups
- lighting candles, butter lamps, incense, etc. in a safe manner.

Hazard monitoring agencies can communicate with other agencies involved with monitoring diverse types of hazards that may result in fires (earthquakes, wildfires floods, etc.) to ensure early notification of potential risks.

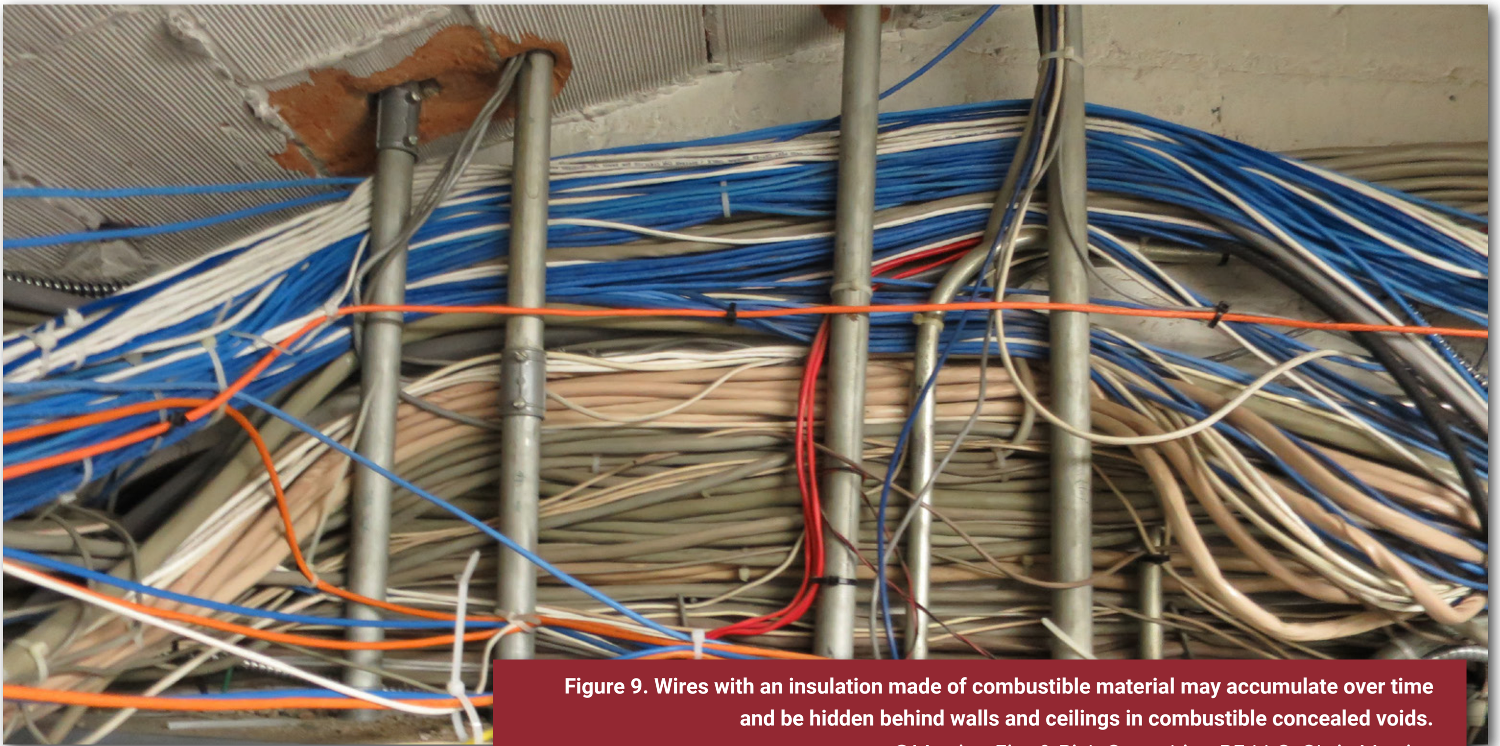

Figure 9. Wires with an insulation made of combustible material may accumulate over time and be hidden behind walls and ceilings in combustible concealed voids.
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Community engagement – traditional knowledge

Heritage sites/structures can be exposed to external fire risks, including wildland fires. Traditional knowledge and methods include centuries of experience managing wildfires through pre-burning and limiting the build-up of vegetation and combustible materials.

Limiting combustible materials on site. Traditional methods can help manage vegetation. These typically low-cost solutions also help other members of the community. For example:

- Use livestock (goats, cows, sheep) to manage vegetation and thereby limit fire spread, fire size, etc.

Open flames – butter lamps, candles, incense. Numerous heritage sites and structures use open flames (e.g., candles, butter lamps, incense, etc) as part of religious ceremonies. The intention is not to stop their use, but rather to reduce their potential to ignite items and create uncontrolled and unwanted fires. Consider several local and traditional methods to assist in reducing ignition while maintaining functionality and traditional practices.

- Stabilize containers and burning material to keep them from tipping over.
- Control, limit and monitor what is being brought into each space, the size of the candles and butter lamps, as well as where they are placed by visitors, tourists, and worshippers, keeping them away from combustible materials.
- Provide non-combustible containers and trays to catch material that drips or tips over.
- Separate open flames from materials that are combustible.
- Implement continuous fire watches in areas with open flames, incense, etc.
- Consolidate items into a separate, protected room, or separate exterior structure.
- Provide individual containers/enclosures to help stabilize and prevent open flames and incense from being tipped over, and if so, at least contained in a non-combustible structure to limit spread.
- Provide automatic detectors and fire extinguishers close by and personnel trained in their use.

2.1.3 Using compartmentation to limit fire spreading to adjacent spaces, floors and structures

Fire, smoke and heat should be contained to the compartment of origin and prevented from spreading to adjacent spaces, floors and structures. This will help protect evacuating occupants, limit the area of damage and reduce the extent and size of the fire for emergency responders to suppress.

Various measures are identified below to help inform the development of a compartmentation strategy. These help to determine where fire separations and compartmentation should be provided. Plans or drawings that identify specific walls, floors and ceilings that form compartmentation/fire separations can be of particular use.

Containing fires to compartments/floor of origin

Compartmentation can help contain fires in several ways. Possibilities for improving compartmentation are as follows (Historic Scotland, 2005; Kidd, 2010; NFPA, 2021c).

A) Repair/Upgrade Existing Walls, Floor and Ceilings

Existing compartmentation, including that providing fire-resistant separations to hazard spaces, exits, walls shared with adjacent structures and so forth can be repaired or upgraded to limit fire and smoke spread.

B) Provide New Fire-rated Compartments and Fire Separations

New fire-rated compartments can separate higher hazard areas to limit fire spread (kitchens, rubbish rooms, storage rooms, laboratories, etc.), as well as to prevent fires from reaching specific areas (e.g., archive rooms, collection areas, etc.). Fire separations can also be provided to divide large spaces such as attics.

C) Protect Unprotected Openings in Walls, Floors and Ceilings

Unprotected openings should be repaired to limit fire and smoke spread to adjacent compartments.

- Doorways can be protected by:
  - keeping doors closed that do not need to be opened, including at night
  - retrofitting doors with self-closers to close automatically
  - latching doors when closed so heat does not push doors open
  - removing objects blocking/propping doors open.
- Vertical openings – stairs, elevators, shafts, atria, dumbwaiters, etc. – need special attention and maintenance.
- Utility/service penetrations can be protected by repairing holes in walls made for utilities (electrical, plumbing, ducts, etc.).
- Mechanical systems can be protected by providing fire/smoke dampers where ducts penetrate fire-rated walls, ceiling and floors, and by shutting down mechanical systems on detection of fire to limit spread and recirculation of fire and smoke.

D) Limit Fire Spread within Void Spaces in Ceilings and Floors

Combustible concealed void spaces often exist below floors and above ceilings. These can be quite extensive in area and height. As there is typically no suppression or detection in these hidden combustible spaces, fires can grow rapidly and spread without anyone knowing and quickly become challenging for emergency responders to fight. The following steps help address the risks these spaces pose.

- Walls should extend from the floor slab up to the ceiling slab, continuing up through the floor and ceiling voids.
- Voids should be restricted in area and fire stopped to limit the extent of a potential fire in each void space. This measure should factor in the maximum fire size the emergency responders can suppress.
- Firestopping materials should be non-combustible to reduce fire burning and limit the fuel load (e.g., gypsum board, brick, masonry).

Compartment exit paths/protected access routes for emergency responders

Exits including access paths leading to exits, exit stairways and exit discharge corridors leading to the exterior of the structure should be compartmented to:

- provide a protected and safe route for occupants to evacuate through
- help limit stairways from spreading fire and smoke between floors
- provide a protected route for emergency responders to access all floors and
- create a protected area from which to fight the fire.

Limiting fire spread to/from adjacent structures and buildings

The potential for fires to spread to/from adjacent structures and from other external fire sources should be mitigated, including by addressing the potential for ignition from:

- direct contact by fire, flame impingement
- radiant ignition through windows and other openings
- hot embers landing on the structure
- ignition of vegetation; and/or
- interconnected mechanical/electrical systems.

Risk reduction measures can help address these issues, including through the use of compartmentation, sprinklers, fire retardant treatments, fuel load management and early detection.

Figure 10. Adjacent spaces in historic Souks, or other structures with no, or limited, separation can facilitate the rapid spread of fires.
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Community engagement – compartmentation

Local communities can assist in informing compartmentation measures.

Emergency responders can gather details regarding the maximum size of fires they can effectively control and incorporate this information into the compartmentation strategy to identify limits on compartment and void sizes to contain fires.

Community/neighbours can undertake risk reduction measures to limit the spread of fire between structures, including to appropriately protect penetrations in shared walls between structures, and protect interconnections between shared mechanical systems.

Tourist agencies can assist with limiting the spread of fire and smoke by keeping doors closed (exits, rooms, etc.).

Traditional knowledge – compartmentation

Reducing potential for external fire spread (Japan)

To help protect wooden structures from external fires, including fires in adjacent properties, structures along narrow streets and wildland fires, a water shield on the exterior can wet combustible exterior facades and reduce radiation levels to limit ignition. Heritage structures including Myoshin-ji Temple, Kyoto, are protected by such systems. In other areas, structures have been separated from each other and, at times, ponds and some trees have been used in the Southern Islands of Japan to help reduce the possibility of ignition radiating to other structures.

Source: Newman et al., 2020

2.1.4 Providing structural protection to help limit structural failure/collapse

Building structures should be assessed to determine if part, or all, of their structure may be susceptible to collapse due to a fire. As structural failures can create significant damage to the structure and its contents and pose a significant danger to occupants and emergency responders, it is important to understand the ability of structural elements to continue supporting loads when exposed to fire and high temperatures. This should include assessing the performance of columns and beams, as well as roofs, floors, ceiling, facades, spires, steeples and domes (FireTech, 2003; Kidd, 2010).

Structural elements that have limited ability to withstand high temperatures for extended durations should be appropriately protected to maintain their structural integrity and load-bearing capacity during a fire (cast-iron columns, steel structural supports, key wooden structural elements, etc.). If protection of these structural elements cannot be provided, it is crucial to understand the failure mechanisms (column, beam, interconnections), potential time to failure of the structural element once exposed to heat, and area(s) of collapse. It is likewise critical to provide alternative mitigation measures such as reducing the size and spread of fire and duration of exposure. Emergency responders should be informed of any structural elements that pose a risk so they can take appropriate precautions during firefighting operations.

Common findings regarding structural protection

- Structural elements keep the structure standing and help limit early collapse. This provides time for occupants to evacuate and emergency responders to fight the fire from within.
- Failure of structural elements can produce local and/or global failures of the entire structure.
- The types of interconnections joining structural elements play an important role in how structures respond to fire, and their potential for failure and/or collapse.
- Structural elements are often not fire protected when first built.
- Some materials may be adversely impacted when suddenly cooled by water (e.g., cast iron).
- Emergency responders are injured and killed each year due to being inside structures or on exterior walls, steeples, facades, domes, etc. when they collapse.

Figure 11. Structural internal and external elements should be appropriately protected to avoid a potential collapse.
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Limiting impacts while protecting structures

Codes typically require structural elements (e.g., beams, columns) to pass fire tests for a specific time. As structural elements in heritage structures are often unique, they typically cannot, or have not, been tested. Risk reduction may therefore include the following requirements.

- Assess the inherent fire rating of structural elements versus fire exposure and determine whether the structure can maintain its load-bearing capacity throughout the fire, or if other mitigation options are needed.
- Assess/model the performance of structural elements to determine if additional protection is needed, throughout the structure, or for individual key structural components and whose loss could lead to a broader collapse than just locally adjacent to that structural component.
- Assess the interconnections of structural elements and the ability to load share and successfully transfer loads if parts of the structure begin to weaken or fail.
- Implement fire-rated measures including intumescent paint, typically a thick paint that expands when heated to provide thermal protection to the structure.

2.1.5 Providing early detection, alarm and notification of a fire

Fire detection and alarm systems provide early, automatic detection and fire notification. These systems help reduce overall response time for occupants to begin egress earlier in the development of a fire; for on-site emergency response while fires are still small; and for emergency responders to arrive on site earlier and help reduce damage (Historic Scotland, 2005; Kidd, 2010; Stovel, 1998).

Common findings regarding fire alarm systems

- Fire detection/alarm systems that automatically detect a fire, particularly early on, are often not present.
- Early detection/notification of occupants and emergency personnel can significantly limit the extent of a fire and the resultant damage, as well as the safety of occupants and responders.
- Structures with no detection need to rely on human detection and notification of emergency responders. This often results in critical delays and damage.
- When systems are present, numerous additional challenges exist, including:
  - smoke detectors absent throughout a space (only in closets, electrical rooms, etc.) resulting in delays in smoke getting to the detector and activating it
  - no automatic alarm provided to emergency responders, thus delaying their response
  - the location of fire panels in remote, unoccupied, non-monitored locations where no one can hear the alarm
  - delays in notifying emergency responders once an alarm condition is noted on site
  - systems that are old, not operational nor maintained and for which parts are no longer available.

Automatic notification to emergency responders

To reduce delays, the fire detection/alarm system should automatically notify and send an alarm to emergency responders or their designated monitoring company. If the system is not capable of performing this function, or the local jurisdiction does not monitor systems, emergency responders should be contacted to determine the most effective way to notify them of a fire quickly and automatically.

Automatic detection of fires

Automatic detection should be provided to detect a fire early. Consider the following when selecting the appropriate form of detection (NFPA, 2022b; Siemens, 2015).

- ***Matching detector to combustion products produced.*** Fires produce varying products of combustion including smoke, heat and carbon dioxide. Selection of detectors should consider those that provide the earliest detection and limit the chance of false alarms. As smoke is typically generated prior to significant quantities of heat, these are typically the most effective to provide early detection and expedite emergency response.
- ***Detector locations.*** To expedite early detection, detectors should be located in each space needing protection, and where ignition sources and combustible materials are located (rooms, combustible/concealed voids, exhibit cases, etc.). Detection will be delayed if smoke has to travel long distances to a detector, or if the fire occurs in a space without a detector.
- Detectors can also be installed to detect exterior fires, including within thatched roofs, combustible facades/cladding, and where automatically activated external drenchers are placed due to exposure hazards from adjacent structures or wildfires. Heat detectors (spot type, linear detection) are often used to limit nuisance alarms.
- ***Reducing impact on aesthetics.*** Several types of smoke detectors are available to reduce impacts on aesthetics. These include the typical spot-type smoke detector, as well as beam-type smoke detectors and air sampling detection.
- ***Access for testing/maintenance.*** Consider accessing detectors for testing and maintenance and keeping the related costs down. For instance, beam-type or air sampling smoke detection systems are easier to access than spot-type detectors on high ceilings that may require ladders or scaffolding.

Manual activation means

Manual pull stations should be provided so that occupants, and those undertaking fire watches, can readily activate an alarm manually.

Notification to occupants

Means should be provided to notify occupants to evacuate, or to direct them to relocate to other areas once a fire is detected. If possible, this notification should be initiated automatically to limit any delays. Notification systems include audible (horns, voice) and visual means. Voice systems allow specific directions to be given and help to expedite response. Consider the language(s) spoken, including by guests and tourists, if voice systems are used. If an electronic notification system is not able to be used, it is vital to have other methods on hand to warn occupants. Other ways may include bells, among others, conch shells, manual sirens, air horns, bull horns and whistles. Part of the training should include recognizing the sound of the alarm signal and what occupants need to do next once it is heard.

Figure 12. Alarms should be recognizable as indicating an emergency condition, and sufficiently loud.
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Monitoring/controlling other equipment/systems

Fire alarm systems should be interconnected with other fire and life safety systems to monitor and control them such as door releases, gas shut-off, fire/smoke dampers, and heating, ventilation and air conditioning (HVAC) shutdown.

Fire/incident command centre

A fire/incident command centre provides a centralized location from which to conduct operations. This centre should include fire detection and alarm equipment and means to help monitor and control other fire and life safety systems. It should be located in a readily accessible and occupied area where equipment can be monitored – along with copies of emergency response plans, drawings and other pertinent information.

Testing, maintenance and servicing

Fire detection and alarm systems need to be periodically inspected, tested and maintained to ensure they are operational and that people understand how to operate them.

Keeping it simple/concise

The fire detection and alarm system should feature clear, concise information regarding the alarm, including the type and location of the detector. This information needs to be in language readily understandable to responders.

Qualifications for designers/installers/testing companies

The person(s) designing, installing, maintaining and testing the fire alarm system should be experienced in fire behaviour, fire alarm systems, codes, and protecting heritage sites and structures. Local regulatory requirements often need to be followed as well. The person(s) should also be familiar with the FRMP and the role played by the detection/alarm system in meeting fire safety objectives.

Assessing existing systems

Existing systems should be assessed periodically to ensure they are operational and address the needs of the FRMP, including in relation to design, operation, automatic notification to emergency responders, and the availability of replacement parts.

Assessing existing fire detection/alarm systems

Areas to review for existing systems include the following.

- Design. Is the design appropriate? Are the layout and type of detectors suitable to quickly detect fires where they may occur? Was the system designed and installed by a qualified person? Does it address the needs of the FRMP and achieve the fire safety objectives?
- Operational. Is the system still functioning? Is it being tested/maintained by a qualified person?
- Age and availability of spare parts. Many systems have a limited lifespan and manufacturers do not stock spare parts for long periods of time. Are spare parts available for the system?
- Automatic notification to emergency responders. Does the system provide automatic notification to emergency responders, and if not, how can this be provided?

Source: NFPA, 2022b

Figure 13. Fire safety systems need to be frequently inspected, tested, and maintained to ensure operability.
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Limiting the impact of detection systems on heritage values

Unique interior finishes and ornate ceilings are often characteristic of heritage structures. Installing detectors on these ceilings can result in damage during installation, or impact aesthetics once installed. Alternative types of detectors exist to help limit these impacts, including the following (Historic Scotland, 2005).

- *Beam-type smoke detectors* have a light receiver and transmitter projecting an invisible light beam up to 100 metres. When smoke passes through the invisible beam, it reduces the light received and an alarm occurs.
- *Air sampling detection* consists of a network of narrow diameter pipes (~2.5 cm) with small sampling ports that run above a ceiling. Air is drawn back to a detector that remotely analyses the air for smoke.
- *Spot-type (typical) detectors* are small detectors that are typically located on the ceiling.
- *Wireless detectors* can help limit the installation of wires in sensitive areas, but thick walls and long distances may impact the ability of the detector to transmit signals and batteries need proper, regular maintenance.

Figure 14. Alternative types of detectors may help limit the impact on heritage values and aesthetics.
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Community engagement – detection and notification

Communities can help detect fires and expedite response in several ways.

Community/neighbours can detect and report fires and anything suspicious, including potential arsonists. Those in very close proximity can provide notification the structure is on fire so that appropriate measures can be taken to limit its spread to the heritage site/structure.

