



Wildfire Hazard Mitigation Handbook for Public Facilities

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Wildfire Hazard Mitigation Handbook for Public Facilities

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INTRODUCTION

The Federal Emergency Management Agency (FEMA) strives continuously to improve the delivery of disaster assistance to State, local, and tribal governments. One important goal of disaster assistance is to reduce the vulnerability of communities to damage from future disasters. This *Wildfire Hazard Mitigation Handbook for Public Facilities* (Handbook) is intended to assist facility owners affected by wildfire disasters by suggesting mitigation measures that can be taken to reduce the vulnerability of damaged facilities to future wildfire incidents. The measures described in this Handbook are applicable to the Public Assistance (PA) Program and are intended to help Applicants for assistance under the program identify options that can be implemented during post-disaster repair and rebuilding to reduce the potential for future damage.

FEMA provides assistance to State, local, and tribal governments under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), 42 United States Code §§ 5121-5206, as amended. Under the Stafford Act, FEMA is authorized to provide resources necessary to reduce the loss of life and property caused by emergencies and major disasters. FEMA works with Federal, State, local, and tribal liaisons to carry out this mission through a comprehensive emergency management program.

FEMA provides funding and technical assistance to State, local, and tribal governments for a range of disaster preparedness and mitigation activities. The Pre-Disaster Mitigation (PDM) grant program provides funding to State, local, and tribal governments for mitigation planning and implementation of cost-effective mitigation projects prior to a disaster.

After the President declares a major disaster, FEMA incorporates mitigation into recovery efforts through several mechanisms. Under Section 406 of the Stafford Act, FEMA provides funding for repair and rebuilding of disaster-damaged public facilities and those of certain private, non-profit entities through the PA Program. As part of the PA Program, FEMA may provide funding for cost-effective mitigation measures undertaken in the course of repairing or rebuilding damaged facilities, sometimes referred to as “406 Mitigation.” Section 404 of the Stafford Act also authorizes FEMA to provide funding to State, local, and tribal governments through the Hazard Mitigation Grant Program (HMGP), sometimes referred to as “404 Mitigation,” for the implementation of long-term mitigation measures.

This Handbook focuses on mitigation that FEMA funds under the PA Program following Presidentially declared disasters in which assistance for the restoration of disaster-damaged facilities is authorized. The Handbook can also be useful for evaluating the mitigation options that are available to planners when developing long-term mitigation strategies or when considering measures to be funded under the HMGP, PDM Program, or other grant programs, even though these other programs are not described in the Handbook.

The Problem

The cost of response and recovery has escalated to unprecedented levels in recent years from the increased frequency and severity of disasters. Between 1999 and 2008, FEMA spent an average of \$2.8 billion per year responding to major disasters. Of that amount, an average of \$1.2 billion was spent repairing or replacing public facilities, which does not include response and recovery costs of other Federal agencies; State, local, and tribal governments; and losses of individuals and businesses. For more information, see www.fema.gov/government/grant/pa/stat2.shtm.

The Solution

The most effective way to reduce excessive loss is through disaster preparedness and mitigation. To best achieve this goal, FEMA encourages the vigorous pursuit of the following objectives.

Objective 1: Break the disaster-rebuild-disaster cycle. Until recently, this cycle was the most common mode of disaster recovery. Repairing substandard facilities to their pre-disaster condition does not protect the community from future damage or reduce long-term costs. The community should work to break this cycle through effective planning, identification of measures that can reduce the potential for future damage, and adoption of appropriate codes and standards for construction.

Objective 2: Strengthen facilities so that they are able to withstand natural hazards more effectively. Cost-effective upgrades that reduce the probability of future damage to vulnerable facilities and that can be incorporated during rebuilding should be considered whenever possible.

Objective 3: Ensure that communities address natural hazards as part of comprehensive planning. Comprehensive plans should include the community's significant natural hazards and the goals and actions that reduce the community's vulnerability to these hazards.

The Result

Achieving these objectives will substantially enhance community resilience and economic sustainability after a disaster, as shown in *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*, a study conducted by the Multihazard Mitigation Council and funded by FEMA (Multihazard Mitigation Council, 2005). The study indicates that hazard mitigation saves an average of \$4 for every \$1 of investment.

PURPOSE OF THE HANDBOOK

This Handbook is intended for use by State, local, tribal, and private, non-profit Applicants for assistance, FEMA and State PA Group Supervisors, and FEMA and State PA Program Project Specialists. The Handbook can be used to identify potentially feasible mitigation measures that can be implemented during the repair and rebuilding of damaged facilities after a disaster.

The Handbook applies to public and private, non-profit facilities eligible for funding under the PA Program and focuses on projects that are commonly eligible for hazard mitigation funding under the program. Due to the urgency in repairing damaged facilities after a disaster, long-term mitigation opportunities are frequently not fully explored, and hazard mitigation funding opportunities through the PA Program are often not fully used. The Handbook can also be used as a resource for mitigation measures that may be eligible for funding under other mitigation grant programs, some of which are noted above.

The Handbook contains information about mitigation measures that address the most common types of damage sustained in wildfires, that have been shown to be successful, and that can be implemented in a timely fashion. The Handbook is not a construction guide. Mitigation measures are described conceptually, and installation details and construction methods are not included.

Users of the Handbook are advised to refer to Disaster Assistance Policy 9526.1, "Hazard Mitigation Funding Under Section 406 (Stafford Act)," for FEMA policy governing funding for hazard mitigation under the PA Program. The policy describes those circumstances under which funding for hazard mitigation is eligible for PA Program funding. It also contains a list of measures that FEMA has determined are cost-effective when certain conditions are met (for example, when the cost of the mitigation measure does not exceed 100 percent of the eligible cost for repairs). The policy is provided in Appendix A of this Handbook.

None of the mitigation measures described in this Handbook should be considered pre-approved or automatically eligible for PA Program funding. The Handbook can be used by Applicants for PA Program funding as a tool for identifying possible mitigation measures and as the basis for discussion with FEMA and State PA Program representatives during the development of scopes of work and cost estimates. It should always be used in conjunction with Disaster Assistance Policy 9526.1 and with other guidance published by FEMA for the PA Program, as described in the next section.

HOW TO USE THIS HANDBOOK

Organization of Mitigation Measures

The Handbook is organized by type of facility. A number of mitigation measures are described for each type of facility. When incorporated into the restoration of a damaged facility, these measures may increase the resistance of the facility to damage from a wildfire. General design issues, effectiveness, limitations, and other considerations of the mitigation measures are also listed.

Public Assistance Program Eligibility

As with all agencies that provide Federal funding, FEMA has criteria that must be met before proposed PA Program projects can be approved. These criteria are based on the requirements of the Stafford Act, its implementing regulations,¹ and policies that FEMA has developed to apply the PA Program to specific circumstances. **Only FEMA can determine the eligibility of an Applicant, facility, work, or cost under the PA Program.** Eligibility criteria are described in FEMA 322, *Public Assistance Guide* (FEMA, 2007). Additional publications, PA Program policies, and other information regarding the PA Program can be obtained at www.fema.gov/government/grant/pa/index.shtm or from the appropriate FEMA Regional Office.

Engineering, Design, and Permitting Requirements

The Handbook does not list site-specific requirements because the engineering analysis, design, and permitting requirements for each project vary widely. However, the Handbook does provide some common code and design issues to be considered when implementing mitigation measures and references containing additional technical information. Repair and mitigation of structural elements most often require a professional engineer who can analyze the condition of the structure and determine the appropriate repair and mitigation.

The mitigation measures described in this Handbook may not be appropriate in areas where other hazards, such as earthquakes and hurricanes are also a factor. Design factors related to non-wildfire hazards should be evaluated when mitigation measures are considered.

¹ The PA Program regulations are published in Title 44 Code of Federal Regulations (CFR) Parts 206.200–206.228.

Considerations for Implementation of Mitigation Measures

The following symbols represent considerations for implementation of the mitigation measures described in this Handbook. The considerations are defined in Appendix B.