Leaders of tourist groups/agencies can work with site managers to assist with detection and notifying people by:

- being observant and reporting any signs of potential fire
- alerting tour groups, occupants and others of fire
- heading evacuation and ensuring their group and other occupants, perhaps unfamiliar with the site/structure and exits, are led safely to a designated area and away from arriving emergency responders and
- communicating with site managers about fire conditions, and the status of both occupants evacuating and those still inside.

Traditional knowledge – detection and notification

Detection, alarm and notification of emergency responders

It may not be possible to provide an automatic fire alarm system at all times due to cost, availability, power/infrastructure, adverse weather and exposure conditions, and the availability of distributors and technicians for installation, testing and maintenance. There may also be times when the existing system is not in service, or a system is being installed or maintained.

There may be opportunities to introduce alternate methods of detection and notification when an automatic fire alarm system cannot be provided.

- ***Detection.*** **Fire watches** can be established to ensure an individual is in constant attendance in areas where fires can occur and can initiate an alarm should they detect a fire.
- ***Notification to occupants.*** Various options exist to provide an **alarm signal** using local resources, such as bells/gongs, conch shells, whistles and air and bull horns. Different tones or quantities of beats could signify differences in the incident type and location. Also consider these options during interim periods when the fire detection and alarm systems are not available.
- ***Notification to emergency responders.*** If the fire alarm system cannot provide automatic and rapid notification to emergency responders, other readily and easily available means may be used such as **cell phones**.

2.1.6 Automatically suppressing fire to reduce fire and water damage

Automatic suppression systems are one of the most effective and efficient means to extinguish fires and limit damage from both the fire and the quantity of water required to put it out. These systems protect structures 24 hours a day and result in much less water than may be needed in manual suppression operations. Factors that should be taken into consideration include (Baril, 1998; Historic Scotland, 2005; Maxwell, 2007; NFPA, 2022a:

Types of automatic fire suppression systems

There are several types of automatic suppression systems to protect the interior and exterior of structures (combustible roof, facades, etc.) as noted in Table 7. There are also systems to protect specific hazards such as stoves and their exhaust ductwork.

Table 7. Types of fire suppression systems

Internal protection	*External protection*
Sprinkler system Water mist system Gaseous systems Foam system Dry/wet chemical system	Sprinkler system Deluge system Radiant ignition spray

Considerations in selecting a type of suppression system

Since each type of suppression system has its advantages and disadvantages, selection should be tailored to the exposures, hazards, vulnerabilities and objectives and consider the following:

- effectiveness in suppressing and extinguishing fire hazards specific to the site
- impact on historic interiors and aesthetics during and after installation
- need for a sealed compartment to maintain concentrations (gaseous type)
- need to interface with other systems (fire detection, HVAC shutdown)
- cost (design, installation, maintenance, testing)
- presence of manufacturers/distributors/contractors in the area to support the system
- potential impact of suppression materials on contents, interior finishes, etc.
- clean-up after discharge and restoration of suppression agent
- weather (impact of freezing temperatures) and
- infrastructure (water supplies, secondary power, space to locate equipment).

Common findings regarding automatic suppression systems

- Most heritage structures are not protected by sprinklers.
- When sprinkler systems are present, they activate rapidly thereby significantly reducing loss, damage and fire spread.
- Sprinklers usually control the fire to the room of origin.
- When sprinklers are not present, there is typically:
  - significant fire and smoke damage throughout the structure
  - significant damage to contents from fire, and water damage from emergency responders and
  - increased injuries and loss of life.
- There are several misconceptions regarding sprinklers, which adversely impact decisions regarding their provision. These misconceptions are typically not supported by 150+ years of experience using sprinklers.
- Governments and other stakeholders are becoming strong proponents of sprinklers.

Source: Baril, 1998

Design/installation

It is beneficial to have someone experienced with fire suppression systems, fire behaviour, codes, and protecting heritage sites and structures, as well as knowledgeable of the FRMP, involved in the design, layout, installation and commissioning of the system, as well as the assessment of existing systems. There are also often local regulatory requirements regarding fire suppression systems and the qualifications of the people who manage them that must be followed. These systems should be monitored by the fire alarm system so that when they activate notification is automatically sent to those on site and emergency responders. Fire alarm systems can also monitor sprinkler valves and provide notification if they are closed which could impair the ability of the system to operate.

Testing and maintenance

Automatic suppression systems need to be periodically tested and maintained to ensure they are operational, and that people understand how to use them.

Water supply

To operate effectively, sprinkler systems require water from municipal water supplies and water storage tanks with adequate flow rates, pressures, quantities and durations of water. Hydraulic calculations are used to determine the adequacy of these water supplies and the ability of sprinklers systems to suppress the fire.

Reviewing existing automatic suppression systems

These systems should be reviewed by a qualified person to assess the design, layout, capacity to extinguish fire hazards, type of suppression agent used, water supplies, obstructions, alignment with the FRMP and ability to obtain spare parts and should also confirm that periodic testing/maintenance has been performed.

Reviewing existing fire suppression systems

Any review of an existing fire suppression system should cover the following points:

- ***Design.*** Is the system appropriate (type of system, type of suppression agent versus fire hazard, piping layout, discharge nozzles, water supplies, etc.)? Has it been designed, installed and maintained by a qualified person or entity? Is it monitored by the fire alarm system?
- ***Hazard.*** Can the system suppress/extinguish the fire hazard (type, fire size at activation, etc.)?
- ***Suppression agent.*** Is the suppression agent sufficient (e.g., water quantity/pressure)? What are the impacts of the suppression agent on materials?
- ***Operation.*** Is the system still functioning? Is it being tested/maintained? Are there obstructions to water spray like painted sprinklers and objects hanging from pipes?
- ***Piping obstructions.*** Has the internal piping been inspected for obstructions such as rust?
- ***Age and availability of spare parts.*** Are spare parts available? How long will these take to obtain?
- ***Inspection/testing/maintenance.*** Are these undertaken regularly? Are there issues?

Misconceptions about automatic sprinkler systems

Concerns, misconceptions and/or misunderstandings exist regarding automatic suppression systems, often resulting in them not being installed. A review of numerous case studies and reports finds only limited support for these concerns and misconceptions (Baril, 1998; Cooper, n.d.; Maxwell, 2007; Mc Gree, 2024).

Correcting misconceptions regarding automatic fire suppression systems	
All sprinklers operate at once (false)	Not all sprinklers operate at once. Only sprinklers in close proximity to the fire operate.
Water damage will exceed fire damage (false)	Water damage needs to be compared to the damage that would occur in a non-sprinklered fire where the emergency responders would discharge significantly more water (e.g.,1.5 million gallons at Windsor Castle), and fire damage would also be much greater (over 100 rooms at Windsor Castle).
Leakage/accidental discharge (very limited)	There are very few data/examples regarding leakage of sprinklers, let alone resulting in mould, damage to contents, etc.
Aesthetic impacts cannot be addressed (false)	Several types of sprinklers can often be incorporated into the historic fabric to limit the impact on historic values and aesthetics (sidewall, long throw sprinklers, etc.).
Damage costs are higher (typically false)	Damage-related costs need to be assessed against the loss of the structure, contents, heritage value, etc., as well as reconstruction and lost revenue costs for a non-sprinkler-controlled fire instead of assessed against doing nothing.

Impact of fire suppression agents on cultural resource materials

While it is essential to control/extinguish a fire, it is also important to reduce the possibility that the suppression agent will have adverse impacts. The following factors should be considered here (Benfer et al., 2016; NPS, 2019).

DURING DISCHARGE

- Physical force of water from emergency responders can cause potential damage to materials whether from hoses or from water dropped from helicopters.
- If large quantities of water accumulate, this may lead to failure of part of the structure due to weight.

SHORT-TERM IMPACTS

- Water solubility of materials can eventually wash these artistic and decorative materials away.
- Chemicals, powder, gas, water, etc, used in suppression can interact adversely with materials.
- In winter, structural elements soaked with water can freeze resulting in adverse impacts (e.g., masonry can crack, delaminate, spall r be displaced).

LONGER-TERM IMPACTS

- Water can produce mould, including on collections, artwork, archives and so forth.
- Water, chemicals and other agents can result in rust, corrosion and other negative impacts.

Increasing demand for automatic suppression systems

In the light of numerous fires at cultural heritage sites and structures, and major associated fire and water damage, more stakeholders are installing automatic suppressions systems to protect their sites and structures. This includes museums such as Museo del Oro (Columbia) and Royal Saskatchewan Museum (Canada); libraries like Duchess Anna Amalis Library (Germany) and the National Library of Scotland; castles such as Schönbrunn Palace Partial (Austria) and Castle Sodra Strandverket; theatres including La Scala in Italy and Stadthalle Concert Hall in Germany; and numerous sacred sites, including in Finland, Norway and Sweden (Kidd & Kippes, 2004; Roche & Lima, 2019).

Opportunities for using sprinklers to help address objectives

Automatic fire suppression systems provide significant benefits related to the protection of heritage sites and structures. They can also help address a diversity of fire and life safety-related challenges, including:

- limited ability to provide compartmentation to restrict fire spread on and between floors
- limited ability to reduce significant quantities of combustible materials
- limited ability to provide infrastructure for emergency responders, including enclosed exit stairways, standpipes, fire hoses and significant water supplies
- limited water supplies for manual firefighting operations
- limited ability to provide access around all sides of the site/structure
- inability of firefighting vehicles to pass through narrow streets and alleys
- extended response times, including due to being in remote areas, and/or
- limited ability to ventilate spaces and reduce damage during firefighting operations.

2.1.7 Manually suppressing a fire in its early stages

Several challenges may exist related to manual firefighting. These include narrow streets, limited access around the site/structure, the presence of adjacent buildings that constrain the set-up of equipment, long response times in getting to the site and in safely fighting fires from within the structure, among others. The provision of manual suppression systems and early detection and notification can help address these challenges. Coordination with emergency responders and the on-site emergency response team (ERT) – including ascertaining their needs, design criteria and layouts – can contribute significantly to manual suppression efforts.

The following sections provide information related to manual suppression equipment (Kidd, 2010; NFPA, 2021c). Section 2.3 provides information regarding operational procedures and considerations in undertaking manual firefighter operations with the use of the equipment noted below.

Fire extinguishers, sand/water buckets and fire blankets

Manual fire suppression means – including fire extinguishers, sand buckets and fire blankets – help manually suppress a fire while it is still small, often prior to the arrival of local emergency responders (Cooper, n.d.; Historic England, 2017; Siemens, 2015).

- Care should be taken using these tools as they are typically effective only for extinguishing very small fires. Fires grow quickly and can rapidly exceed the capacity of such means.
- Fire suppression means should be located throughout the site/structure at short travel intervals, and near higher hazard areas.
- Multiple extinguishers, blankets and buckets, and the like may be needed to suppress the fire.
- Occupants should be trained in their use and location and should have a backup plan in case the fire proves impossible to extinguish, including understanding how to keep themselves between the fire and the exit.

Standpipes/hose reels (internal)

Standpipes are fixed pipes with hose outlets and attachments and often provided in stairways on each floor. Emergency responders connect their hoses to these pipes to fight fires. Water is supplied by the building's water supply system or pumped into the pipe from outside by the emergency responders.

Standpipes/hose reels can help significantly to:

- reduce the time to set up and discharge water on the fire, as there is no need to drag numerous hoses into position, interconnect and attach them to hydrants and fire trucks, and pressurize them with water prior to their use
- limit the number of emergency responders needed to carry, set up and control hoses once the water is flowing
- limit hoses blocking travel paths and exits, including stairways and
- facilitate faster response to fight fires on upper levels and attics, as well as large area structures and remote areas where emergency vehicles cannot reach.

Water cannons/monitor nozzles (external)

Water cannons/monitor nozzles are high-flow nozzles located around a structure that are readily available for use. These are controlled manually or automatically. Some are located above ground while others are below ground to limit the aesthetic impact.

These can be used by those on site prior to the arrival of emergency responders. They can also be used to suppress external fires from combustible facades and roofs, as well as fires from adjacent structures, vehicles, wildlands and so on.

Figure 15. Standpipes and hose reels can significantly help emergency responders control fires.
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Emergency responders and the ERT should consider the following:

- combustibility of the façade and roof, and the locations of hazards
- locations, height and size of openings allowing water spray into the structure
- quantity of water discharged from each nozzle
- height and distance water can be projected and
- obstructions to spraying the structure such as trees, electrical wires and structures.

Figure 16. Fire hydrants and external water monitor nozzles enable early fire suppression activities.
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Water supplies and fire hydrants

Fire hydrants allow access to the municipal water supply and other water sources. Providing sufficient water includes ensuring (NFPA, 2022e):

- an adequate pressure and flow rate to reach the fire and extinguish it
- that the total quantity of water is sufficient to last the duration of the fire and
- water supplies and fire hydrants are located where needed.

Fire hose threads must be compatible with the threads of on-site equipment to ensure that they can be interconnected with each other. Hose thread compatibility should be confirmed with emergency responders.

Providing sufficient, robust, readily available water supplies for fighting fires

There are three important aspects to providing adequate water.

Pressure/flow rate of water

- Water should be provided continuously at sufficient pressure and flow rate throughout the duration of a fire.
- Higher water pressures are needed to reach upper floors and remote areas.
- Municipal supplies, fire hydrants, etc. have limits on pressures/flows. Some fire hydrants only flow a few hundred litres per minute, or less, and at low pressures.
- Emergency responders may not have fire pumps to supplement these supplies and increase pressures.
- Fire pumps are needed to extract water from lakes, ponds, fountains and other sources.

Quantity of water

- Fires can last for hours. Water supplies need to be of sufficient size to accommodate this duration.
- Fountains, pools, water features, ponds, tanks, water towers, etc. have very limited and finite capacities. These typically contain insufficient quantities of water to extinguish fires.
- Water supply trucks also carry a finite amount of water and their supplies may only last for minutes not hours (1,000–2,000 litre capacity with fire hoses each discharging 500–1,000 litres per minute).
- Once empty, trucks take significant time to refill, including time to drive to the source of water, refill and return, while the fire continues to grow exponentially. For example, the fire at Windsor Castle required over 1,000,000 gallons of water to extinguish.

Location of water supplies

- Water supplies should be located strategically and in close proximity to the site/structure.
- Running long lengths of hoses takes time and introduces significant water pressure losses.

Requirements to fight fires internally

There are advantages to fighting fires internally, rather than externally, including an increased ability to discharge water directly on the fire. Water from external approaches often fails to reach the fire due to obstruction by roofs and façades. In addition to the equipment noted above, enclosed access routes/stairways to protect emergency responders while inside are key to fighting fires internally and more effectively.

Challenges presented in fighting interior fires

Heritage sites/structures present particular challenges for interior or internal firefighting operations.

Upper floors. Limited fire-rated access routes and stairways create challenges for access to upper floors. Hoses also need to be laid out – including up stairways which then obstructs the use of stairs. Stairs are often of limited width and stability, with some being small radius, circular stairs. These present challenges for emergency responders wearing 25–30 kg of gear and carrying hoses.

Attic spaces. Conditions in attics can quickly become untenable due to significant quantities of exposed combustible construction as well as large quantities of combustible storage. Given attics typically have no suppression systems nor standpipe systems, hose lays are often required along open, non-fire-rated stairs. There is also limited, if any, ventilation for smoke, toxic products and heat from the fire and steam generated from firefighting operations. Sufficient water pressure is needed to overcome the elevation.

Hidden voids. These hidden, combustible or concealed voids lead to unseen rapid fire spread to areas remote from the fire's origin, and/or in voids directly above/below emergency responders, putting them at risk.

Below ground levels. These levels often have limited protected access routes. These levels are not typically sprinklered and have limited ventilation for heat, smoke and steam from the hose spray thus creating further challenges to effective firefighting.

Figure 17. Hand tools, such as pike poles and axes, can help in accessing areas and materials that may not be easily reached.
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Hand tools (pike pole, axe)

Hand tools can readily assist with manual firefighting. For instance, a pike pole – a long pole with a hook at one end – can be used to pull down wall hangings, tapestries, banners, curtains and items hanging from ceilings, which may be on fire, making it easier to access and extinguish these manually and keep the fire from spreading.

Ventilation of heat/steam during firefighting operations

Ventilating the fire compartment releases heat and smoke from the fire and steam created by fire hoses. If means to manually or automatically vent are not provided, emergency responders may need to create ventilation openings. This takes considerable time, personnel and resources, including to access high areas and cut through thick, multi-layer roofs of varying materials (e.g., stone, wood, lead and copper) in several locations. **Note that keeping a fire unventilated does not extinguish the fire due to oxygen starvation, as heated, combustible materials ensure the fire will resume burning, often vigorously, in the presence of any oxygen including outside the building as it finds paths to fresh air.**

Community engagement – manual suppression activities

Communities can help manually fight fires and assist firefighters in several ways.

Community/neighbours. Numerous stores in Kyoto, Japan have small, red water buckets to help limit the spread of fire in the event of an incident. They also serve as constant fire prevention reminders.

The community at the World Heritage Site of Shirakawa-Go Japan is trained and engaged in preventing fires as well as manual firefighting operations and the use of the water monitor nozzles provided on site.

Special Fire Hydrants termed ‘citizen hydrants’ in Japan are used by both emergency responders during fires, as well as the local community on a daily basis to water vegetation and clean. Through frequent use, the local citizens become familiar with their locations and use and can readily access the hydrants during an initial fire response while waiting for emergency responders.

Emergency responders. To help create awareness about the uniqueness and history of the natural and cultural heritage they are helping protect, and to engage emergency responders, there may be opportunities to open up sites/structures specifically to them and their families, providing private tours with access to areas that may not normally be available.

Source: Newman et al., 2020

Traditional knowledge – manual suppression systems

Water supplies using gravity pressure. In Kyoto Japan several heritage sites and structures, including Kozan-ji Temple and Ninna-ji Temple, use water from gravity-fed water tanks. These systems do not rely on power so in the event of other hazards such as earthquakes, which often trigger fires, water will still be provided at high pressure to protect these sites.

Source: Newman et al., 2020

2.1.8 Helping occupants with evacuation procedures during a fire

During a fire or other emergency event, occupants need to securely evacuate and travel to a place of safety. The following section helps detail some of the measures to consider along with local requirements and good practice procedures related to evacuation and exit systems (Marrion and Jacoby, 2007; Tubbs, 2007).

Early detection and notification of occupants

Early detection and notificaton is important to allow occupants to evacuate prior to the onset of untenable conditions. An automatic detection and alarm system can help address this issue (see also Section 2.1.5). If not available, or not appropriately designed to provide early detection and alarm, alternate detection means like fire watches to detect fires and alternate notification means should be provided, such as bells, conch shells and air horns.

Exit access routes/exit stairways

Several factors can help facilitate the use of exits and expedite evacuation, including:

- exits of sufficient width and short travel distances to allow rapid evacuation
- multiple exits to limit queuing and increase flow-through capacity
- exits remote from each other to provide alternate means to evacuate should an exit become blocked
- removal of obstructions from paths (locks, storage, etc.)
- presence of exit signage to direct occupants, particularly visitors
- illuminated exit paths with emergency power
- fire-rated access routes and exit stairways to protect occupants
- Doors, gates, fences that
    - swing in the direction of travel so occupants do not push door(s) shut
    - do not require special knowledge or more than one action to open
    - have all locks removed, at least during occupation.

Typically, fire codes provide safety guidance regarding exits, including minimum numbers and widths of exits, minimum separation distances and maximum travel distances. Incorporate local requirements and good practice measures into safety procedures.

Exit discharge

Exits should discharge occupants to a safe place outside the structure, avoiding inside areas where the fire may yet extend.

Evacuation strategy/operational procedures during emergency response

Evacuation strategies should be developed and tailored to the site/structure, including physical features like exits and stairways. Factors related to human behaviour and occupant characteristics (SFPE, 2018), including the ability to sense a fire, hear and respond accordingly to an alarm, familiarity with the site/structure and the ability to evacuate, should be taken into account. Other factors to consider follow.