Project may be cost-prohibitive



Maintenance required to maintain effectiveness



Engineer needed



Structural aesthetics could be affected



Weather considerations



Local code requirements



Short lifespan

Environmental and Historic Preservation Considerations

When providing funds under the PA Program, FEMA must consider a range of Federal environmental and historic preservation laws, regulations, and Executive Orders that apply to the use of Federal funds and require the funding agency to ensure compliance prior to funding. The size and type of project, project site, and area conditions generally determine the level of review for compliance that must be performed. Environmental and historic preservation laws, regulations, and Executive Orders that commonly apply to PA Program mitigation projects are summarized in Appendix B. More information on FEMA's environmental and historic preservation compliance responsibilities is available in

FEMA 322, *Public Assistance Guide* (FEMA, 2007) and at www.fema.gov/plan/ehp.

Reviews for compliance with these laws, regulations, and Executive Orders must be completed before FEMA can approve funding for PA Program mitigation projects and before the projects are started because the review may identify steps that need to be taken or conditions that need to be met as the project is implemented. Project Specialists evaluating potential mitigation measures should coordinate with the Regional Environmental Officer or designee for the appropriate procedures necessary to support the compliance reviews.

Mitigation Keywords

A mitigation keyword refers to a mitigation element that is used in at least two mitigation measures in this Handbook. Keywords are intended to help the reader become familiar with mitigation elements by understanding their application in different measures. Mitigation keywords are italicized and bolded in the document and defined in Appendix C.

Appendices

The Handbook includes the following appendices:

- Disaster Assistance Policy 9526.1 (Appendix A)
- Considerations for Implementation of Mitigation Measures (Appendix B)
- Glossary and Keyword Index (Appendix C)
- Defensible Space (Appendix D)
- Acronyms (Appendix E)
- References (Appendix F)
- List of Contributors (Appendix G)

OVERVIEW OF THE PUBLIC ASSISTANCE PROGRAM

The PA Program is authorized by the Stafford Act. Under this program, FEMA provides recovery assistance to State, local, and tribal governments and certain private, non-profit entities following Presidential declarations of emergencies and major disasters. The program provides assistance for extraordinary costs for debris removal, emergency protective measures, and permanent restoration of damaged facilities. Under the program, which is based on reimbursement of actual costs, the Federal government provides a minimum of 75 percent of eligible costs.

The Stafford Act and its implementing regulations stipulate that funding for permanent restoration of damaged facilities is limited to work that is necessary to restore a facility to its pre-disaster design. The PA Program may also provide funding for upgrades that are necessary to meet current codes and standards and for hazard mitigation measures, as described below.

For more information about the PA Program, see FEMA 322, *Public Assistance Guide* (FEMA, 2007), go to www.fema.gov/government/grant/pa/index.shtm (PA Program website) or contact the appropriate FEMA Regional Office.

Upgrades Necessary to Meet Current Codes and Standards

When a disaster-damaged facility must be repaired or replaced, PA Program funding may be used to pay for upgrades that are necessary to meet current codes and standards. This situation typically occurs when older facilities, particularly buildings, must be repaired in accordance with codes that were adopted after the original construction.

For the cost of an upgrade to be eligible, the code or standard requiring the upgrade must:

- Apply to the type of work being performed. If a facility must be replaced, an upgrade would apply throughout the facility. If a facility needs repair work only, upgrades would apply only to the damaged elements.
- Be appropriate to the pre-disaster use of the facility.
- Be reasonable, formally adopted, in writing, and implemented prior to the disaster declaration date. The appropriate legislative authority within the applicable jurisdiction must have taken all requisite actions to implement the code or standard.
- Apply uniformly to all facilities of the type being repaired within

the Applicant's jurisdiction. The standard must not allow selective application or discretionary enforcement by public officials. The standard must be applied regardless of the source of funding for the upgrade work; it cannot be applied selectively based on the availability of funds.

- Be enforced during the time that it was in effect. FEMA may require documentation showing prior application of the standard.

Mitigation measures described in this Handbook may be required by applicable codes and standards. In such circumstances, the measures may be eligible for funding under the PA Program as part of the restoration of a damaged facility if the above five criteria are met.

Hazard Mitigation Under the Public Assistance Program

Section 406 of the Stafford Act authorizes FEMA to provide funding for hazard mitigation measures that go beyond the scope of work that is eligible under the program. PA Program guidelines for the eligibility of hazard mitigation measures are described in Disaster Assistance Policy 9526.1, "Hazard Mitigation Funding Under Section 406 (Stafford Act)" (see Appendix A).

Users of this Handbook should note that the eligibility criteria for mitigation measures under the PA Program are much different from the criteria for funding mitigation measures under the HMGP, PDM Program, and other mitigation programs. Applicants for PA Program funding should consult with State and FEMA PA Program representatives when considering mitigation measures for the restoration of disaster-damaged facilities using PA Program funding. As stated above, the Handbook should always be used in conjunction with Disaster Assistance Policy 9526.1 and with other guidance published by FEMA for the PA Program.

INTRODUCTION TO WILDFIRE DAMAGE

Wildland/Urban Interface Fire Hazards

A wildfire is an uncontrolled fire that spreads through vegetative fuels. Vegetative fuels include those that are characteristic of wildlands, such as trees, grasses, understory growth, and ground litter; and those that are purchased at nurseries for home or community landscaping purposes, including trees, mulch, grasses, and ornamental plants. In addition to the presence of fuel, the occurrence and severity of wildfires are governed by weather, such as high temperatures, low humidity, high winds, and drought conditions; and topography (for example, canyons and gulches act as chimneys, intensifying fires in certain areas). Different combinations of these factors contribute to the potential severity of wildfires.

In the wildland/urban interface, buildings and other human development intermingle with vegetative fuels, exposing the development to potential fire damage when wildfires occur. Other factors that affect the vulnerability of development to wildfire are location, weather conditions during the wildfire, and the fire-suppression capabilities of local response agencies.

Increase in Wildfire Risk

The pressure to develop land over the past several decades has fueled the expansion of the residential and commercial environment outward from community centers and into the surrounding wildland. In the western United States, nearly 40 percent of new home construction is adjacent to or intermixed with wildland vegetation (Firewise Colorado, 2001). Combined with an increase in fuel loads due to construction and changes in vegetation, this trend has resulted in greater exposure of development to the occurrence of wildfire. The result is a significant increase in the risk of damage to development from wildfire.

This risk is also increased by the trend towards larger wildfires. According to the National Oceanic and Atmospheric Administration, the number of fires in the United States has declined every year since the early 1980s, but the number of acres burned has increased steadily every year since the mid-1990s. In terms of number of acres burned, six of the ten worst fire seasons on record have occurred since 2000.

Occurrence of Wildland/Urban Interface Fires

Wildland/urban interface fires are a threat across the United States. According to the National Interagency Fire Center, wildfires occurred in every state in 2006, burning over 9 million acres.

Major fires in the wildland/urban interface have the potential for vast destruction by destroying homes and other structures, causing mass evacuations, and causing injuries and deaths. Notable recent examples are:

- East Bay Hills, Oakland, California, 1991: This fire burned 1,600 acres and resulted in 25 fatalities, the destruction of 3,300 single-family homes and 450 apartment units, and damages of \$1.5 billion.
- Florida Wildfires, 1998: This fire burned 500,000 acres and resulted in evacuations of 35,000 residents, closure of an interstate highway, and damage or destruction of 337 homes.
- Rodeo-Chediski Fire, Arizona, 2002: This fire burned over 462,000 acres, making it one of the largest fires in state history, and destroyed 426 homes.
- Southern California Wildfires, 2003: These fires, which burned 750,000 acres in six counties around Los Angeles and San Diego, destroyed 3,700 homes and resulted in 29 fatalities.
- Southern California Wildfires, 2007: Striking the same region as the 2003 wildfires, the 2007 fires burned over 500,000 acres, destroyed 1,700 homes, and displaced over 900,000 people, the largest evacuation in California history.

Wildfire Damage to Public Facilities¹

Wildfires propagate by consuming available fuel, including vegetation and combustible materials. In an approaching wildfire, facility components that are combustible can be ignited by embers, firebrands, flames, radiant energy, and convective energy, as described below.

- Burning embers and firebrands, carried on air currents, can travel significant distances in advance of a wildfire and land on a facility, igniting exterior materials, or enter the facility through an opening, igniting interior materials.