Figure 18. Exit signs can help quickly guide occupants to a safe area.
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A) ROLES AND RESPONSIBILITIES

- of the ERT and occupants
- names and contact details of people to reach during or following the evacuation

B) EVACUATION-RELATED PROCEDURES

- means of reporting fires and other emergencies
- evacuation strategy (total evacuation, relocation)
- crowd management procedures
- procedures for special events/large gatherings
- procedures to help people unfamiliar with the site and structure, or who may have special assistance needs
- means to account for all evacuated occupants
- measures to address occupants who may not have evacuated and
- procedures to assist those who may not speak the local language.

Figure 19. Exits should be available for use, neither obstructed nor locked.
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C) COMMUNICATIONS

- distinctive means of signalling occupants to evacuate that can be heard and seen throughout the site/structure
- ability to address persons that speak in varying languages and
- means of communications with the ERT like phones and radios.

D) PHYSICAL LAYOUT/EMERGENCY PROVISIONS

- drawings and plans of site/structure
  - locations of exit routes, exit stairs and exit discharges to the exterior
  - gathering locations remote from hazards and emergency responders
  - fire safety provisions such as fire panel, fire extinguishers and fire hoses
- posting drawings and plans throughout the site/structure.

Figure 20. The evacuation strategy should ensure that the layout of the evacuation system, and signage and direction arrows, are in sync, clearly indicating how to proceed.
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Alternative evacuation considerations

At heritage sites, often only limited opportunities exist to change or add new exit stairways, alter the widths of historic doors, decrease travel distances or increase the widths of corridors, without significantly impacting the structure. Accordingly, a few alternatives may be beneficial to consider.

- Limit the number of occupants to those the site/structure can safely accommodate.
- Undertake a timed egress study to assess the time to evacuate versus the time until untenable conditions are reached and ensure adequate time or other mitigation measures are provided.
- Provide smoke detection and alarms throughout the site to ensure early detection and notification, improve compartmentation where possible, mark exits clearly, ensure fire wardens are available to assist occupants, including those not familiar with the structure/site, and provide drawings/plans of evacuation routes.
- Relocate obstructions, such as the shoes removed at entrances to sacred sites, and direct parking vehicles and buses away from emergency responder access/parking areas.

All assessments regarding the above points should be undertaken by qualified personnel and reviewed and approved by local authorities.

Community engagement – evacuation-related activities

Communities can help with evacuating sites and structures in numerous ways.

Community/neighbours. can refrain from parking close to sites/structures and blocking exits and entrances for emergency responders.

Leaders of tourist groups/agencies can assist with helping to evacuate sites and structures, as follows.

- If shoes are removed prior to entry, have visitors and tourists place them in a location away from the entrance or exit to prevent obstructions and delays in evacuating occupants.
- Be familiar with locations and exit capacities, including for exits remote from the main entrance.
- Use crowd management capabilities to move people quickly and efficiently to safe areas outside.
- Identify a designated safe meeting area for groups where all persons can be accounted for.

Figure 21. Some sites and structures require footwear removal before entering. Relocating footwear out of exit paths and stairs facilitates faster evacuation.
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2.2 Emergency preparedness

Emergency preparedness involves undertaking measures to help anticipate, prevent, prepare for, respond to and recover from a fire. These measures are operational components of the FRMP once it has been developed and agreed upon by stakeholders and will help define how it is to be implemented and monitored.

2.2.1 Information needed to develop fire preparedness measures

Fire prevention and preparedness measures help to ensure that parts of the FRMP are being implemented, monitored and enforced, and they provide details to help recognize, manage, report and control fire hazards. Measures often include a number of organizational/operational procedures that support implementation of the FRMP (Bonnette, 2019; Friese, 2019; Historic Scotland, 2005; Kidd, 2010; NFPA, 2021b; NFPA, 2021c) as shown in see Table 8.

Table 8. Overview of fire prevention and preparedness measures

Item	Procedures
General prevention/ preparedness measures	Identify measures to help monitor, manage and reduce ignition sources and combustible materials, and prevent their interaction. • Practice good housekeeping such as removing rubbish, closing doors, limiting storage, reducing grass/ vegetation, prohibiting smoking, cleaning chimneys/stoves, avoiding cooking on site, maintaining egress paths, avoiding unsafe decorations, proper handling of combustible/flammable materials. • Monitor open flames (e.g., maximum flame size, holders, locations, monitoring, duration, extinguished when unattended, fire watch following extinguishment, fire extinguishers). • Manage special events carefully including exhibits, shows, filming and ceremonies by controlling crowds, maximum occupant loads, egress, use of tents, props, decorations, candles/open flames, food/cooking and fire extinguishers, etc.). • Monitor construction/restoration work, including hot works. Identify procedures to help ensure mitigation measures are effective. • Ensure fire protection equipment, systems and features to prevent and mitigate fires are in place, operational and tested, and that no obstructions exist that would impair performance. • Identify appropriate inspection, testing and maintenance requirements for verification of each prevention and mitigation measure by qualified entities on a frequent basis (e.g., fire-rated walls, fire detection and alarm systems, automatic suppression systems, fire extinguishers, exits, security systems, building systems) to ensure they are operational and functional as designed. • Implement impairment measures for fire and life safety systems taken out of service due to an emergency, or planned maintenance, and note the maximum duration, fire watches, and compensatory measures to be established.
Training/drills and awareness	• Create awareness including through training, regular emergency drills and tabletop exercises, and develop other ways to continually raise awareness regarding fire and other emergency events on site and with the community.
Updates	• Review and update the FRMP periodically and ensure requirements are appropriately implemented and that systems and features are fully operational.
Monitoring/ enforcement responsibilities	• Identify persons/entities responsible for implementing, monitoring and enforcing these measures, along with their roles, including for: * implementation and monitoring of FRMP requirements, * inspecting and maintaining fire and life safety systems, features, measures, etc. * creating awareness, conducting training, capacity-building and drills and * coordination with emergency responders. • Specify internal reporting requirements for issues that may arise.
Accessibility	• Make the information regarding measures accessible and available to all those on site.

Figure 22. Historic sites/structures are often used for functions that include using fire, such as cooking; therefore, fire prevention and preparedness procedures are critical.
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Beneficial impacts of preparedness and training – heritage sites in Japan

In Kyoto, Japan, the historic neighbourhood of Ponto-cho has numerous traditional wooden structures located along narrow alleys close to each other. Over the centuries the area has experienced many fires. In 2016, the local community and the emergency responders worked together effectively to combat another fire, extinguishing the blaze within a short period, and limiting the affected area to five structures. Prior awareness training and collaboration between the various entities helped to detect, notify and respond to this fire and halt its spread.

Source: Newman et al., 2020

2.2.2 On-site emergency response measures

During the response phase of a fire, an ongoing and dynamic interaction exists between the fire, the occupants, the structure/site and collections, and emergency responders. Operational and strategic measures can help coordinate these elements for a more effective response (Historic Scotland, 2005; Kidd, 2010).

Emergency Response Team Strategy (on-site team)

An on-site ERT should be established to manage the response phase. An ERT strategy should also be developed and include the following points in the preparedness plan:

- evacuation of occupants
- removal of objects and collections
- initial firefighting efforts while awaiting local emergency responders
- monitoring/mitigating the impact of fire on collections, contents and the structure and
- engaging with emergency responders.

Items incorporated into the ERT strategy that should be coordinated with other measures include:

- identifying the roles, responsibilities and contact details of the ERT members
- how to notify occupants and emergency responders and ensure communication throughout the event
- how to initiate evacuation strategies and account for occupants
- how to establish an incident command centre (location(s), information, etc.)
- the actions to be taken by staff such as shutting doors, shutting down equipment and utilities
- undertaking firefighting operations, if applicable
- securing/relocating contents (artwork, archives, furnishings, etc.)
- assessing the situation, monitoring and stabilizing occupants, contents, site and structures
- working with local emergency responders and identifying their needs, challenges, resources and required equipment
- plans to engage with the media and community, including volunteers that may arrive to assist
- the contact details of key stakeholders, contractors and other actors to assist, including pre-arranged contracts to help reduce response and recovery time and
- coordination of emergency equipment/supplies and pre-arranged agreements regarding emergency generators, refrigeration trucks, tarps, off-site storage and so forth.

Evacuation strategy/drills

Evacuation strategies should be implemented, and training and drills conducted, during the emergency preparedness phase to help create awareness, identify potential challenges and ensure people are aware of the strategy, measures to implement and how to evacuate safely.

Object removal strategy

It may be desirable to remove or relocate objects and collections during a fire. Risk reduction measures should limit this need, or at least reduce the quantity of items to be removed or relocated during a fire. This situation can be dangerous to firefighters entering a burning building in search and rescue operations for people who have re-entered the building to save collections. If needed, appropriate planning measures, training and equipment should be in place to ensure the process is undertaken safely. Below are important points to consider as part of this strategy (Kidd, 2010; Historic Scotland, 2005; Tandon, 2016).

- Determine what personal protection equipment is required to enter the site/structure while it is on fire such as protective gear, breathing apparatus and communications equipment.
- Identify who will continuously monitor fire conditions and potential structural collapse, the criteria used to determine whether removals should be stopped, and the qualifications and experience of personnel with these responsibilities.
- Establish how people will be notified to cease removal operations and evacuate immediately.
- Communicate with emergency responders regarding the status, number and locations of people in the structure, and the locations of objects being removed.
- Update an inventory list of objects to be removed, including their priority, weight, size and the number of people needed to remove each object.
- Specify the tools required to remove objects from walls and display cases, whether power will be available for tools, and the viability of carrying objects due to size, weight and any other factors.
- Estimate the time required to remove each object from its location, including access with equipment or ladders, removing screws, securing objects to walls and so forth.
- Provide the travel path and exits to be used for quickest access to the exterior.
- Stipulate where objects should be relocated as they are removed from the structure.
- Outline security measures, including inventory lists tracking each piece as it is moved outside the structure, into shelters and moving trucks, and as it arrives at off-site storage facilities.
- Establish how objects will be transported from the site, where they will be stored off site, and what environmental conditions and fire safety measures should be provided to protect them while in temporary storage facilities.
- Identify how the local community can be engaged to assist with this process and communicate appropriate procedures for them to follow to keep both the community and the collection safe.
- Determine which regulatory measures may impact accessing sites/structures during fires.
- Ensure coordination with local emergency responders and the resources they provide.

Object removal strategies may change depending on the event, location and the extent of fire and may reflect the need to be flexible and responsive to accommodate changing conditions.

Figure 23. In the removal strategy of artwork and collections, consider that significant time may be required to remove each individual piece, including if attached to walls or locked in display cases.

Approaches to improve the effectiveness of emergency preparedness measures

The following approaches can help increase the effectiveness of emergency preparedness measures.

- *Accessibility.* Ensure that emergency preparedness measures are easily available in multiple locations, both on and off site, and retrievable without entering a site/structure that may be on fire.
- *Consolidated.* All emergency preparedness measures should be kept together in a consolidated document.
- *Simple/clear/accurate.* Make measures simple, graphical and easy to understand. Consider that they may be read at night, or printed in only black and white, not colour.
- *Updated.* Any changes relating to hazards, systems, site conditions, best practices, recent incidents, feedback from training exercise, etc. should be reviewed and strategies updated as necessary.
- *Shared.* Emergency preparedness measures should be shared with stakeholders such as occupants, contractors, the ERT, local emergency responders, and community and tour agencies as applicable.

2.2.3 Awareness training/drills to support the implementation of preparedness measures

Following the development of the emergency response strategy, it is beneficial to undertake awareness-raising and capacity-building activities, as well as training and drills during the emergency preparedness phase with stakeholders and those on site such as staff, occupants, users, visitors and tour agencies to help with the successful management of a fire event and to reduce losses.

Awareness/capacity-building training programmes

Stakeholders should receive broad training, including the following components (Historic Scotland, 2005; Kidd, 2010; Maxwell, 2007).

FIRE SAFETY TRAINING/AWARENESS-RAISING

Stakeholders require training in overall risk reduction, preparedness, emergency response and resilient recovery procedures in general, as well as procedures specifically developed for the site/structure and its unique characteristics, exposures and vulnerabilities. Key issues include:

- fire hazards, fire behaviour, ignition sources and combustible materials
- risk reduction measures and fire protection systems
- egress system components and their locations
- strategies (FRMP, fire prevention and preparedness, evacuation strategy, emergency response, evacuation, collections removal, ERT procedures)
- roles/responsibilities and
- the use of manual firefighting and other emergency equipment.

FIRST RESPONSE FIREFIGHTING (FIRE EXTINGUISHERS)

Persons undertaking firefighting-related duties should be trained to know the locations and proper use of fire extinguishers and other manual firefighting equipment, as well as how to keep themselves safe during use.

EVACUATION TRAINING/DRILLS

Occupants should be familiar with evacuation including, for instance, their assigned duties, alarm signals, evacuation routes, designated meeting areas and evacuation procedures.

EMERGENCY RESPONSE TEAM TRAINING

The ERT should be trained on their roles, responsibilities and actions during a fire or other emergency event.

DRILLS

Drills should be conducted frequently with occupants, the ERT, the site manager and emergency responders.

FREQUENCY

Training and drills should take place frequently (at minimum every 6 months), including at the following times: during the development of the initial FRMP; change in personnel and new hires; change in or with the introduction of new hazards, processes and systems; changes or updates in emergency response strategies and procedures; and prior to work-related to construction or renovation.

Figure 24. Fire safety equipment may require training to be properly located and used by the Emergency Response Team members and other stakeholders.
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DOCUMENTATION

All training and drills should be documented, including the time, attendees, content, duration and so forth.

2.2.4 Fire preparedness planning to be undertaken with emergency responders

There is considerable benefit in working with local emergency responders, including in preparatory work at the site/structure in case of fire and other emergency events. This includes helping inform emergency responders about the emergency response tailored to that specific site/structure. This provides an opportunity to discuss unique and sensitive areas as well as structure and contents that are present and need to be handled with care.

Conveying information to emergency responders

The goals and benefits of pre-planning with local emergency responders include (Cooper, n.d.; McLean, 2012; STORM, 2017):

- helping them understand the importance of, and need to protect, the site, structure and collections, and limiting damage during firefighting and salvage efforts
- understanding the site/structure so responders can more effectively fight a fire (e.g., site access, building access, layout, entrances, exits, command centre, fire systems, occupant gathering locations, exposures, vulnerabilities, hazards, and locations of sensitive collections, contents, furnishing, interiors)
- clarifying information regarding occupants, such as their number, location and special needs
- securing the evacuation strategy, including location routes for evacuating occupants versus emergency responders accessing the structure and bringing in equipment
- transmitting details of fire protection equipment, including the fire alarm panel, sprinklers, standpipes, fire hydrants and fire extinguishers
- understanding specific challenges such as hazardous materials, access to remote spaces, the operation of equipment on site

- participating in training drills on site and
- obtaining their assistance following the event, given how critical time is to halting ongoing damage such as the risk of collapse and mould.

Providing emergency responders with plans/maps and related pertinent information will assist them in their work. This graphic information should be clear and take the form of dedicated, consolidated maps that show:

- site details like access, layout, roads, driveways, occupant gathering points
- structures, including entrances, stairs, exits, command centre
- sensitive, unique, vulnerable characteristics of the site/structure
- collections, exhibits, art, critical contents (layout, protection systems)
- life and safety features/fire protection systems
- firefighting systems, equipment, resources (hydrants, extinguishers etc.)
- compartmentation (fire separation walls, floors/ceilings)
- water supplies (location, quantity, pressure, flow rates)
- utilities (shut-off valves for gas, water, etc.) and
- hazardous materials (type, quantity, locations, protection).

Figure 25. Emergency response systems on site need to be maintained to ensure operationality.
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Gathering information from emergency responders

It is beneficial to gather information from emergency responders to help understand their operations, resources and capabilities, as well as how they might fight a fire at a specific site/structure and the associated firefighting challenges they foresee. This information can help inform overall risk reduction measures, including information related to the following:

- how emergency responders will be notified of a fire condition, or other emergency event
- alternative means to expedite notification of an emergency event
- response timeframes, including how long it may take from notification to arrival on site, time to setup and start discharging water, and time to extinguish the fire
- available resources (personnel, equipment, gear, types/capacity of vehicles)
- ease of access to the structure/site for emergency response equipment
- type of access needed around the site/structure
- amount of water needed and from where it will be sourced
- need for ventilation of heat, flame and steam from each space and how this will be achieved
- accessibility of each area throughout the site/structure (above and below ground levels, attics, roofs, remote areas for fire vehicles)
- whether the fire will be fought from the inside, or externally
- resources needed on site to help more effectively fight fires (access into the site/structure, water supplies, standpipes, fire hydrants, etc.)
- challenges foreseeable on site and options to help address them
- possible assistance with collections removal and/or allowing others to assist
- periodic reviews to assist in helping to identify hazards, and updating the response plan as necessary and
- participation by emergency responders in on-site training activities and drills.

Community engagement – emergency preparedness-related activities

Communities can help with emergency preparedness in numerous ways.

Training of citizens in protecting heritage. Emergency responders can help develop programmes to create awareness and train the local community, including site managers, owners and tourists. This includes preventing, detecting and responding to fires.

Disaster Imagination Game (DIG). This highly participatory activity can help engage the local community and emergency responders. It involves workshops, tabletop exercises and role-playing activities to help community and emergency responders understand and identify risks and the various risk reduction and response measures. DIG has been used successfully in Japan.

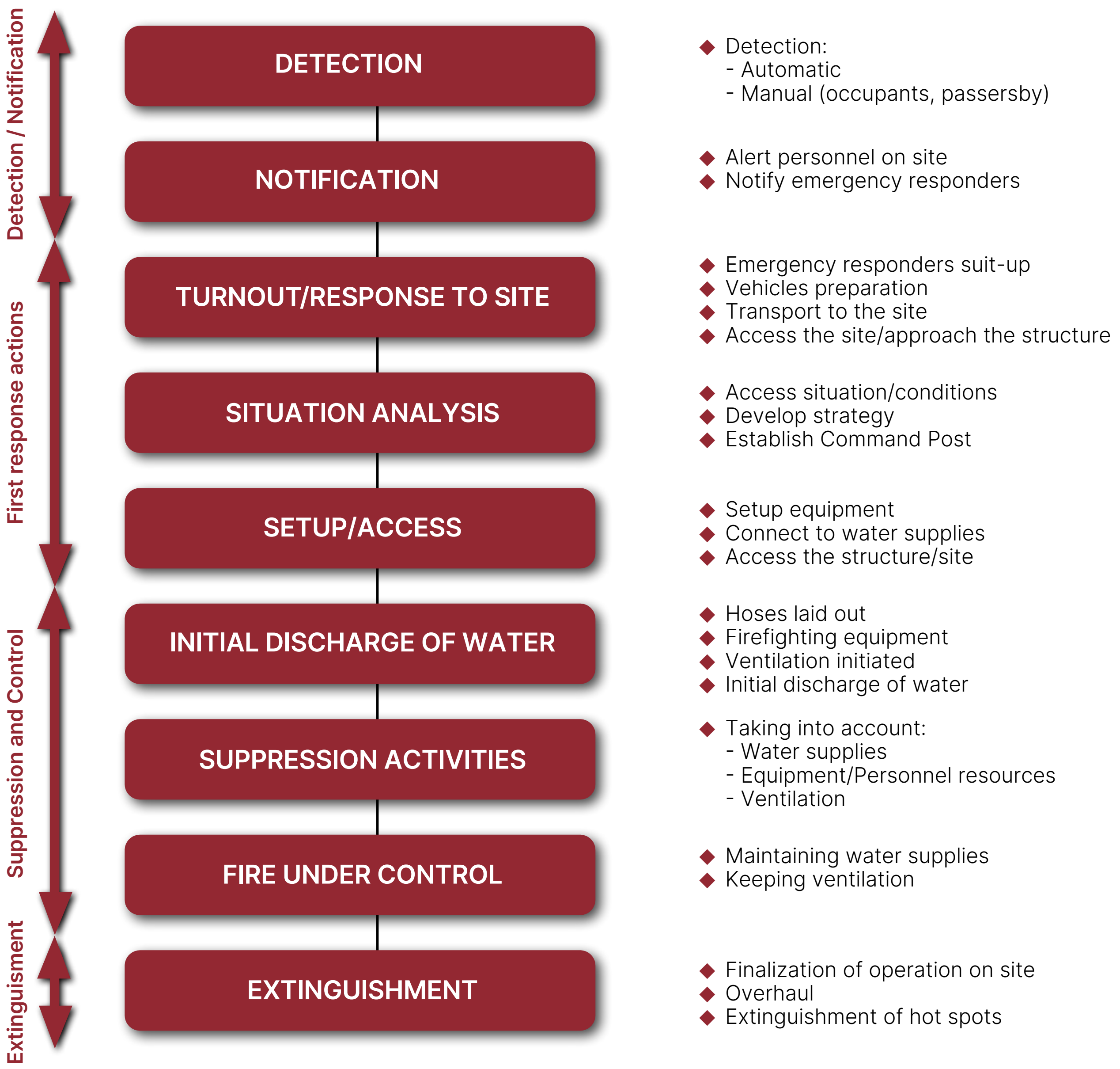
Heritage sites and emergency responder liaison meetings. Since a number of entities are involved with heritage sites and structures, as well as emergency response, it is beneficial to coordinate meetings among these stakeholders to discuss and address risks related to fires and other disasters. In Japan, the Kyoto Cultural Properties Disaster Prevention Measure Liaison Meeting (Kyoto Bunkazai Bosai Taisaku Renraku Kai) established a group to protect cultural properties from disasters, including stakeholders from a variety of heritage and emergency response entities.