¹ As stated above, public facilities and facilities owned by certain private, non-profit entities are eligible for funding under the PA Program. For purposes of this Handbook, references to “public facilities” include any facilities eligible for funding under the PA Program, including private, non-profit facilities.

- Flames from the combustion of nearby materials can transfer to a facility and cause ignition of facility components.
- Radiant energy from combustion of nearby materials can be sufficient to cause ignition of facility components, even if the components are not on the exterior of the facility.
- Convective energy, in the form of hot gases, removes moisture from the air, penetrates openings, and can be sufficient to cause ignition of facility components.

A wildfire can deform or melt facility components that do not initially ignite. Damage to power systems can cause surges that damage electrical and mechanical equipment.

Facilities that are particularly vulnerable to wildfire damage include those that have the following characteristics:¹

- Combustible construction materials or materials that deform or melt when heated
- Combustible exterior components or attached structures
- Openings such as vents, that allow heat, embers, or firebrands to enter the facility and ignite combustible components within the facility
- Features such as overhangs that allow heat, gases, embers, and firebrands to be trapped adjacent to combustible materials
- Features such as gutters, decks, and fences that allow combustible debris to accumulate, providing fuel adjacent to the facility that can ignite, resulting in ignition of facility components
- Interior components that can ignite when the facility exterior is heated

Although the facility design and construction materials may contribute to vulnerability to wildfire, the presence, type, and density of vegetation has a significant impact on the level of risk to the facility. Vegetative fuels can lead surface fires to the facility and produce embers and firebrands that can cause ignition when striking or entering the facility. Additionally, leaf litter, needles, and other vegetative matter that accumulate in or near a facility can ignite and spread fire to the facility. Although measures to reduce or eliminate vegetative fuels may not be eligible for PA Program funding, these measures are critical to reducing the vulnerability of a facility to a wildfire and the cost of the measures can be minimal.

¹ The order in which these characteristics are presented is not related to their importance. The vulnerability of a specific facility is based on many factors, including topography and available local fire suppression capabilities.

Wildfire Code Requirements and Standards

State and local officials have sought to reduce the vulnerability to wildfire by developing code requirements and standards for construction in areas where wildfires pose a risk. The codes and standards have been developed over time to expand fire protection beyond traditional fire codes that address interior structure fires to include measures to protect structures from the exterior threat posed by wildfires.

At the national level, the International Code Council has prepared the International Wildland Urban Interface Code (IWUIC), which supplements the International Building Code that has been adopted by many States. The model code regulations included in the IWUIC bring together requirements for planning and design for buildings constructed or modified within wildland/urban interface areas. Other nationally applicable standards, such as the National Fire Protection Association (NFPA) Fire Protection Infrastructure for Land Development, NFPA 1141 (NFPA, 2008a) and Standards for Reducing Structure Ignition from Wildfire, NFPA 1144 (NFPA, 2008b), provide similar guidance.

Because the presence of vegetation that could fuel a wildfire is the greatest threat to life, health and safety, and buildings and other facilities, requirements for fuel reduction and the creation of **defensible space** have often been the focus of codes and standards for reducing vulnerability to wildfires. These requirements are intended to reduce the rate of fire spread and provide a safer environment for fire suppression. The requirements are focused on the removal of vegetation, such as trees, brush, and grasses, to create firebreaks immediately adjacent to buildings and other structures, and reduced fuel zones that disrupt the horizontal and vertical continuity of combustible vegetation. Defensible space is described in Appendix D of this Handbook.

Additionally, codes and standards have been developed for planning, zoning, and land development components that are designed to reduce vulnerability to wildfires. The codes and standards may include requirements to avoid areas of increased risk, such as canyons that can accelerate the rate of fire spread; requirements for building separation; specifications for streets and driveways to allow ingress/egress; and specifications for water supply.

The protection of individual facilities is guided by codes that have incorporated **ignition-resistant construction standards**, which include requirements designed to reduce the potential for ignition, particularly due to flying embers and firebrands, in areas prone to wildfire hazards.

Ignition-resistant construction standards are based on the use of **fire-resistant materials**, **noncombustible materials**, and 1-hour fire-rated assemblies.

Designating an area as a fire severity zone is based on factors such as fuel, topography, and weather. The designation includes the potential severity of wildfire that could occur (for example, extreme, high, or moderate wildfire severity). The assessment and mapping of fire severity zones and dissemination of information about the areas provide an additional tool for planning and designing facilities and development to reduce vulnerability to wildfires. Many State and local governments use fire severity zones to set standards for ignition-resistant construction that vary depending on wildfire severity. The IWUIC provides for three classes of ignition-resistant construction based on the severity of the fire hazard in the area in which the building is located. Accordingly, the fact that a facility is located in a fire severity zone may guide the selection of mitigation measures.

Elements of Successful Wildfire Mitigation

A comprehensive effort to reduce the vulnerability of public facilities to wildfires incorporates the following elements:

- Definition of the fire severity zone to determine the potential fire severity at the location of the facility.
- Establishment of **defensible space** around the facility to keep wildfires away from the facility and allow for fire suppression activities.
- Modification to, or incorporation of, components that reduce the potential for ignition in the event that a wildfire approaches the facility.

The last element may be eligible for PA Program funding during restoration of a damaged public facility if required for repair of damaged elements under current codes and standards or if it is a cost-effective hazard mitigation measure. Components that reduce the potential for ignition, which are the focus of this Handbook, should include:

- Noncombustible components that resist ignition
- Fire-resistant assemblies to reduce the spread of heat and flames
- Components that prevent the trapping and intrusion of hot gases, embers, and firebrands that could cause ignition

This Handbook provides information about the typical ways the following facilities are damaged by wildfire and the measures that can be taken to reduce the potential for the damage.

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I. BUILDINGS

In this section, mitigation measures that can reduce the vulnerability of buildings and attached structures such as decks and ramps to wildfire hazards are described. One measure that is not included and may not be eligible for PA Program funding, creation of **defensible space** around the building, may be critical to reducing the vulnerability of the building to wildfire hazards. Information about creating a defensible space is provided in Appendix D.

Typical Damage to Buildings: In general, the factors that make a building vulnerable to wildfire damage are:

- Proximity to topographic features such as steep slopes, ridges, and saddles, which can contribute to the spread of wildfire; high wind conditions increase the risk
- Proximity to fuels including vegetation, other materials, structures, and accumulated debris, and lack of defensible space
- Building components that do not consist of **fire-resistant** or **noncombustible** materials but are exposed to radiant heat, hot gases, flames, embers, or firebrands that may cause ignition of the components
- Openings through which hot gases, embers, and firebrands can intrude and cause ignition within the building

A reduction in the vulnerability of a building to wildfire damage is most effectively achieved through measures that address all of these factors.

Although the type and design of public buildings vary widely, building components that are most susceptible to damage during wildfires are common to many building types. These components are described below.

Roofs: Roofs are the most vulnerable component of the building. They can be exposed to flames and, due to their horizontal orientation, are especially susceptible to ignition by airborne embers and firebrands. Combustible debris may accumulate on the roof or in gutters. Aside from creating a defensible space, installing a Class A rated roof is the most critical element in reducing a building's vulnerability to wildfire.

Exterior walls: Exterior walls that are not constructed to ignition-resistant construction standards are vulnerable to ignition due to flames, radiant heat, and airborne embers and firebrands. Combustible materials within the wall may ignite due to conduction of heat from

exterior materials. Openings for utilities and other purposes may allow hot gases and embers to intrude, causing ignition within the building.

Vents: These components may ignite if not constructed of **fire-resistant** or **noncombustible** material or may allow hot gases and embers to intrude, causing ignition within the building.

Exterior doors, windows, and skylights: Door, window, and skylight assemblies may ignite if not constructed to **ignition-resistant construction standards**. Additionally, gaps around doors and breakage of glass in doors, windows, and skylights may allow hot gases, embers, and firebrands to intrude, causing ignition within the building.

Ramps, decks, and other attached structures: These structures are often constructed of combustible materials that provide fuel for flames that can spread to the building. Additionally, hot gases and embers may ignite vegetation or materials stored beneath these structures, causing them to ignite.

Foundations: Foundations may be constructed of combustible materials that can ignite. Additionally, hot gases and embers may penetrate the foundation through vents and windows and ignite material stored in crawl spaces.