Fire Prevention Awareness Day. Local communities, municipalities and emergency responders can designate a specific day of the year as Fire Prevention Awareness Day for Heritage Sites and Structures. In Japan, for instance, various awareness-raising activities take place annually on 26 January.

Source: Newman et al. 2020

2.3 Emergency response

Figure 26. Fire emergency response steps



2.3.1 Main challenges to be addressed during fire emergency response

Time is critical in a fire as flames spread quickly. Numerous activities must be undertaken in a timely manner and with appropriate resources to effectively control and extinguish the fire quickly.

When developing the FRMP, it is critical that the components comprising the various steps in emergency response are assessed, including their impacts on time and resources. This should then inform the provision of risk reduction and response measures.

For emergency responders, the following impacts on response should be further understood and addressed appropriately to help expedite an effective response (Historic Scotland, 2005; Kidd, 2010; Maxwell, 2007; NFPA, 2020). On-site emergency response will be undertaken as previously noted by the ERT.

Reducing detection and notification time

Potential delays related to notification of occupants and emergency responders should be reduced, or eliminated, including by providing smoke detection throughout applicable spaces, and automatic notification to occupants and emergency responders.

Common findings regarding fire response

- Time is critical. Reducing response time to fires limits damage.
- Detecting the fire early, notifying emergency responders and getting them to the site to suppress the fire in the shortest time possible, with appropriate resources, is critical to reducing damage and injuries.
- Areas where delays can occur should be identified and mitigated as they allow the fire to grow unchecked.
- Emergency responders may have limited resources available (e.g., vehicles, equipment, personal protection equipment, personnel).
- Sites and structures may have limited resources available to assist in firefighting effectively (e.g., enclosed stairs, standpipes, adequate water quantity and pressure).
- Once fires grow past a certain size, they may be beyond the physical capability of emergency responders to extinguish.
- A tailored response strategy developed with local emergency responders, and coordinated within the FRMP, is beneficial to understanding the challenges and identifying applicable risk reduction measures.

2.3.2 Key factors regarding response time

Pre-response turnout/preparations

The time from the notification of emergency responders to the departure of equipped vehicles to the site should be understood clearly. It is critical to account for potential delays, such as firefighters responding to another fire, or another emergency event, or lack of a permanently-staffed fire station (i.e., volunteer departments).

Response time to site

Factors that can affect the time it takes to arrive at the site include:

- traffic, weather
- responding to a previous fire
- long travel times due to remote location and
- obstructions linked to prior events (e.g., blocked roads after flooding, earthquakes).

Examples of challenges to fire response times and access

Communities can help with emergency preparedness in numerous ways.

Training of citizens in protecting heritage. Emergency responders can help develop programmes to create awareness and train the local community, including site managers, owners and tourists. This includes preventing, detecting and responding to fires.

Rural and remote areas. Bhutan's Taktsang Palphug Monastery (Tiger's Nest), located on the cliffs of the Paro Valley mountains, which was burned down on 19 April 1998. Access involved a three-hour hike with no possibility for vehicles.

Urban areas. The Sao Paolo Fire Brigade at times sends initial responders ahead on motorcycles to get through traffic faster than trucks.

Islands. St Michael's Mount, Cornwall, United Kingdom becomes an island for 16 out of each 24 hours due to tides, increasing response time to at least 45 minutes.

Lagoon/islands. Venice is a series of islands situated in a lagoon and firefighters use fireboats to reach sites through canals and employ handheld ladders to scale buildings and reach heights.

Access to the site and structure

Several measures can reduce challenges and the time required to get equipment on site, including by:

- confirming vehicles fit through gates and fences and other potential barriers and that these are not locked
- ensuring roads, driveways and paths are of sufficient width and can bear vehicle weights
- making sure that non-emergency vehicles are not parked adjacent to the structure on streets so that emergency responders can set up their equipment in close proximity to the site
- providing multiple access points to the site/structure where possible and
- preparing contingency plans in the case of demonstrations, strikes, armed conflicts and so forth.

Figure 27. Narrow streets make access and setting up equipment difficult for emergency vehicles.
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Situation analysis

Put in place measures to assist emergency responders in gathering information on occupants, the site/structure, collections and the fire itself and develop an informed strategy for search and rescue and firefighting operations. Essential information includes:

- whether occupants are still in the building, and their locations and condition
- the extent of the fire spread and the collapse potential (area of origin, current involved areas)
- firefighting resources (water supplies, enclosed stairways, standpipes, etc.)
- fire alarm information (first detector to activate, extent of spread, etc.) and
- locations for establishing the command centre.

Equipment of emergency responders

It is vital to have appropriate firefighting equipment available for firefighting operations (see Table 9). Absence of this equipment may impact firefighting, search and rescue operations, and the removal of collections. Consider other risk reduction measures, including providing automatic fire suppression systems to help address these challenges and reduce damage and losses.

Table 9. Firefighting resources (typical)

Firefighting resources	Primary means
Water	Fire hydrants (sufficient pressure, flow rate, duration)
Pumps	Fire engine/pumpers (pressurized water to reach high/remote areas)
Ladders	Ladder trucks (up to 25 m high reach)
Personal protection and other equipment	Turn-out/bunker gear and breathing apparatus Tools, equipment (hoses, saws, axes, etc.)

Equipment/resources on site

Providing resources on site for emergency responders, including fire protection equipment, fire extinguishers, fire-rated access routes, standpipes and sufficient water, are highly beneficial.

For structures that have equipment, it is important to ensure compatibility with the local fire department's equipment (i.e., fire hoses must be compatible with the threads of equipment on site).

Examples of challenges emergency responders can face once on site

Wangduephodrang Dzong Fire. In Bhutan, firefighters used a water tank truck to fight the fire. After short periods, they needed to drive back down to the river, refill, and drive back to the fire, during which time the fire continued to expand.

La Fenice Fire. During the fire at La Fenice in Venice, where the Vigili del Fuoco uses fire boats, challenges arose in reaching high places with ladders. In addition, as the Vigili del Fuoco depends on the canals to get close to buildings, drainage/cleaning of the canals near La Fenice at the time of the fire created further challenges in fighting the fire.

Shangri-La Fire. During the night of the fire in Yunan Province China, the hydrant water supply was shut down due to freezing weather, which caused delays in accessing water for firefighting, and allowed the fire to expand.

Regulatory requirements

Codes, laws and other regulatory requirements may present additional requirements impacting emergency response and operations, including some related to access to structures, control and securing sites, overseeing emergency operations, entering structures to remove contents, investigations and scene documentation.

Numbers of firefighters and mutual aid

Fires require many emergency responders. Additional assistance may therefore be required from adjacent towns and this requires advance coordination.

Examples of duration and number of emergency responders and required equipment in response to various fires

Even with a lot of responders and emergency equipment, there was still significant damage to each of these structures (NFPA, 2021b; NFPA, 2021c).

Fire	Duration (hours)	Emergency responders	Vehicles
York Minster, United Kingdom, 9 July 1984	3+	150	Unknown
Los Angeles Library, 29 April 1986	7.5	350	60
Central Synagogue, New York City, August 1998	3	250+	45
Le Manège militaire de la Grande Allée à Québec, April 2008	Unknown	125	25
Universal Studios, California, 1 June 2008	18	400	Unknown
National Museum, Prague, 12 Feb 2016	2	150+	Unknown

Figure 28. Scaffolding, gates, locks, debris and other objects can block firefighting efforts.
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2.3.3 Additional activities of emergency responders during the response phase

Emergency responders not only fight fires but they also undertake other activities requiring equipment and personnel. It is crucial to account for these needs.

Search and rescue

Emergency responders prioritize search and rescue operations with a view to securing the safety of occupants. Early detection and notification should therefore be provided and coupled with on-site training and drills for occupants. Training will help ensure safe evacuation, allowing emergency response-related resources to focus on controlling and extinguishing the fire.

Removing/saving contents and collections

Emergency responders have at times assisted in removing contents and collections (FireRescue, 2018). As there is considerable risk with such activities, they should be discussed and agreed in advance with emergency responders, and appropriate procedures, personnel protection and equipment put in place. The time, tools and number of people required to remove each piece needs to be accounted for, as well as how their safety amidst developing fire conditions will be monitored.

2.3.4 How fires are eventually extinguished

While a fire may take hours to extinguish, it will ultimately be controlled due to a lack of combustible materials to burn and/or the effective application of sufficient extinguishing agents. Additional time and resources are needed to confirm that all hot spots are out and to limit the chance of the fire re-igniting.

The resources and time needed to undertake various response-related operations should be accounted for in risk reduction measures (i.e., sprinklers, standpipes, protected routes, water supplies, etc.), as well as in prevention and mitigation measures. These should be in place ahead of time to enable early notification and response so that the fire can be readily managed and extinguished by emergency responders.

Traditional knowledge response

Water cisterns for firefighting water. At the World Heritage Sites of Berat and Gjirokastra in Albania, fire is one of the most damaging hazards. Part of this damage has resulted from limited supplies of water and the narrow streets that impact firefighting operations and accessibility. Heritage structures present unique opportunities and resources to address this issue. A pilot project explored the potential of using traditional large cisterns in various houses as part of a dispersed water resource system that firefighters and residents could use to respond quickly in the event of a fire outbreak.

Source: Mamani, 2017

Figure 29. Firefighting equipment may vary in each city (pumpers, ladders, water tankers, etc.) so it is critical to understand existing resources and capabilities.
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2.4 Recovery, rehabilitation and building back better

The Recovery Phase typically consists of four primary steps:

- damage assessment
- treatments
- resilient recovery/rehabilitation/building back better
- reoccupation.

Detailed measures to address each of these steps should be developed and include the following elements (Historic Scotland, 2005; Kidd, 2010; Maxwell, 2007; NFPA, 2021c).

Cause/origin assessments

Prior to undertaking treatment and salvage efforts, discussions should be initiated with stakeholders – such as building officials, insurance companies and emergency responders – and include cause and origin investigations. At times, it will be necessary to document the site prior to starting the recovery phase through collecting and preserving evidence, undertaking analyses to assess where and how the fire started and why it spread as it did and ascertaining whether systems operated as intended. It is vital, therefore, to not disturb the scene. These assessments can take time to initiate and get appropriate personnel on site. Such delays should be considered conservation work and salvage-related activities may not be able to commence until these assessments have been completed.

Ensuring all fires and hot spots are extinguished

Precautions should be made to ensure the fire is out completely. Small fires may persist in areas with smouldering debris, and concealed combustible spaces may still be burn. Caution should be taken to ensure that this does not occur, and that emergency responders confirm all fires and hot spots are fully extinguished.

Shutting down utilities

Utilities can introduce ignition sources (electric), fuel sources (gas) and additional water damage (plumbing). These should be shut off to avoid the creation of another fire and/or explosion following the initial blaze or water damage.

Health and safety rules

Health and safety rules should be followed to protect personnel on site. This includes proper procedures, training and use of suitable safety gear (e.g., protective clothing, gloves, goggles, breathing apparatus/respirators, etc.), monitoring of air quality and site conditions and following requirements for accessing confined spaces.

Containing potentially contaminated firefighting run-off water

Fires generate many toxic products that can enter firefighting runoff water and contaminate soil, as well as local groundwater, streams and other bodies of water. Measures to avoid this should include containing the water and assessing whether it poses a hazard, and, if necessary, identify means for its proper containment and disposal.

Structure/façade/foundation assessments

Assess the overall structure, including structural elements (beams, columns) and connections, floors, ceilings, roofs, façades and other features such as domes and steeples. These structural elements are impacted by heat, flames and suppression materials and can adversely impact their ability to continue to support structural loads. (e.g. steel, cast iron).

Fire-proofing materials can also spall, or break into smaller pieces, and fall off during a fire, while materials such as intumescent paints may expand and require replacement.

Persons with expertise in historic structures and structural systems should participate in the assessment. Work needs to be undertaken in conjunction with local authorities, including to assess structural stability and potential public safety concerns, and to help identify ways to support and keep the structure in place, rather than tear it down prematurely.

Evacuation and exit system

An assessment of the exit system should be undertaken post-fire, including to establish which exits are still available for use. It is important to know if part of the structure remains occupied, as the evacuation system may incorporate the damaged area and may be neither accessible nor safe.

Additionally, during the recovery phase, it is necessary to ensure safe ways to readily evacuate those inside from salvage areas.

Figure 30. Evacuation/exit systems should be assessed to ensure the safety of people undertaking recovery and reconstruction efforts.
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Assessing fire-damaged fire-rated separations

Assessments of fire separation should be undertaken by experts in fires and structures. Many materials lose their fire resistance once exposed to high temperatures or to water. Other materials can spall, leaving less material and lowering its fire resistance rating. These materials should be replaced as necessary. Doors should be assessed as well to determine if the remaining material and thickness after burning can still achieve the intended fire rating.

Minimizing ongoing damage

Damage can continue to occur even after the fire has been extinguished.

- Smoke and soot can be acidic and adversely affect many types of materials, including through discolouration as it adheres to surfaces.
- Water and suppression agents can cause damage to the structure, equipment and materials, including corrosion, mould and mildew.
- Temperatures and humidity levels can precipitate the growth of mould and mildew, as well as impact the structure, finishes and contents, including due to both high and freezing temperatures.

Water removal

Water should be removed as early as possible, especially where it has pooled or settled on lower levels, thereby enabling the structure and contents to dry out as quickly as possible. This helps limit ongoing damage and the development of mould and mildew, improves air quality and reduces the chance of pooled water becoming a breeding ground for insects. In cold weather areas this can also reduce the impact from freezing water. Care needs to be taken where water may be contaminated, and appropriately addressed where this is the case.

Air quality

Fires create a significant number of toxic by-products. It is critical to continually monitor air quality and take appropriate precautions (e.g., self-contained breathing apparatus, etc.) through mitigation measures to improve air quality. This will create a safer work environment and limit further damage to the structure, contents and systems from exposure to toxic products (e.g., lead at Notre Dame Cathedral).

Hazardous materials

Care should be taken when identifying and handling materials. Hazardous materials need to be identified early on and removed as soon as possible by persons with expertise and appropriate equipment, including breathing apparatus. Attention should also be paid to overall air quality throughout the structure, including in lower levels, confined spaces and other areas with limited ventilation.

Fire and life safety systems and building systems

Assess fire and life safety systems (fire alarm, suppression systems, etc.) and all building systems, including electrical, lighting, mechanical and plumbing systems to determine the extent of damage. These systems, or parts thereof, should be repaired or replaced, as necessary. Fire and life safety systems should be prioritized and returned to working order even in a phased manner so as to continue to protect the historic site/structure and occupants. Efforts to make building systems operational again help restore the environment and protect contents.

Fire risk management plan during salvage and restoration work

Fires can occur during the recovery phase, including during treatment, salvage and restoration work. They may be caused by salvage-related operations and equipment (e.g., cutting/welding, open flames, temporary lighting) as well as electrical equipment that may have been damaged and not repaired (e.g., corrosion, short circuits, overheating).

FRMPs should include ways to reduce risk of fire during this period, as well as detail how to put in place mitigation measures should a fire start. Plans should outline how to detect, notify, control and extinguish the blaze, as well as address the personal safety of workers (see Part 2 for additional details).

Separate/contain damaged from undamaged areas

If only parts of the site/structure are damaged, consider separating the damaged areas from the undamaged areas to limit the chance of fire in the area undergoing restoration.

Personnel, equipment and materials

Numerous personnel, resources and equipment will be needed during salvage and recovery efforts. These should be identified beforehand (e.g., contractors, freezer trucks, dehumidifiers, air scrubbers, air movers, rubbish dumpsters, emergency generators, lights, materials to board up openings). It is beneficial to have agreements in place ahead of time to expedite the process.

Building back better

The site/structure should be reassessed and include lessons learned from the fire, and the FSMP updated as needed. This should feed into the overall reconstruction/renovation plan to create a more resilient site/structure following a fire.

Figure 31. Fire safety systems should be checked to ensure they are operational after a fire occurs.
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03 Special considerations during renovation and construction activities at cultural heritage sites and structures

Fires during renovation and construction periods continue to devastate numerous heritage structures and sites. Table 10 provides an overview of several of these fires.

Whether renovation and construction work is undertaken on a site/structure, or an adjacent, neighbouring site or structure, a specific FRMP should be developed and tailored to address the increased and existing risks, and to propose ways to reduce these for the entire duration of the work. Local laws, codes and other applicable regulations will also need to be identified and addressed.

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Table 10. Fires that occurred during construction and renovation work

Nantes Cathedral (France, 1972)	Universal Studios Original Master Recordings (United States, 2008)
Uppark (England, UK, 1989)	Sao Pedro de Alcantara Chapel (Brazil, 2011)
Windsor Castle (England, UK, 1992)	Smithsonian National Museum of Natural History (United States, 2011)
Teatro Petruzzelli (Italy, 1991)	Wangduephodrang Dzong (Bhutan, 2012)
La Fenice (Italy, 1996)	Novodevhichy Monastery (Russian Federation, 2015)
Central Synagogue (United States, 1998)	Saint-Donatien Basilica (France, 2015)
Harbin New Synagogue (China, 2004)	Museum of the Portuguese Language (Brazil, 2015)
Duchess Anna Amalia Library (Germany, 2004)	Lingguan Mansion (China, 2017)
St Catherine's Church (Poland, 2006)	Jiulong Temple (China 2017)
Trinity Church (Russian Federation, 2006)	Glasgow School of Arts (Scotland, UK, 2018)
Cutty Sark (England, UK, 2007)	Notre Dame (France, 2019)
Le Manège Militaire (Quebec, Canada, 2008)	Old Stock Exchange (Denmark, 2024)

3.1 Why does the risk of fire increase significantly during renovation/construction periods?

Heritage sites and structures are not only exposed to vulnerabilities, hazards and risks during typical day-to-day operations, they also face a significant increase in risk during renovation and construction.

Numerous common themes emerge in the assessment of past fires during renovation and construction regarding how they start, develop and spread, as well as the performance and/or effectiveness of risk reduction measures, if these are present. Typically, fire hazards are increased while risk reduction measures are reduced. Additional delays, impairments and challenges exist for emergency responders as well. These challenges include: delayed notification often due to lack of automatic detection and/or automatic notification; significantly increased challenges regarding access to the site/structure for emergency responders due to temporary fencing, scaffolding, heavy equipment and security measures; limited water supplies; limited or obstructed fire hydrants; unenclosed stairways and limited protected access routes to upper levels; and constrained functioning of fire protection equipment, standpipes and hose outlets (Captain, 2019; Historic England, 2017; Kidd, 1995; Middlemiss, 2019).

Table 11. presents a brief overview of these challenges, along with the increased vulnerabilities of sites/structures during renovation and construction activities.

Table 11. Fires during construction and renovation activities: common findings, vulnerabilities and Implications

Changes to risk reduction measures		Implications
Increased ignition sources	Significant increase in the number, type and intensity of ignition sources, in addition to those already present, including: • hot works (cutting, welding, open flames) • high temperature lights (halogen, incandescent,) • temporary lighting • temporary electrical wiring, equipment • high current-drawing equipment • heaters • intentional fires	There is increased potential for ignition due to the additional quantity, intensity, type and distribution of ignition sources during this time, including intentional fires. Work on the exterior introduces new, additional ignition sources and exposure in areas that may not be protected by sprinklers, smoke detectors, etc.
Increased combustible materials	Significant increase in the quantity, type and location of combustible materials throughout the site/structure, in addition to combustible materials already present, including: • construction materials • construction debris, rubbish • site trailers • packaging materials for equipment, systems • combustible scaffolding, planks, etc.	Fast-growing fires of longer duration are created by significant quantities of combustible materials introduced, including on the exterior and interior of the site/structure.
Loss of compartmentation	Increased lack of fire separations on floors and between floors, including due to: • new holes in walls and ceilings to run new equipment, utilities • doors blocked open, or removed for restoration • new, unprotected penetrations in floors, ceilings, walls • walls opened up/removed	Increased lack of fire separations and lack of compartmentation further enable fire, heat and smoke to spread horizontally and vertically beyond the area of origin, and potentially throughout the entire structure.
Lack of fire detection	Fire detection systems often not present. If there is a detection system, this is typically: • not operational (neither maintained, installed, repaired nor upgraded) • impaired (e.g., detectors covered over to limit nuisance alarms from dust) • detectors not located in the area of origin.	Significant delays can arise in detecting a fire, as well as in alerting occupants and notifying emergency responders if there is no detection system present nor operational, and/or if smoke detectors are not located near the fire. Very few systems automatically notify emergency responders.
Lack of automatic notification of emergency responders	Frequent lack of means to automatically notify emergency responders when a fire is detected.	Significant delays to emergency responders as well as to ERTs on site.
Lack of automatic suppression systems	Automatic suppression systems are typically not provided to limit fire spread. When systems are provided, they typically are: • not operational (not maintained, are being installed or upgraded, etc.) • impaired (sprinklers covered over, not in area of origin, no water supply, valves shut off, etc.) • not designed to address the significant increase in hazard.	Fires will continue to grow and spread, at times beyond the capacities and resources of emergency responders and will affect significant portions of the structure not fitted with sprinklers.
Lack of manual suppression resources (e.g., fire extinguishers, standpipes, wool blankets)	Lack of equipment to assist occupants and emergency responders in manual firefighting operations. Limited detection and alerting of occupants available, to enable use of suppression systems while the fire is still small.	Small fires that could potentially be extinguished with early detection and manual suppression equipment will row and spread quickly.
Lack of structural protection	Limited fire ratings of structural elements (beams, columns, floors, roofs, facades, steeples, domes, etc.) exist and/or may be in the midst of repair or upgrading.	The potential for premature structural collapse (floors, roof, facades, domes, steeples, etc.) is increased.
Lack of awareness, training, drills	Limited knowledge of stakeholders and those on site (e.g., contractors, craftspeople) regarding fire safety challenges and procedures, and lack of training or drills.	Activities that increase fire risks will persist.
Lack of a FRMP tailored to this work	Limited fire risk assessments, risk reduction measures, emergency preparedness, emergency response and resilient recovery strategies and measures.	Limited risk reduction measures and planning in place increase the risk of significant potential damage to the site, structure and contents.

3.2 Additional risk management measures to be implemented during renovation and construction

is critical to develop an FRMP specifically to address renovation and construction activities and increased risks during this time (Maxwell and Chatham, 2020). This FRMP should be approved by all stakeholders and regulatory agencies prior to the start of any work – whether to the structure, floors, rooms or even exhibits and display cases. Risk assessments and the development of risk reduction measures should address existing conditions, including those detailed in Parts 1 and 2, as well as ignition sources, combustible materials and impacts on prior risk reduction measures because fire-related risks often increase significantly during this time.

3.2.1 Risk reduction measures to consider during renovation/construction

During restoration, renovation and construction related activities risk reduction measures should be undertaken including the following (Captain, 2019; Historic England, 2017; Kidd, 1995; Middlemiss, 2019; NFPA, 2021c).

Ignition sources

The risk reduction plan should include measures to minimize existing ignition sources as well as identify and reduce any new ignition sources that have been introduced. These include electrical systems (equipment, lighting, wiring), hot works, smoking, cooking, heating, arson and intentional fires.

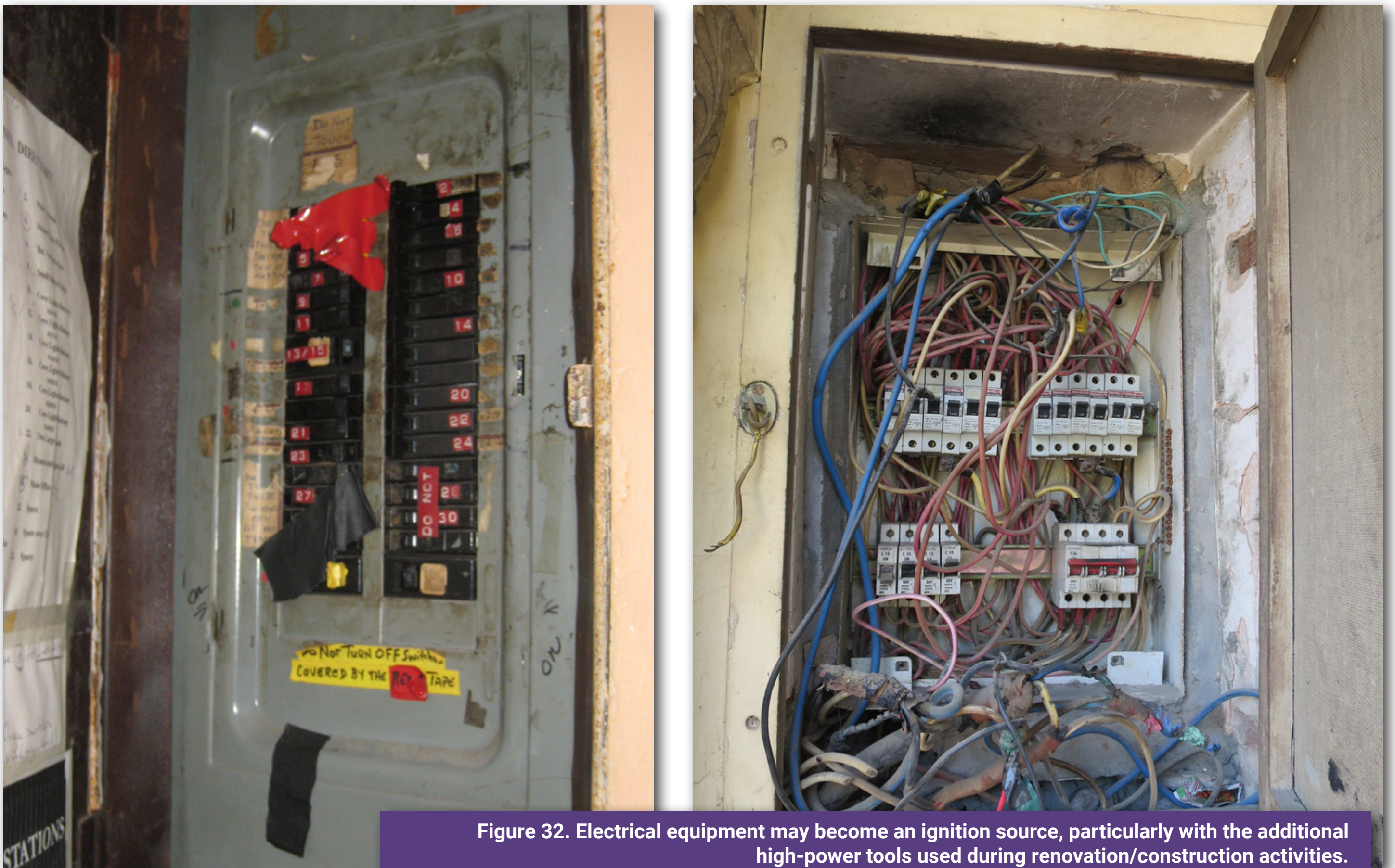

Figure 32. Electrical equipment may become an ignition source, particularly with the additional high-power tools used during renovation/construction activities.
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Identification of potential ignition sources and considerations for preliminary fire prevention measures

The following is a broad overview of examples and is not intended to be a comprehensive list (NFPA, 2022c; NFPA, 2021c).

Electrical systems (equipment, lighting, wiring)

- Ensure all newly introduced electrical systems, equipment, lighting, etc. are appropriately designed and installed by qualified personnel, and address local, applicable requirements.
- As existing electrical equipment, wiring, circuit breakers may be used, assess and confirm they are appropriate for use, and support the capacity needed for any equipment that may be used.
- Engage a qualified and experienced electrical contractor to frequently review the site and installations during the work, as well as to ensure that sources of ignition are mitigated, including:
  - temporary electrical equipment, including wiring, outlet boxes, circuit breakers
  - large, high heat-output portable space heaters (gas, electric)
  - high current-drawing equipment, including saws, drills, motors
  - use of appropriate extension cords, rather than multiple extension cords and outlet strips
  - temporary lighting, ensuring it is appropriately and permanently affixed
  - lighting, ensuring low temperature lights/fluorescent lights are used rather than high wattage/high temperature lights
  - potential overloading of existing electrical system by heavy equipment, undersized wiring, breakers, etc. and
  - ungrounded lightning protection systems.

Hot works(Ref)

- Remove all hot works from the site and use alternate methods if possible (hot works include cutting, welding, brazing, open flames, heat coils, blow torches used in construction work for stripping paint, re-roofing operations, welding operations).
- Remove all hot works from structures to a safe, remote location where work can be performed.
- Develop, implement, train, monitor and enforce a hot work permit programme (for further reading, see Factory Mutual, 2003; NFPA, 2024, NFPA, 2021b).

Smoking

- Prohibit smoking throughout site, including scaffolding, roof areas, remote areas.

Cooking

- Prohibit cooking on site, on scaffolding, roof areas, remote areas.
- If cooking cannot be prohibited, establish a designated safe location away from the site/structure. Develop appropriate cooking procedures and provide fire extinguishers.

Heating equipment

- Use heating equipment appropriately, including by placing on non-combustible surfaces, using listed/approved equipment, avoiding extension cords directly adjacent to fire extinguishers and ensuring safe separation distances to combustible materials.

Arson/intentional fires

- Address the risk of potential arson-related fires, given the significant quantities of combustible materials, limited protection, limited security and an unoccupied site.

Spontaneous ignition

- Prohibit the use of materials that can lead to spontaneous combustion (e.g., linseed oil).

Sources: NFPA, 2022c, ; NFPA, 2021c

Combustible materials

It is important to identify combustible materials usually present on site daily, including those noted previously, as well as large quantities of combustible materials introduced during renovation or construction-related works. (Captain, 2019; Middlemiss, 2019) These may include the following:

- construction-related materials (e.g., wood, scaffolding, security fencing)
- construction trailers, site huts, sheds, trailers, etc.
- flammable/combustible liquids (e.g., solvents, cleaners, paints, kerosene, petrol/gas)
- flammable/combustible gases (propane, acetylene, butane, oxygen, etc.)
- combustible tarps, drop cloths, coverings
- exposed wood, lath upon removal of plaster, wallboard, etc.
- rubbish, debris; and
- storage (construction materials, combustible packaging, equipment, etc.).

Measures to reduce these risks may involve:

- removing/reducing the quantities of combustible materials (keep a maximum one-day supply)
- regulating/prohibiting their use on site
- relocating/isolating them to safe, protected areas
- replacing them with non-combustible materials
- mitigating the hazard they represent and
- in the case of rubbish, ensuring their removal each day from the site/structure.

Figure 33. Ignition sources in proximity to combustible materials increase the probability of ignition.
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Automatic detection and alarm systems

Means should be provided to automatically detect a fire as early as possible (automatic detectors, manual pull stations, etc.) with some form of detection operational 24 hours a day to detect a fire as early as possible.

If a detection and alarm system is present, ensure:

- the system is operational and not shut down for repairs, or replacement
- that temporary covers placed on detectors used to prevent debris, dust, etc. from causing false alarms, are removed at the end of each workday
- that it provides automatic notification to all occupants and
- that it automatically transmits an alarm to emergency responders.

If no automatic detection/alarm system is present and operational, or detectors are not provided throughout the site/structure or are covered by protective covers, provide a manual means for detection and notification such as a fire watch, and potential early suppression.

Manual detection and alarm/notification – fire watches

Continuous fire watches should be undertaken throughout the day and night to reduce the chance of a fire, and to provide early detection if no automatic fire detection/alarm system is available. These inspection rounds throughout the site/structure should be frequent and include one or more persons depending on the size of the site/structure and time to make rounds. The inspections should continually observe the entire structure/site for a fire, and potentially unsafe conditions.

The person(s) undertaking a fire watch should be trained and have the means to immediately notify occupants (e.g., alarm, bell, bullhorn, air horn), as well as the ability to notify emergency responders without delay, contact the site manager and undertake appropriate response measures.

Compartmentation/fire separations

Measures should be in place to ensure that compartmentation is not compromised, avoiding the spread of fire/smoke:

- A compartmentation strategy should be developed and implemented to help contain a fire and prevent it spreading to other areas or floors.
- Compartment areas under renovation or construction should be isolated from those areas where no work will occur.
- Openings where doors may have been removed for refurbishment should be protected to limit the spread of fire and smoke.
- Doors should not be held/blocked open.
- All doors should be closed at the end of each work period, and at the end of each day.
- Unprotected penetrations for new services must be protected as soon as possible.
- Only limited penetrations should be made in floors, ceiling and walls for repairs, running utilities and HVAC systems. They should be no larger than needed and appropriately fire-protected as soon as possible after being made.

Automatic fire suppression systems

Automatic fire suppression systems should be left operational throughout the period of construction. Ensure that:

- they are not shut off
- water supply is continuously available
- discharge is not obstructed by construction material, equipment, etc. and
- combustible loads do not exceed the design capacity of the system.

If the system is impaired for any reason due to renovation or maintenance work, or is being expanded, a strategy needs to be developed and in place to limit downtime to a minimum and ensure that all parts of the system that can be left operational are left operational. If the system is taken out of service, work must be coordinated to ensure that this is for shortest possible time (under eight hours) and that the system is back in service at the end of each day. If this is not possible for any reason, a fire watch needs to be established with appropriate firefighting equipment and firefighting personnel on standby to rapidly address any fire. Local authorities may need to be notified as well.

If new fire suppression systems are to be installed, these must be put in place and operational as soon as possible.

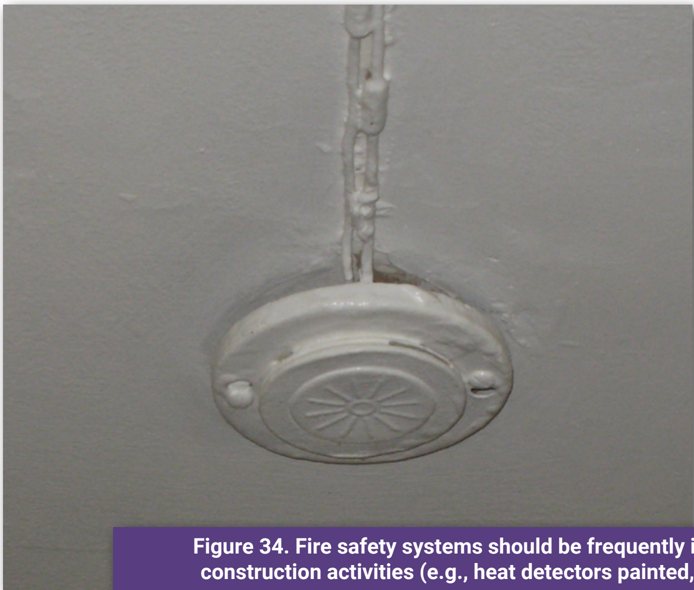

Figure 34. Fire safety systems should be frequently inspected and tested during this period, ensuring they are not damaged by construction activities (e.g., heat detectors painted, or smoke detectors covered, to limit false alarms due to dust and debris).
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Egress

Exits for occupants and construction workers must be maintained and kept unobstructed. This includes keeping stairways fire separated, marked, illuminated and free from obstructions. Exits should consist of multiple paths, limited travel distances, no dead ends and must discharge people to a safe area away from the structure, construction work and debris. It is important to refer to local code requirements on this matter.

Manual suppression – fire extinguishers/blankets

Fire extinguishers should be provided throughout the site and structure (NFPA 2024b). These should be:

- the appropriate type for the hazard
- located near hazards and hazardous operations, as well as throughout all areas
- located within short travel distances, so that people can readily access them
- in sufficient quantity, in case the fire is larger than anticipated, or takes longer to extinguish, with multiple extinguishers at each location and
- inspected frequently to confirm they are present and operational.

Means for automatic detection and notification should be provided to alert occupants to fire and they can respond while the fire is still small.

Water supplies

Sufficient water supply flow rates, pressures and quantities must be available and unimpaired. Access to fire hydrants should remain visible and accessible, and not be obstructed. If these become impaired or not available for a short term (i.e., eight hours maximum or as per local requirements), alternative measures to provide sufficient water should be put in place to address the increased risk.

Construction phasing

Consider how the construction work is phased, including installation, repairs and shutdown of fire and life safety systems. Existing systems should remain operational and new systems installed as early as possible, including fire separations, enclosed stairways, and automatic and manual suppression systems and multiple means of egress maintained.

Develop/update plans and procedures

All plans should be updated or developed, including plans and procedures related to alarm system impairments, fire watches, hot work permits and the use of heating equipment.

Management/operational measures

Strategies, measures and procedures detailing management and operations on site need to be developed. These should include details of the roles and responsibilities of all stakeholders including contractors, and the development, approval, monitoring, enforcement, updating and auditing of plans. Representatives of the contractor should be responsible for preventing fires during their work.

Fire risk managers

A designated representative from the site should be identified as the fire risk manager. This individual should have appropriate qualifications in construction, fire safety and cultural heritage sites and structures. They will also in part oversee the development, approval, monitoring, enforcement, updating and auditing of plans, as well as the work of contractors and all training, capacity-building and drills.

The counterpart to the site's fire risk manager is the contractor's own fire risk manager, a designated, qualified representative proposed by the contractor to the site manager who will oversee all efforts related to fire and life safety for the contractor.

3.2.2 Emergency preparedness measures to consider during renovation/construction

Emergency preparedness measures should be updated or developed to address specific conditions relevant to the work in process. These include addressing the following issues (Historic England, 2017; Historic Scotland, 2005).

Emergency preparedness and response strategies

All emergency preparedness and response strategies should be updated, including those for the ERT, evacuation strategies and collections removal measures.

Awareness, capacity building and training

Measures should be developed and implemented to create awareness, build capacity and conduct training and drills. Instructors should be appropriately qualified.

All personnel involved with the project should be part of these programmes, including:

- the site manager, owner
- all persons on site, including contractors, sub-contractors, crafts people
- the design team such as architects, engineers, conservators and
- the ERT.

Frequent follow-ups should be conducted to reiterate the need for safety, and to note deficiencies and issues encountered by those on site. These should include:

- daily safety talks each shift starts to remind workers about fire safety and to highlight issues that have arisen
- weekly training/refresher meetings to further re-enforce procedures and highlight issues and concerns.

3.2.3 Emergency response considerations during renovation and construction

Consider the following additional items that affect emergency response during renovation and construction activities.

Emergency response team on site

If an on-site ERT does not exist, consideration should be given to establishing one, including for the duration of any renovation and construction activities. ERT plans (see Section 2.2) should be further developed to address needs during renovation and construction work.

Working with local emergency responders

Stakeholders, contractors and other concerned parties should work closely with the emergency responders, including by informing them of any work to be undertaken and identifying and addressing challenges that may affect them during this time. Particular issues that should be discussed with emergency responders include:

- the extent of the work to be undertaken
- how impairments to systems will be managed
- hazardous operations and materials
- the status of all fire and life safety systems throughout the construction work
- maintenance of water supplies and fire hydrants, ensuring they are operational, unobstructed and have adequate signage
- the most effective means of notifying emergency responders regarding fires.

Potential issues affecting emergency responders during firefighting operations on construction sites include:

- making sure that emergency response equipment can get close to the structure and access is not impaired by, for instance, temporary hoarding, work vehicles, scaffolding, site huts/trailers
- maintaining access to upper and lower floors and keeping stairways enclosed to provide access and protection for internal firefighting
- the impact of scaffolding – combustible itself – on external firefighting and the ability to get near the structure to access upper floors and the roof, as well as to discharge water onto and into the structure that is not obstructed by the scaffolding and
- the collapse potential of scaffolding, the structure and the façade during a fire.

Figure 35. Scaffolding, storage of combustible materials and work sheds make for difficult access and firefighting operations, and introduce significant combustible loads.
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Figure 36. Temporary measures during restoration and construction should be clearly marked and simple to understand.
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04 Considerations to reduce risks related to wildfires

While Parts 2 and 3 discussed the prevention and mitigation measures for built heritage structures, Part 4 focuses on the risk management of wildfires that impact natural heritage sites as well as cultural heritage sites and landscapes.

Wildfires have occurred throughout history. Flora (e.g., trees, plants, shrubs, peat, grasses) and fauna (e.g., animals, birds, insects, fish) in fire-prone areas have often been able to adapt to what were smaller, more frequent, shorter duration and less severe fires than today. Often, such fires also benefitted biodiversity (He, et al., 2019; Kelly et al., 2020; UNEP, 2020). However, due to numerous factors, including increases in quantities of combustible vegetation, warmer and drier climates, the introduction of non-indigenous plant species, and increases in human-made ignition sources, fires have increased in duration, frequency, location, and impacts on ecosystems (Abatzoglou and Williams, 2016; Bowman et al., 2017). As a result, **both natural and cultural heritage face growing threats of wildfire disasters** (Ryan et al., 2012; UNEP, 2022).

It is important to underline, however, that rather than merely a resource to be protected in the context of fire disasters, **heritage also has an active role to play in the mitigation of fire risks**. For example, traditional ecological knowledge, skills, and practices can contribute to the preservation and restoration of the ecosystem in which heritage lives and can thereby help mitigate risks of wildfires (Lake et al., 2017). Therefore, Part 4 also highlights good practices to both enhance community engagement and mainstream living heritage and traditional knowledge in fire risk management so these become common and accepted in developing FRMPs.

4.1 Engaging communities and leveraging heritage in fire risk management

The engagement of local communities and mainstreaming of traditional and local knowledge can meaningfully inform the development of effective and sustainable FRMPs and reduce fire-related risks (CalFire, 2014; Lake et al., 2017; NPS, 2022; UNDRR, 2022). Local laws, codes and other applicable regulations will also need to be identified and addressed as part of this planning approach.

The numerous benefits that community engagement and use of traditional knowledge present include the following (UNDRR, 2022; Lake et al., 2017; NPS, 2022; Province of Victoria, 2010; VSG, 2022).

Community Engagement

- The local needs, values, customary laws, and norms around cultural and environmental protection can be better understood and more effectively integrated into FRMPs.
- Knowledge and understanding of the sacred natural sites of communities – including the terrain, wildlife, trees/vegetation, and native species critical to local culture – can lead to the identification and protection of intangible and tangible heritage.
- Local communities and indigenous peoples possess extensive, detailed knowledge including of the local geography, environment, vegetation, wildlife, weather patterns and hazards to help inform FRMPs.
- Local networks, leadership structures and community relationships can provide valuable advice and facilitate coordination, development, implementation, enforcement and engagement of the plan.
- Relationships and ties that span borders, languages, and cultures help facilitate regional coordination.

Use of traditional knowledge and skills

- Traditional ecological wisdom, historic incidents, lessons learned and traditional risk reduction measures and practices, such as creating ‘green breaks’ and the ‘fighting fire with fire’ approach, are time-tested ways to mitigate and reduce the frequency and severity of wildfires.
- Reading environmental signals such as animal behaviour and plant signs, as well as understanding moon phases, cloud patterns and other natural signs can provide traditional early warning systems of impending hazards.
- Knowledge and understanding of the frequency and severity of seasonal rains, drought cycles, monsoons and so forth helps improve effective forecasting and longer-term planning – as does identifying preparedness and risk reduction measures.
- Traditional knowledge and practices regarding water resources management, fishing, hunting, and harvesting, maintaining biodiversity, and long-term preservation of food, water, and medicine resources, can also reduce vulnerability to wildfires.

The promotion of the participation of local communities – including the indigenous peoples, in the policymaking process and in planning and implementation – and respecting their knowledge and cultures is a powerful and equitable way to reduce the wildfire risk. (Lake et al., 2017; UNDRR, 2022)

Traditional knowledge and practice of “cultural/controlled fires”

Living heritage, including traditional ecological knowledge and practices, can be drawn on by communities to reduce fire disaster risks. Instead of seeing fire as a devastating force to be extinguished (“Zero Fire” policy), for thousands of years indigenous communities have harnessed fire in ecosystem management and used “cultural fires” or “controlled burning” as an essential risk reduction measure to address wildfire risks, nurture ecosystems, and enhance livelihoods. Such good practices can be found from Australia to Europe to North America and beyond, including the World Heritage Sites of Canaima National Park (Venezuela) and Kakadu National Park (Australia).

Source: UNEP, 2022

4.2 Fire risk reduction measures to address wildfires

First, a wildfire risk mapping/evaluation should be conducted for heritage sites, considering different aspects including past fire events, location of the sites and surrounding environment, and any other special characteristics (for the identification of fire risks, refer to the Introduction of this Guide). If wildfires are deemed a credible hazard, they should be addressed in the FRMP for the heritage sites.

Numerous risk reduction methods are available to reduce wildfire risks (CalFire, 2014; International Code Council [ICC], 2021; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010; Prestemon et al., 2013; VSG, 2022).

Reducing ignition sources

Potential ignition sources should be identified. These may include:

- climatic conditions (e.g., extensive droughts, high temperatures, fires following earthquakes, downed electrical lines from high winds)
- open burning of fields, vegetation and trees
- open flames (e.g., campfires, cooking, grills, fire pits, outdoor fireplaces)
- smoking and matches
- fires on adjacent sites or in adjacent structures
- utilities (e.g., electrical lines, lighting, generators, solar/wind farms)
- vehicles (e.g., cars, trucks, trains, maintenance vehicles)
- fireworks
- candles and lanterns
- spontaneous ignition sources (e.g., manure, paint- and oil-soaked cloth, batteries)
- natural, such as lightning, volcanoes and
- intentional/arson.

Once these are identified, risk reduction measures should be developed to reduce the potential for ignition by:

- reducing/removing ignition sources (type, quantity, relocation)
- requiring permits for any fires/open flames (open burning, campfires)
- preventing the interaction of ignition sources with combustible materials (separation/distance, clearings) and
- limiting the potential for secondary ignitions (i.e., reduce use of plants that produce embers that could travel to and ignite adjacent areas).

Figure 37. Ignition sources of different kinds – such as electrical equipment, appliances, and rubbish bins – may be present around natural or archaeological sites.
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Reducing Combustible Materials

Combustible materials should be identified, including their quantity, arrangement, combustibility, location, proximity to potential ignition sources, and may include (Australia Building Codes Board [ABCB], 2023; CalFire, 2014; ICC, 2021; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010; VSG, 2022):

- vegetation, with attention paid to type, condition (alive, dead, age), location, quantity, density, combustibility, ease of ignitability and so forth
- structures (permanent, temporary)
- renovations (construction materials, debris, rubbish, flammable/combustible liquids, etc.)
- maintenance-related materials/equipment (e.g., sheds, trailers, wood)
- utilities (e.g., propane tanks, pipelines) and
- flammable/combustible liquids and gases.

Measures to reduce the risks of combustible materials include (ABCB, 2023; CalFire, 2014; ICC, 2021; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010; VSG, 2022):

- removing/reducing the quantity of combustible materials by
  - removing materials from site
  - pre-burning of materials in prescribed fires by qualified personnel under controlled conditions
  - mowing, cutting, thinning/pruning and removing
  - grazing (goats/livestock)
- reducing the combustibility of materials in the area by
  - replacing the kind of vegetation that is more combustible (e.g., oily, aromatic) with less combustible species
  - keeping the vegetation watered and preventing it from drying out
  - replacing vegetation with non-combustible surfaces such as rocks
  - using green firebreaks, rock, and water features to create non-burnable safe zones
  - regularly cleaning combustible debris (e.g., plant debris, needles, grasses, moss, cones) from gutters, between fences, adjacent to structures, archaeological sites and so forth.
- reducing the quantity of easily ignitable materials
- relocating/isolating combustible materials to safe, protected areas:
  - storing rubbish in metal containers
  - storing solid and liquid fuels in metal containers and
  - storing paper informational items (brochures, maps, leaflets) in sealed plastic or metal containers
- regulating/prohibiting the use of particular vegetation/materials on site and
- mitigating the hazard that combustible materials represent.

Measures to help create awareness and regulate ignition sources and combustible materials include (ABCB, 2023; CalFire, 2014; ICC, 2021; NFPA, 2022d; NSW, 2019):

- developing regulations to manage the wildland/urban interface (e.g.., regional planning, zoning, subdivisions, individual structures)
- enforcement of laws and regulations
- educating the public and local community (e.g., public meetings, media) and
- creating awareness and imposing restrictions (e.g., no burning, no open fires) including during times of higher risk through the media, internet, television, radio, signage, displays, mailings and local news.

Traditional knowledge measures that can help reduce combustible materials

- Forest clearing of undergrowth and debris to reduce fuel.
- Selectively harvesting timber to help reduce fire risk.
- Controlled/nomadic grazing to reduce vegetation that can add significant fuel for wildfires.
- Cultural/prescribed burning conducted with in-depth cultural and ecological knowledge.
- Herbal fire suppressants and using specific plants to create natural fire retardants.
- Traditional landscaping practices in choosing more fire-resistant vegetation.
- Constructing/renovating structures using fire resistant materials

Sources: Lake et al., 2017; VSG, 2022; WFCA, 2024, UNDRR, 2022

Figure 38. Cutting and clearing vegetation can greatly reduce fire spread and duration.
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Detection

Early detection will help limit the size of the fire that emergency responders need to suppress, as well as help to ensure that the local community can evacuate safely. Manual and/or automatic detection implies monitoring for, and detecting, ignition sources, potential unsafe conditions and wildfires in the early stages of development. Detection may include fire watches and the use of fixed structures such as fire watchtowers as well as planes, drones and satellites.

Detection of Wildfires by Satellites

In some areas various resources may be available to monitor and provide early detection of wildfires via satellites. For example, the United States National Aeronautics and Space Administration (NASA) Fire Information for Resource Managers Systems (FIRMS) provides active fire data for near-real time applications, globally, within a few hours of the observation (https://firms.modaps.eosdis.nasa.gov/). Similar systems exist in other regions (Mallinis et al., 2016).

Notification

Means of notification should be provided to alert emergency responders, as well as site staff, the local community and visitors if they need to evacuate. Alerts may include sirens, phone calls, text messaging, bullhorns, bells, news broadcasts and other methods. Various traditional knowledge measures may be available that can help with notification such as smoke signals. Additional information may need to be provided regarding the fire, as well as informing people how to safely evacuate and which routes are safe to use. Communities should be aware of the means of notification and monitor these accordingly. (CalFire, 2014; NFPA, 2022d; Parliament of Victoria, 2010)

Evacuation

Evacuation routes should be maintained and kept clear for the community, site staff and visitors, and emergency responders. This includes ensuring roadways and paths are unobstructed and separated from vegetation, as well as marked and illuminated. Dead end paths and roads should be clearly marked and provide sufficient room to turn emergency vehicles around. Multiple paths should be provided, where possible, in case one becomes inaccessible (CalFire, 2014; ICC, 2021; NFPA, 2022d; NSW, 2014; VSG, 2022).

Safe Zones

Evacuation is not always possible or practical. Safe zones and community shelters should be designated to enable sheltering in place as a measure of last resort, including for both people and livestock (Maranghides and Link, 2023). Safe zones can take many forms but should include a large area characterized by non-combustible surfaces such as rocky terrain, sand dunes, watering holes, beaches, and areas where combustible materials are non-existent, or extremely limited. Safe zones should ideally be surrounded by green firebreaks or a boundary that has been recently burned in planned fires (i.e., black zones that are less likely to reignite). Safe zones should include stored water, emergency supplies, methods of communication, and ideally provide access to a safe, non-combustible building that can filter air to provide temporary refuge from wildfire smoke. Safe zones should not be located where mudslides or debris flow risk is present. Safe zones can also include areas where recent prescribed fires were deliberately set to create areas that are less likely to reignite. (Maranghides and Link, 2023; CalFire, 2014; NSW, 2014)

Fire breaks/separations

Fire breaks and separations between combustible materials help contain the fire and limit it from spreading.
This includes a number of traditional methods to slow or limit fire spread, including (Cui et al., 2019; Curran et al., 2018; WFCA, 2024):

- creating 'green firebreaks' that involve areas of vegetation that are of low combustibility and grown within strategic locations in the landscape to create fire breaks (Cui et al., 2019; Curran et al., 2018).
- creating fire breaks through natural barriers to control the spread of wildfires, including rivers, lakes, ponds, rocks or other natural features that are non-combustible and can help limit fire spread
- using trails, paths, roadways that have limited combustible material to create a separation
- creating windbreaks to help slow and/or redirect the winds, and hence the direction of the wildfire spread (USDA, 2024) and
- diverting rivers or engaging/flooding floodplains on a temporary basis to protect communities from wildfires(Graziosi, 2023).

Figure 39. Vegetation, often found around archaeological sites and historic structures, may expose these to wildfires.
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Manual suppression

Means to manually suppress a fire should be provided and readily available, particularly in areas where people are located. This may include fire extinguishers of the appropriate type, size, quantity and location and even metal buckets containing soil/sand, shovels, and leather gloves. These sites should include clear signage indicating where larger containers exist to enable refills. This low technology but highly effective fire suppression approach would enable rapid quelling of a small fire (for instance, started by a cigarette, match or campfire) before it has the potential to become a wildfire disaster. The means for detection of a fire and notification of it should be provided so that occupants can respond quickly and effectively while the fire is still small. Notification should be both audible and visual, where possible.

Water supplies

Adequate water supplies are needed in sufficient quantity, flow rate and pressure. These must be accessible and in close proximity to where they may be needed. Their location should be in areas that may not be readily impaired or compromised so that they remain accessible and usable. Water supplies may include lakes, ponds, water tanks/cisterns, gravity tanks, pools, municipal water supplies and fire hydrants, as well as involve various traditional knowledge systems, including (CalFire, 2014; ICC, 2021; Lake et al., 2017; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010):

- means for harvesting, storing rainwater for firefighting purposes
- ritualistic dances to invoke protection from wildfires
- efficient use and management of water resources to suppress wildfires, particular during times of the year when wildfires are more likely
- construction of water storage systems such as clay-lined holding areas and
- effective irrigation systems and efficient water use in agricultural areas to prevent drying of vegetation.

If these are not available, determine how to bring water/suppression agents to the site (water tank trucks, planes, helicopters able to carry water, etc.). Clear signage and safe access to these water supplies should be provided.

If water supplies become impaired, or are unavailable for short periods, due to time of year/season, drought or climate change over time, develop alternative measures. These include alternative water sources, mutual aid agreements and tighter restrictions on ignition sources (e.g., no campfires, burning) during these periods.

Management/operational measures

Strategies, measures and procedures should be developed detailing management and operations on site. Incorporate details regarding the roles and responsibilities of all stakeholders, including having a designated Fire Risk Manager for the site (see section 2.2.1).

Site work

Natural heritage sites, landscapes and heritage structures are exposed not only to the vulnerabilities, hazards and risks of wildfires during typical day-to-day operations, but are also faced with the introduction of a significant increase in risks during work that may be undertaken on site (e.g., thinning of trees, utility work, renovations to structures on site). All these risks should be addressed in the FRMP. (ICC, 2021; NFPA, 2022d; NFPA, 2022c; Parliament of Victoria, 2010)

4.3 Emergency preparedness measures to limit the impact of wildfires

Emergency preparedness measures help prepare for, prevent, respond to and recover from wildfires. The following emergency preparedness measures for wildfires (CalFire, 2014; ICC, 2021; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010; VSG, 2022) supplement the measures presented in Section 2.2.

Emergency Response Team (ERT) on site

An ERT should be established to manage the preparedness and response phases. This includes developing and implementing plans related to the following: evacuating occupants and livestock; fire prevention and reducing ignition sources and fuel loads, including through regular inspections and maintenance programmes; removal and/or protection of exposures during a fire (e.g., archaeological sites, structures); monitoring the development and impact of fires; and engaging and assisting emergency responders. Mitigation measures should be readily available on site along with persons trained in their use and rapid implementation. Such measures may include exterior deluge sprinkler systems; covering exposed archaeological sites, structures and vegetation with non-combustible materials to protect them; and wetting down surfaces. These measures should be regularly tested and any systems inspected and maintained.

Figure 40. Preparedness measures – including inspection, testing and maintenance of hydrants, water supplies and firefighting equipment – should be undertaken periodically.

Capacity-building and training

Measures to build capacity and conduct training and drills should be developed, implemented, and enforced. These should include the site manager, owner, persons on site (visitors, contractors, and others) as well as the local community and ERT. Frequent follow-ups should be conducted to reiterate the need for safety, and note deficiencies and issues encountered.

In addition, cultural and natural heritage sites have the potential, as living laboratories and learning hubs (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2024), to raise awareness and foster learning and education on environmental and climate issues for local communities, youth, and visitors and to drive concrete actions to achieve sustainable changes.

Engagement with emergency responders

Local emergency responders should engage in all activities related to wildfires, including preparation, capacity-building and training. They need to be familiar with the site, including topography, access, water resources and vulnerable areas, including, for instance, archaeological sites, historic structures and particular vegetation that needs special protection. Emergency responders should also be aware of the need to limit potential damage to these areas during firefighting operations. (NFPA, 2022d; NSW, 2019)

Addressing secondary hazards triggered by wildfires

Wildfires can also produce secondary hazards that need to be considered and incorporated into the overall DRMP in developing the FRMP and preparing for wildfires. These include:

- loss of vegetation that can destabilize hill slopes and potentially lead to erosion, landslides and mudslides, further impacting access and habitation areas (Addison & Poommen, 2020; Girona-Garcia et al., 2021)
- ash and partially combusted fuels can impact waterways, including water quality, water availability, the free flow of water, pooling and damning, and the potential use of waterways as transportation means, etc. (Moody et al., 2013) and
- smoke from fires can impact local and regional air quality for days to weeks after the fire (Hyde et al., 2017).

Measures should be taken to address these secondary hazards even without a wildfire directly impacting the site (Abatzoglou, 2014). The same factors should also be considered during planned fires and whether these secondary hazards may impact nearby communities. In each case a plan should be developed. Measures to create awareness and prepare for these secondary hazards include:

- taking steps to reduce potential post-fire erosion and runoff of debris into waterways using log erosion barriers placed parallel to the contour and either staked or entrenched in place to slow runoff and catch or store sediment (Robichaud et al., 2008, 2013)
- developing information for the public on what precautions they need to undertake under different levels of smoke exposure
- developing alternate access (and evacuation) plans in the event of hazardous smoke levels, debris flows washing out or blocking access and egress routes
- developing a management plan to maximize public safety that includes guidelines for partial or full closure under varying levels of smoke or risk of other secondary hazards;
- creating awareness of what levels of smoke could be produced in a planned fire versus the levels that the public would encounter during an uncontrolled fire (Hyde et al., 2016) and
- educating the public and local community on secondary hazards through public meetings, media and other means.

Engagement with the local community

The ERT can help improve the effectiveness of risk reduction by working closely with the local community (Lake et al., 2017; CalFire, 2014; NFPA, 2022d; NPS, 2022; Parliament of Victoria, 2010; UNDRR, 2022).

- ***Create awareness*** among the local community regarding collaboratively identifying hazards and mapping fire-prone areas, how they can help prevent fires, how to report fires and unsafe conditions, how to monitor and obtain information related to fire conditions, and when, how and where they should evacuate.

- ***Implement fire prevention by explaining*** how the community can form fire prevention councils, identify fire risk managers, and build capacity to oversee and implement fire prevention measures and help reduce ignition sources and combustible materials to limit fire and its impacts on their properties as well as other sites.

- ***Improve communication*** by providing updates on conditions, prevention measures and restrictions to the community using multiple communication methods to ensure that messaging is received. It is critical to ensure everyone is aware of, and familiar with, the means of communication. Messages should be clear, concise and in multiple languages where needed. The design and implementation of these methods must be robust, reliable, well-maintained and operational during any emergency event.

- ***Facilitate intergenerational knowledge-sharing***, including passing down fire risk management wisdom and traditional fire stories from generation to generation.

- ***Organize periodic community training and drills*** involving the ERT of the heritage site, local fire brigades, mutual aid, local communities and relevant others.

Possible considerations for incorporating traditional knowledge in preparedness

- Traditional Fire Agreements: Utilize community agreement on safe fire use.
- Seed Banking: Preserve native plant seeds for post-fire habitat restoration.
- Underground Storage: Store essential items underground (root cellars) for protection during wildfires.
- Sacred Area Protection: Safeguard designated sacred areas to maintain balance and prevent fires.
- Traditional Firebreak Maintenance: Regularly maintain traditional firebreaks for effectiveness.

Sources: Cui et al., 2019; First Nations Development Institute, 2015; NFPA 1140, 2021; NFPA 914, 2021

4.4 Emergency response measures to suppress wildfires

Emergency response to wildfires includes a addressing a number of items (CalFire, 2014; ICC, 2021; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010; VSG, 2022) in addition to those referred to previously:

Working with local emergency responders

Stakeholders should work closely with emergency responders, through the following:

- public fire safety education (ignition sources, fire hazards, risk to life and property, fire prevention programmes, challenges in wildfires, etc.)
- the most effective means to monitor for fires and notify emergency responders
- community notification (means of disseminating information/notifications, information to be provided, identification of safe roads and sheltering areas
- education of media to appropriately understand and communicate risks
- understanding the needs of emergency responders and the issues they may face
- maintaining water supplies and fire hydrants, ensuring they are operational, unobstructed and provided with visible and clear signage
- maintaining access to the site and ensuring emergency response equipment can get to the site, and access is not impaired due to a wildfire and
- the establishment of an incident command centre (command structure, responsibilities, etc.), training and mutual aid.

Pre-planning

Emergency responders should work with site managers to help pre-plan firefighting operations. Provide information to help make informed decisions including concerning topography, type of vegetation, combustibility, ground cover and weather conditions.

Detection and notification

Appropriate means should be provided for early detection and notification so that the ERT may respond before the fire grows beyond their capacity to control.

Access

Roads, paths, trails, bridges, gates and the like will need to accommodate fire trucks and other apparatus and involve factors to consider including width, height, weight, grade and surface. These access points should be clearly labelled on the plans and maps of emergency responders. Dead ends should be very limited in length and allow fire apparatus to readily turn around. Multiple routes and means of access need to be provided to access and evacuate the community and emergency responders from these areas, including by having multiple paths in case one is blocked or unsafe to use (CalFire, 2014; ICC, 2021; NFPA, 2022d).

Figure 41. Hydrants and water supply sources should be marked, readily visible and not hidden under vegetation.
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Figure 42. Multiple, separate, clear roads to sites with limited vegetation immediately adjacent enable access and evacuation.
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Water supplies

Adequate, accessible, reliable, protected and dedicated water supplies are critical and may include municipal (hydrants), mobile (trucks, planes, helicopters, boats) and natural sources. (CalFire, 2014; ICC, 2021; NFPA, 2022d) Where possible, in advance of fire season, water tanks or water towers should hold emergency reserves. Means should be provided to access these reserves with equipment to draw water and provide adequate spraying and discharge from hoses.

Resources/equipment

The equipment needed to combat wildfires will be different from what is used to fight fires in structures, and will include the need for special hand tools, power tools (saws) and heavy equipment (bulldozers, tractors, ploughs). (CalFire, 2014)

Provide equipment that gives real-time information on the fire (fire size, direction, speed), property (terrain topography, type/density of vegetation, specific hazards) and current/upcoming weather (temperature, wind speed/direction, humidity).

Protective measures/personal protection equipment

Firefighting gear, such as personal protection equipment (PPE) should be worn for fighting wildfires and include additional protective measures such as providing and training in the use of fire shelters in case firefighters become trapped. (NFPA, 2022f) Standard PPE includes Nomex or equivalent fire-resistant brush shirts and pants, leather gloves, hard hats, fire boots and, when possible, respiratory gear to limit exposure to particulate matter and other fire combustion products.

Monitoring

Following the end of active suppression-related activities, take measures to monitor the fire site for any flare-up of 'assumed out' fires or secondary hazards.(CalFire, 2014; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010) These could include:

- removing personnel from the area to limit exposure to smoke and potential for flare ups and re-ignition of fires
- if smouldering vegetation is present (tree trunks, roots, peat), this should be monitored regularly for several months to ensure the fire does not restart – especially if elevated wind is in the forecast (Irannezhad, 2020; Kreye et al., 2014)
- monitoring recently supressed sites where thermal belts can form due to inversions and
- monitoring levels of debris and conducting a risk assessment of potential debris flow if a rain event occurs.

Training

As wildfires differ significantly from fires in built structures, emergency responders need to have sufficient awareness, working knowledge and training in how to fight wildland fires as well as in understanding fire behaviour; the relevant laws, procedures and industry standards; equipment; the importance of measuring site conditions, weather and so forth.(CalFire, 2014; NFPA, 2022d)

4.5 Recovery measures for wildfires

In addition to the recovery-related efforts noted in Section 2.4, include the following measures in connection to wildfires (CalFire, 2014; NFPA, 2022d; NSW, 2019; Ryan et al., 2012; VSG, 2022).

- Secure the site, ensure spot fires are all extinguished and conditions are safe.
- Survey and record damage to site, structures, vegetation and wildlife once the situation allows, including through visual assessment, drones, and satellites.
- Assess damage to archaeological sites and historic structures located on the site, including the extent and level of damage, and establish a means to protect them in the short term and develop a restoration strategy.
- Assess the terrain for potential erosion, landslides, fires and other risks, as well as threats from rainstorms.
- Develop or update a detailed recovery plan to stabilize conditions and damaged areas, including by saving vegetation and addressing issues related to the potential impacts of rains, water run-off and the destabilization of terrain, as well as for recovering the vegetation, wildlife and the overall ecosystem (Girona-Garcia et al., 2021).

4.6 How to limit exposures from wildfires

Wildfires may expose specific vegetation such as individual trees, groves and forests, archaeological sites, wildlife and cultural heritage structures to fire, including through direct flame impingement, radiation and burning embers. The following are additional recommendations to reduce wildfire risks, including to items, sites and structures (Hedayati et al., 2023; CalFire, 2014; ICC, 2021; NFPA, 2022d; NSW, 2019; Parliament of Victoria, 2010; Ryan et al., 2012; ABCB, 2023).

Limiting ignition

- Separate combustible materials and vegetation from those that are exposed and vulnerable to reduce direct contact by flames and exposure by radiant heat.
- Render materials less combustible (façade, roof coverings, overhangs, weather stripping) and more resistant to ignition by direct flame impingement, flying embers/brands, and so on through, by example, fire retardant treatments and reducing locations for embers to land on structures.
- Restrict openings into structures (windows, doors, vents, etc.).
- Limit places for embers or burning debris to land or accumulate such as gutters, eaves, under raised structures, and between fences.

Reducing the time, temperature and duration of radiant exposure/keep surfaces cool

- Provide automatic and/or manual suppression systems to protect the outside and inside of structures, reducing radiant exposure and the thermal impact of fire.
- Wrap the most vulnerable areas and items in fire resistant materials to limit radiant heat, thermal impact and the duration of exposure.
- Relocate vegetation, create green firebreaks, for instance, to reduce the duration of thermal exposure and resultant impacts.

Removing Combustible Material

- If particular vegetation, structures, archaeological materials and wildlife can be removed, develop and implement plans for their removal and transport to a safe location.

Suppressing fire

- Provide resources to manually suppress fire (personnel, PPE, water, early notification), including on-site fire brigades to protect specific, pre-identified structures, trees, vegetation, archaeological sites from fire.
- Where possible, use water-drip systems from reserve water tanks in gutters, roofs, and other high risk ember aggregation locations to reduce ignition risks and fire spread during a fire emergency (Smith et al., 2018).

4.7 Ecological impacts of wildfires

Due to numerous factors, including climate change and increases in human-made ignition sources, fires have intensified in temperature and increased in duration, frequency, locations, and severity across ecosystems. (Abatzoglou and Williams, 2016, UNEP, 2022) These factors will likely continue to increase in the future, further exacerbating both short- and long-term ecological impacts including on vegetation, water supplies, air quality, wildlife and endangered species, making it much more challenging for these ecosystems to survive, let alone return to pre-fire conditions, especially following more severe fire events.(UNEP, 2022) There is, therefore, growing concern over the significant ecological impacts of fires on wildlife, vegetation, water resources, air quality and carbon sequestration and their combined impacts on overall ecosystems that are vital to understand as they continue to reinforce the urgent need to reduce the impacts of wildfires and their resultant ecological impacts. (Kelly et al. 2020; Morrison, 2022; UNEP, 2022)

4.7.1 Land and water impacts

The increase in frequency of intense fires is leading to greater challenges in maintaining ecosystems, globally. (Kelly et al., 2020; UNEP, 2022) The decrease between subsequent fires can limit the availability of seed trees capable of restoring the side. This issue, coupled with a loss of soil nutrients, results in limited regrowth of vegetation –particularly trees – and these large carbon sinks. (Agbehsie, et al.; 2022) Although, many shrub species have evolved to resprout following fires, even when it appears the fires have top-killed a lot of the vegetation, it is important to consider when the fires occur, especially when conducting prescribed fires. Many of these shrub species rely on stored belowground carbohydrates, which may be insufficient if fires occur just after the plants start to regrow in a given year. (Agbehsie, et al.; 2022)

With these warming atmospheres, studies have shown that there is not only an increase in wildfires but also in intense rainfall events. (UNEP, 2022) This is because warmer weather facilitates higher moisture content in the atmosphere, resulting in more intense rains. Under these severe fire regimes, vegetation-less soil and limited root structures to hold the soil in place, it becomes challenging for the land to absorb water well, resulting in flash floods, erosion and landslides. These conditions further exacerbate vegetation regrowth, as any remaining fertile soils can be washed away. (UNEP, 2022)

The challenges in the ability of the land to absorb water further results in increased water runoff into waterways and wetlands. This introduces not only significant quantities of water with the potential for flooding and reshaping waterways and landscapes, but also brings in contaminants that potentially kill wildlife and vegetation in the water. (Moody et al., 2013; Morrison, 2022; UNEP, 2022) As well, many water resources for animals and water sheds for local communities exist in these natural heritage areas that are being adversely impacted (Morrison, 2022; UNEP, 2022). Debris, sediment and soot accumulating in the water can impact wildlife and vegetation in the water (algae, coral) including blocking sunlight and impairing its photosynthetic efficiency. This can in turn impact oxygen levels, food and overall wildlife habitability. (UNEP, 2022) Debris can create dams as well and negatively affect the free flowing of waterways.

How to limit impacts

After wildfires have occurred, the following are several actions that can be taken in advance of rain and storms to reduce the impacts of increased runoff into waterways from debris flow (Robichaud, et al., 2008; Robichaud, et al., 2013; UNEP, 2022).

- Use natural barriers. Trees can be felled and placed perpendicular to the landscape to create contoured log terraces that act as barriers to reduce hillslope debris flow. These can be incorporated into the landscape without loss of aesthetics.
- Use mulch or straw alongside re-seeding to promote the growth of new vegetation to limit debris flow.
- Use metal fencing or silt fences to create barriers to catch debris flow. Although more effective, these can alter the aesthetics of the site and may be less desirable as a result.

4.7.2 Air Quality Impacts

Wildfires emit by-products in significant quantities, including greenhouse gases (e.g., carbon dioxide, methane, nitrogen dioxide) and other toxic and hazardous pollutants (e.g., soot, particulate matter, polycyclic aromatic hydrocarbons, hydrogen cyanide, sulphur dioxide). (UNEP, 2022) These have significant impacts particularly on people and wildlife not just in the near vicinity of these fires; these by-products also readily disperse globally as well and likewise impact climate change. (Hyde, et al., 2017; UNEP, 2022)
Additionally, the vegetation and forests provide significant carbon sinks that help to clean and maintain air quality. Thus, reducing the quantity of this vegetation adversely impacts the process, slowing down the production of oxygen and further contributing to climate change.(Ramirez, 2021; UNESCO et al., 2021)

Impacts of Wildfires on Air Quality and Carbon Sequestration

Forests must be protected because they are the largest carbon sinks in the world, absorbing 7.6 billion metric tons of carbon dioxide annually. It is important to note, however, that each year we continue to lose wildlands to fire. As carbon sinks they emit CO2 as they burn. In terms of deforestation and loss of carbon sinks, wildfires are a significant contributor, impacting nearly 40% of global forest loss between 2003 and 2018.

Regarding natural World Heritage Sites, since the mid-2010s, intense wildfires associated with extreme temperatures and drought conditions have been a cause of high emissions at some sites. The most prominent examples are wildfires in the Russian Federation's Lake Baikal in 201680, and in Australia's Tasmanian Wilderness81 and Greater Blue Mountains Area in 2019 and 202082. Each of these wildfires generated greenhouse gases emissions above 30 Mt CO2e in a single year, higher than the national annual emissions from fossil fuels of more than half of the countries in the world. Other recent fires have burned tropical forest ecosystems where fire has historically been rare, such as in Bolivia's Noel Kempff Mercado National Park in the Amazon Basin. As climate change causes warmer and drier conditions that lead wildfires to become more intense and droughts more severe, the ability of some forests to fully recover from such events may become increasingly hampered, potentially exacerbated by past or present land management practices. Recovery may be difficult even in areas where recurring wildfires constitute an integral part of ecosystem dynamics because human-induced climate change impacts disrupt these dynamics. More intense fires could lead to short-term emissions spikes and reduced capacity for sequestration in the longer term, thus reducing overall carbon storage in sites that do not have a history of fires.

Sources: Morrison, 2022; Ramirez, 2021; Van Wees, 2021; UNESCO, WRI, IUCN, 2021.

How to limit impacts:

During fires, monitor air quality to ensure that appropriate decisions are made to protect public and employee health. In the case of planned fires, a clear decision tree should be used to ensure that decisions to stop the fires are made when key conditions are met. Stop the planned or prescribed fire under the following conditions if (California Code of Regulations [CCR], 2001; Hyde, 2017):

- wind directions shift and make it likely that smoke will impact a sensitive group (e.g., hospitals, schools, residential areas, areas with large numbers of persons outside,).
- smoke reaches sensitive areas or if smoke reaches critical highways and access roads.
- smoke concentration levels exceed unhealthy levels for people with asthma and similar conditions.
- smoke results in a significant loss in visibility, especially in areas where trails may occur in hazardous terrain and where good visibility is essential.

During wildfire events, similar decision trees can be adopted to decide whether areas or sites can be left open for public use if there is no risk the active fire will spread to those areas. For example, even when there is no risk the fire will spread due to combustible barriers (such as lakes or rivers), the smoke could still seriously impact public health. (Hyde, 2017) In these cases, decisions to close access to sites and trails could be made to protect the public.

4.7.3 Wildlife impacts

As fires impact land, air and waterways, wildlife from birds to animals to fish and insects are all impacted (Kelly et al., 2020; UNEP, 2022). In the past, animals and plants in fire-prone areas where fires were less severe were often aware of the signs of fire and able to react appropriately and adapt to periodic fires. However, they may not be able to react to, nor survive, today's more severe fires. Additionally, wildlife in areas previously not prone to fire are often not as sensitive to the signs of fire or imminent danger, particularly with the intensity and rapid onset of these fires. Research (Kelly et al., 2020) indicates over 4,400 land and water species are at risk due to these catastrophic wildfires.

If animals do survive wildfire, they are often faced with new challenges including finding food, shelter, and protection from predators which these forests and vegetation once provided. (Nimmo, et al., 2019; UNEP, 2022) For migratory species, these fires can also impact their ability to find food, fresh water and shelter during their migratory journeys. In the short term, this can lead to dehydration and starvation, as well as impact their ability to reproduce and feed their off-spring thus increasing their susceptibility to predators. In the longer term this may impact migratory patterns and ultimate destination, as well as the quantity of their species – all of which impacts local ecosystems (Nimmo, et al., 2019; UNEP, 2022).

How to limit impacts

Existing structures used to help wildlife move between areas intersected by roads could be adapted to help reduce the impacts of wildfires on wildlife. Specifically, such **wildlife corridors** could be adapted to lead to limited or non-combustible zones without loss of aesthetics or ecosystem function (Jaynes, 2023).

4.7.4 Overall collective ecological impacts

It is important to understand the overall short- and long-term impacts wildfires can have on ecosystems. This includes not only the individual impacts to air quality, land, flora, water sources and wildlife, but the impacts these have collectively on each other, and how ecosystems and biodiversity can change in areas experiencing wildfires, as well as adjacent areas. There is often a fine balance among wildlife, vegetation and water and air quality, as there are numerous dependent, interconnected interactions; changes in one area can readily upset this balance (UNEP, 2022).

Loss of vegetation, for instance, may result in loss of shelter and thus greater exposure of some species to predators resulting in rapid declines in population numbers or the loss may result in wildlife relocating due to lack of food and shelter(Nimmo, et al., 2019; UNEP, 2022). In turn, their predators may increase in numbers and/or then find alternate wildlife as prey, or these predators may relocate as well, thus impacting the balance of other ecosystems. Without vegetation, migrating birds may have fewer safe areas to rest, less food to eat, fewer insects available to feed their nestlings. This may change migratory patterns, all with potential impacts including on population numbers. Loss of water sources can impair the ability of wildlife to hydrate, as well as slow the growth of vegetation, impacting fish populations. Fewer fish means fewer food sources for some wildlife and for humans as well.

It is therefore important to understand these interrelated impacts, including potential shifts in seasonal behaviours and life cycle events (i.e., migration, mating, egg laying, hibernation), predator and prey interactions, food, air quality and water sources, and the potential impacts these have on ecosystems. (Nimmo et al. 2019; ABCB, 2019; UNEP, 2022)

4.7.5 Resultant impacts on natural and cultural heritage sites

Natural heritage sites – including those with unique and natural features, geological and physio geographical formations and areas that constitute the habitat of threatened, endangered and iconic species of animals and plants – contain rare ecological processes unique landscapes, old growth forests, and critical water sources. Natural sites also possessing value from the point of view of conservation, biodiversity, science or natural beauty all need to be protected, as they are at risk from more severe wildfires. This also includes the need to protect the cultural heritage sites that may be contained within, or adjacent, to natural heritage sites that may also be at risk, including heritage structures, archaeological sites, and rock art.

The protection of these natural heritage sites from severe wildfires will help reduce the resultant short- and long-term ecological impacts. Such efforts help to maintain the critical role natural heritage plays in the conservation of ecosystem integrity and biodiversity and in the protection of endangered species. This is an essential component in the culture and heritage of indigenous communities, contributing to local economies, providing climate stability and enhancing the well-being of all species, including humans.

05 Final reflections on the development and implementation of Fire Risk Management Plans

As part of the organization, planning, implementation and monitoring process for FRMPs, whether for day-to-day operations or during renovation and construction periods, the following key elements can assist in the development of the overall process for both natural and cultural heritage (Historic England, 2017; Historic Scotland, 2005; Kidd, 1995; NFPA, 2021c; CalFire, 2014; Lake et al., 2017; NPS, 2022; UNDR, 2022; Parliament of Victoria, 2010).

Identifying objectives and scope

- The scope of work, goals, fire safety objectives, priorities, schedule, responsibilities and resources should be among the goals and objectives clearly identified early on in the process.

Establishing the Fire Risk Management Team

- The Fire Risk Management Team should consist of a dedicated group on site (i.e., owner, site manager, representatives of site staff) who will take into account collective needs and collaborate with a broader range of stakeholders. These include the rest of the site staff (security, administration, maintenance), occupants, visitors, emergency responders, the local community, local leaders and elders, community groups, local municipalities, tourists, tourist agencies, disaster management agencies, architects, engineers, preservationists, conservators, insurers, as well as contractors and sub-contractors involved in renovation and construction projects.

- The respective roles and responsibilities should be clearly defined, and the individuals identified who will represent each of these stakeholder groups in terms of coordination and cooperation.

Engaging local communities is important for numerous reasons.

- Local networks, leadership structures and community relationships can provide valuable advice and facilitate coordination, development, implementation, enforcement and engagement of the plan.

- Local needs, values, customary laws and norms around cultural and environmental protection can be better understood and more effectively integrated into plans.

- Knowledge and understanding of sacred natural sites, including the terrain, wildlife, trees/vegetation, and native species critical to local culture – and intangible and tangible heritage aspects – can be identified and protected.

- Engagement creates a sense of ownership and increases participation and preparedness; it helps reinforce self-reliance and the long-term sustainability of the plan.

- Relationships and ties that span borders, languages, and cultures help to facilitate regional coordination.

Engaging Fire Risk Experts on the Team and Fire Practitioners

- The team should incorporate persons with an expertise in fire risk management, particularly as it relates to protection of heritage sites/structures and construction.

- Their qualifications should include significant experience in hazard/risk assessments, human behaviour, emergency preparedness, emergency response, resilient recovery, evacuation, fire dynamics/behaviour, firefighting, fire protection systems, fire prevention planning, codes, forensics and construction site safety (ICC, 2015; SFPE, 2004).

- They should also have expertise and significant experience as to how these specifically apply to protecting cultural heritage sites and structures.

- It is also important to engage with fire practitioners with expertise in Integrated Fire Management, which implies a holistic approach involving fire prevention, fire ecology and cultural and socioeconomic aspects.

Identifying a Fire Risk Manager on Site

- Each site will need a Fire Risk Manager. This person can be the site manager, or the role and responsibilities can be assigned to someone else with appropriate expertise. Training should be provided as applicable for this person to help support them in this crucial role.

Engaging Contractors

- Contractors should have expertise in the required work, including but not limited to construction, site safety, fire and life safety systems, heritage sites/structures, codes and regulatory requirements.
- Detailed contracts defining the responsibilities of the contractor should be developed with professional legal advisor(s) and agreed upon with the contractor. The contracts should include the following points.
  - The contractor is responsible for protecting the site/structure from fire, and other potential hazards, during their work.
  - The contractor is required to undertake and abide by the process, schedule, documents to be developed, the qualifications of personnel, the owner's review/approval requirements, implementation plans, monitoring and enforcement plans, disciplinary actions and ongoing training plans particularly in relation to how fire risks will be managed and mitigated.
  - The roles and responsibilities of specific individuals should be clearly defined, including the identification of the contractor's own Fire Risk Manager, and their qualifications and expertise, for review and approval by the site manager/owner prior to engagement. Any change in personnel by the contractor must be approved by the site manager/owner.

Developing a Fire Risk Management Plan

Long-term FRMP

- The FRMP should be developed and integrated with the overall site DRM plan, which addresses other hazards.
- Adverse impacts from fires, including their initiating other short- or long-term hazards (e.g., wildfires leading to erosion and impacts on water supplies, air quality, transportation), should be identified and addressed in the FRMP, as well as integrated within the overall DRM plan.
- A broad range of stakeholders should be engaged in its development, implementation and monitoring.
- Incorporate local, traditional knowledge, methods and materials.
- A hazard, exposure, vulnerability approach addressing all DRM phases should be integrated into the FRMP.
- Address other hazards that may result in fire, or that may impair risk reduction measures (e.g., earthquake damaging water supplies, causing a fire, adversely effecting emergency response).
- THE FRMP should be kept effective, efficient and simple where possible.

FRMP during renovation/construction work

- A FRMP tailored specifically for the renovation/construction period should be developed by skilled experts, including those qualified in fire risk management and protecting heritage sites and structures, emergency response and construction safety. The contractor is often required to develop this plan, which will require review and approval from the site manager/owner.
- The site manager/owner, as well as the contractor and all entities undertaking work on site, should each have individuals qualified in fire risk management review or approve the FRMP prior to any work being undertaken.
- The FRMP should be continuously reviewed and updated as applicable by qualified experts, and re-approved among stakeholders if any changes are needed as the work progresses, given the fast pace of construction and on-site changes.

Figure 43. The FRMP should be developed and tailored to address increased risks during renovation and construction work.

Incorporating Traditional Knowledge

Understanding and integrating traditional knowledge into FRMPs has the following benefits.

- Local communities possess extensive, detailed knowledge, including of the local geography, environment, vegetation, wildlife, weather patterns and hazards to help inform FRMPs (Balehegn, 2019)
- Historic incidents, lessons learned, and risk reduction measures are often passed from generation to generation providing a wealth of local and regional knowledge of effective measures.
- Indigenous fire prevention and management practices are time-tested to reduce the frequency, severity and duration of fires, including through removing undergrowth by using controlled fires.
- Traditional knowledge promotes sustainable management of water resources; understanding fishing, hunting, and harvesting methods and seasonal pattern shifts to prevent starvation and extinction; seed saving to maintain availability and crop biodiversity; and long-term preservation of food, water, and medicine resources (First Nations Development Institute, 2015).

Obtaining Approvals

- The FRMP should be reviewed, revised as applicable and approved by stakeholders, including emergency responders and local authorities, if required.
- Approvals from local authorities may be needed including for construction and renovation work. As codes at times may not address the unique needs of heritage sites/structures, conversations with local authorities may be necessary regarding the approach taken, the intent of codes and the risk reduction measures provided to address these, as well as to demonstrate that the level of safety for occupants, emergency responders and the site/structure is higher than dictated by the codes.
- A detailed analysis comparing the level of safety provided by a hazard/risk-based approach versus local codes requirements, as well as the involvement of a fire engineering expert in the project, can significantly help in work with local authorities to obtain approvals.

Addressing Regulatory Requirements

- All applicable regulatory requirements, including codes, laws, regulations, rules and good practice procedures should be followed and integrated into the FRMP, as required. This includes addressing local fire and life safety requirements at a minimum.

Potential challenges of codes in relation to protecting heritage sites and structures

Prescriptive codes are often developed around past fire losses. Thus, requirements may at times be more reactive rather than proactive. Requirements may also be based on generic occupancy types (e.g., residential, assembly, etc.), rather than specific risks at that site/structure. As such, they may not address the particular exposures and vulnerabilities of the site's valuable contents, finishes, collections and so on. Accordingly, prescriptive code requirements may not always address the unique protection objectives and needs of heritage structures and content, especially to the degree assumed by stakeholders. This may be due to their:

- limited applicability to the unique needs and objectives of protecting heritage sites and structures
- limited quantified effectiveness given their generic nature versus the need to address specific hazards
- potential adverse impacts on historic fabric and solutions that may not be cost effective and
- prescriptive rather than risk-informed solutions that may not be able to fully achieve the fire safety objectives, including protecting the site, structure or contents to the degree desired (Marrion, 2016).

Equipment/Systems Approvals

- Equipment, systems and materials used should be approved and accepted by local authorities. This helps ensure they have been tested appropriately for their intended use in accordance with approved standards and meet a minimum level of performance, safety and reliability for the intended use.

Awareness/Capacity-building

- Awareness-raising and capacity-building programmes should be created for all FRMP team members and stakeholders, including local communities, and should cover DRM, fire, human behaviour, preparedness, prevention and mitigation, emergency response and resilient recovery, as well as the DRMP for the site/structure. The programmes should seek to:
  - create awareness among all stakeholders about the numerous fire hazards and vulnerabilities, the importance of responding quickly and the challenges faced by emergency responders
  - learn from past fires and losses and how they started and progressed, which measures worked, what did not work and why
  - unravel common misconceptions including regarding fire, sprinklers and codes and
  - understand emergency response, particularly the impact of time and the type and significant level of resources needed to suppress varying sizes of fire.
- Establish an ongoing training and certification programme for contractors and all their employees and sub-contractors. The programme should certify that all those working on the site have undertaken the appropriate initial training and will receive ongoing training, including the following.
  - All persons working on the site should be required to take part in the awareness, training and capacity-building programmes, and obtain and maintain a certificate, or be prohibited to work on the site.
  - Initial awareness and training sessions should occur prior to anyone being able to work on site.
  - Daily safety meetings with all personnel should occur, including to remind everyone of the need for fire safety and their associated responsibilities, as well as to address any challenges that arose the previous day.
  - Frequent, ongoing training with all personnel on site should occur on a recurring basis (minimum weekly), or more often as needed.

Implementing the Fire Risk Management Plan

Once the FRMP has been developed and agreed on by the stakeholders and all applicable authorities, it should be implemented. This may include the further development of emergency preparedness and response measures (see Sections 1.2 and 1.3). If construction and renovation work is necessary, see Section 2.2 regarding the need to develop a tailored FRMP to specifically address the increased fire risk during this time.

Monitoring, and Enforcing the Fire Risk Management Plan

- Implementation of the FRMP should be continuously monitored and enforced to ensure that implementation meets requirements and needs, and that all procedures, measures, maintenance, training, drills, etc are undertaken. Means should be developed and implemented to help monitor and enforce the FRMP.
- On-site inspections and monitoring should be provided continuously to identify issues and hazards, and notify all stakeholders, including the site manager and appropriate personnel, when deficiencies are noted so that these can be addressed, mitigated and resolved as soon as possible. Periodic reviews and assessments by an alternate stakeholder may also be beneficial.
- During renovation and construction work, on-site supervision, monitoring and enforcement should be provided by separate individuals representing the site manager/owner and each contractor and sub-contractor.

Reviewing and Updating the Fire Risk Management Plan

- Continuous reviews of the FRMP, including training and maintenance programmes, should be undertaken at least quarterly by a person with expertise in fire and life safety. Reviews should be and updated or revised as needed. This includes when changes occur, including due to hazards, changes in environmental and site/structure conditions, occupants, management, risk reduction measures, and construction and renovation work. Reviews should incorporate feedback gathered from training programmes.
- Ensure that any changes will not adversely impact the ability to achieve the intended objectives of the FRMP and the overall DRM Plan and that approvals are obtained from all stakeholders.

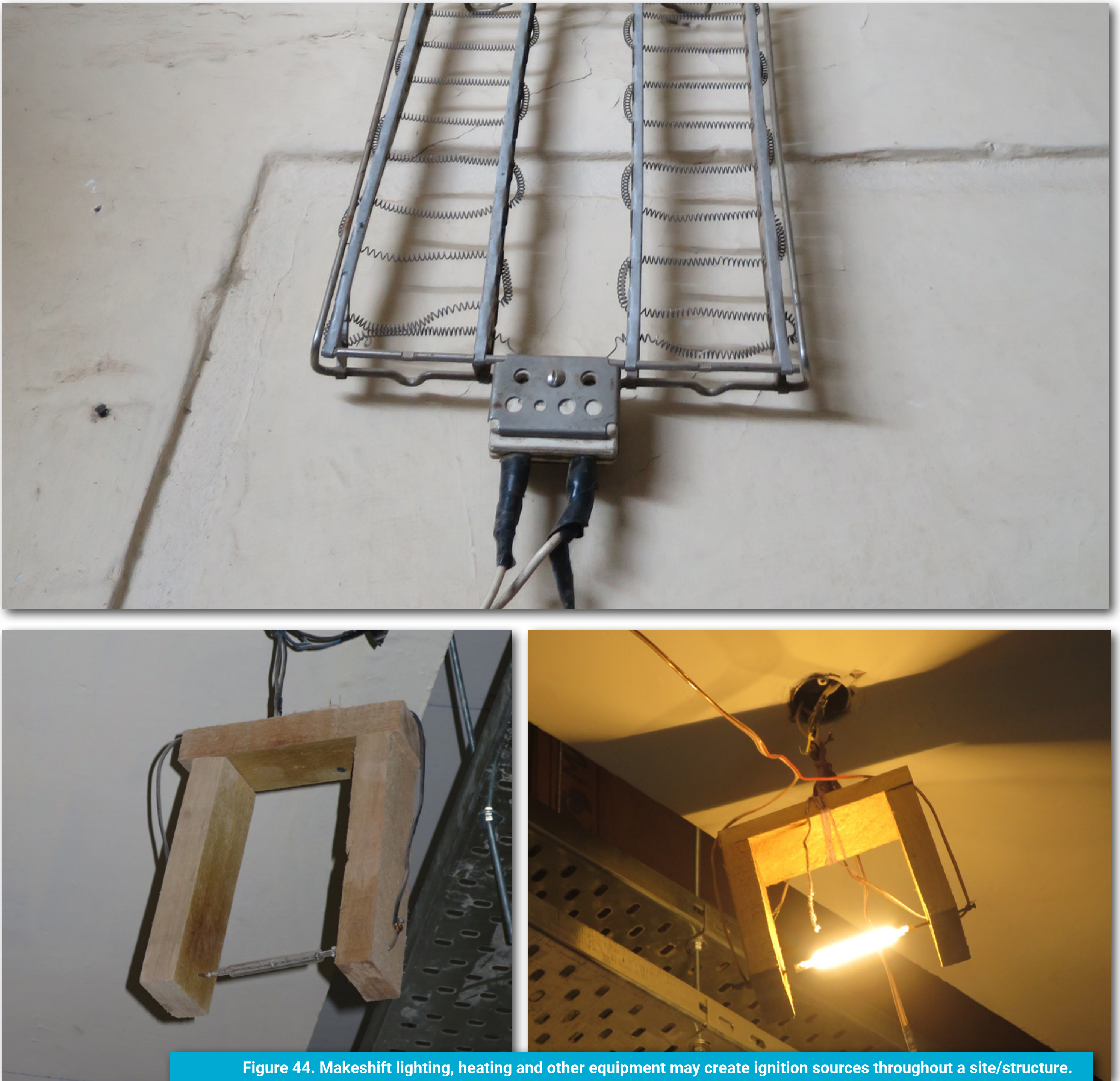

Figure 44. Makeshift lighting, heating and other equipment may create ignition sources throughout a site/structure.
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GLOSSARY

Build back better* The use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment.

Capacity* The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience.

Cultural Heritage**
For the purposes of this work, the following shall be considered as "tangible cultural heritage":

a. monuments: architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of Outstanding Universal Value from the point of view of history, art or science.
b. groups of buildings: groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of Outstanding Universal Value from the point of view of history, art or science.
c. sites: works of man or the combined works of nature and man and areas including archaeological sites which are of Outstanding Universal Value from the historical, aesthetic, ethnological or anthropological point of view.

And the following shall be considered as "intangible cultural heritage":

a. oral traditions and expressions, including language as a vehicle of the intangible cultural heritage;
b. performing arts;
c. social practices, rituals and festive events;
d. knowledge and practices concerning nature and the universe;
e. traditional craftsmanship.

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

Disaster management* The organization, planning and application of measures preparing for, responding to and recovering from disasters.

Disaster risk assessment* A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend.

Disaster risk management* The application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

Disaster risk reduction* An approach aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Disaster risk* The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Exposure* The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Fire disaster management The organization, planning and application of measures preparing for, responding to and recovering from fires.

Fire hazard A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation due to fire.

Fire mitigation The lessening or minimizing of the adverse impacts of a fire event once ignition has occurred.

Fire preparedness The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current fires.

Fire prevention Activities and measures to avoid fires from starting. *Annotation*: using the modifier 'disaster' to prevention – 'disaster prevention' would include all prevention and mitigation to keep a hazard from becoming a 'disaster'. 'Fire Prevention' would just entail preventing 'fire', not preventing a 'fire disaster', and thus is focused herein on prevention and not mitigation measures.

Fire risk The potential loss of life, injury, or destroyed or damaged assets, which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of fire hazard, exposure, vulnerability and capacity.

Fire risk assessment A qualitative or quantitative approach to determine the nature and extent of fire risk by analysing potential fire hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend.

Fire risk management The application of fire risk reduction policies and strategies to prevent new fire risks, reduce existing fire risks and manage residual fire risks, contributing to the strengthening of resilience and the reduction of fire-related losses.

Fire risk reduction An approach aimed at preventing new and reducing existing fire risks and managing residual risk through preventing fires from occurring (*fire prevention*) and through mitigating their impacts (*emergency preparedness*, *emergency response*, *fire mitigation*, *resilient recovery)* should ignition occur, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Hazard* A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

Mitigation* The lessening or minimizing of the adverse impacts of a hazardous event.

Natural Heritage** For the purposes of this work, the following shall be considered as "natural heritage":

a. consisting of physical and biological formations or groups of such formations, which are of Outstanding Universal Value from the aesthetic or scientific point of view;
b. and precisely delineated areas which constitute the habitat of threatened species of animals and plants of Outstanding Universal Value from the point of view of science or conservation;
c. or precisely delineated natural areas of Outstanding Universal Value from the point of view of science, conservation or natural beauty.

Preparedness* The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.

Prevention* Activities and measures to avoid existing and new disaster risks.

Resilience* The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Response* Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Recovery* The restoration or improvement of livelihoods and health, as well as the economic, physical, social, cultural and environmental assets, systems and activities of a disaster-affected community or society, aligning with the principles of sustainable development and 'build back better', to avoid or reduce future disaster risk.

Residual risk* The disaster risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. *Annotation*: The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.

Rehabilitation* The restoration of basic services and facilities for the functioning of a community or a society affected by a disaster.

Reconstruction* The medium- and long-term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community, or a society affected by a disaster, aligning with the principles of sustainable development and 'build back better', to avoid or reduce future disaster risk.

Traditional knowledge*** Traditional knowledge (TK) is knowledge, know-how, skills and practices that are developed, sustained and passed on from generation to generation within a community, often forming part of its cultural or spiritual identity.

Vulnerability* The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

* United Nations Office for Disaster Risk Reduction (UNDRR) terminology, www.undrr.org/terminology (accessed September 2021).
**UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage, UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage (accessed March 2024).

*** World Intellectual Property organization, https://www.wipo.int/tk/en/tk/ (accessed May 2024).

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FIRE RISK MANAGEMENT GUIDE

PROTECTING CULTURAL
AND NATURAL HERITAGE FROM FIRE

As climate change and human activities increasingly pose threats to cultural and natural heritage sites, the need for robust fire risk management has never been more critical. Fires have ravaged iconic heritage sites globally, causing lasting damage to humanity's shared treasures, ecosystems and communities.

Prevention, early detection and effective response are vital to the safeguarding of heritage in the 21 st century. UNESCO's Fire Risk Management Guide for Cultural and Natural Heritage tackles these challenges by offering essential principles, methodologies and processes to reduce fire-related risks. This guide empowers site managers, conservators, community leaders and emergency responders with the tools and knowledge to create tailored Fire Risk Management Plans (FRMPs).

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