Contents: Building contents are often combustible and once ignited, can contribute to the spread of fire through the interior of the building.

Equipment: Equipment such as heating, ventilation, and air conditioning equipment may be damaged by heat or flames or may allow hot gases and embers to enter the building through gaps where the equipment penetrates the building exterior.

The following sections contain mitigation measures for common types of wildfire damage to various building components.

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A. Roof

Introduction: Roofs may be steep-sloped (roofs with a slope greater than 3:12) or low-sloped (low-sloped roofs include flat roofs). The components of the roof assembly, with examples of these types of roofs, are listed below.

Component	Examples of Steep-Sloped Roofs	Examples of Low-Sloped Roofs
Roof covering	Shingles, tiles, panels	Membrane, built-up roofing
Underlayment	Asphalt impregnated felt	Insulation board
Decking	Plywood or oriented strandboard sheathing	Corrugated metal, concrete-filled metal, concrete panels
Framing	Depends on structure but often wood-based composite	Depends on design but often steel or concrete

Roof assemblies have a **fire-resistance rating** based on their resistance to external fire exposures. The American Society of Testing and Materials International (ASTM) classifies roof assemblies as Class A (highest rating), B, or C using test method E108. Assemblies that fail the test (do not meet Class A, B, or C criteria) are unrated. A Class A rated roof assembly is recommended when considering mitigation options.

A roof assembly includes all of the interacting roof components such as the roof covering and roof deck. Installing a **noncombustible** roof covering or deck alone is not necessarily sufficient for the roof assembly to achieve a Class A rating. Under 406 Mitigation, mitigation can be applied only to the damaged element. However, when determining the material to repair or replace the damaged element, the entire roof assembly should be considered to achieve a Class A rating. For example, a roof with a **fire-retardant-treated** wood shingle roof covering can reach a Class A rating only if coupled with a specific cap sheet **underlayment**.

Causes of Damage: The roof is the most critical component of the building's vulnerability. Damage results from ignition of:

- Roof covering, due to flames, radiant heat, or contact with airborne embers and firebrands; or ignition of debris such as pine needles and leaves that have collected on the roof

- Roof deck, due to ignition of the roof covering, exposure to heat transfer by conductive heat, or intrusion of embers through gaps such as displaced tiles
- Debris that has collected in gutters and underneath tiles at the roof edge
- Eaves and overhangs, which may trap heat, hot gases, and embers

Mitigation measures for common types of wildfire damage to roof components are discussed in the following sections:

A.1	Roof Covering	6
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A.1 Roof Covering

Problem: Roofs with coverings that are combustibile can ignite due to contact with flames, radiant heat, airborne embers and firebrands, or accumulated roof debris that has ignited.

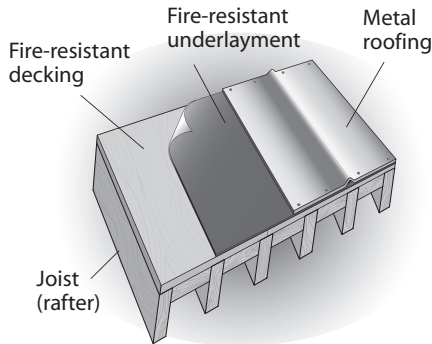
Mitigation Objective: Prevent ignition of the roof covering by installing a Class A rated roof assembly.

Mitigation measures to prevent ignition of the roof covering include:

- A.1.a Install an Appropriate Roof Covering on a Steep-Sloped Roof 7
- A.1.b Install an Appropriate Roof Covering on a Low-Sloped Roof 8
- A.1.c Install Flashing at Roof Valleys and Intersections with Roof Vents, Walls, and Chimneys 9

A.1.a Install an Appropriate Roof Covering on a Steep-sloped Roof to Achieve a Class A Rated Roof Assembly

Description of Mitigation Measure: Install a **noncombustible** roof covering such as clay and concrete tile, slate, **fiber-cement** tiles, and metal shingles and panels. Other materials included in Class A rated roof assemblies are fiberglass-reinforced asphalt shingles and exterior rated **fire-retardant-treated** wood shake or shingles.



Effectiveness: Noncombustible roof coverings that are part of a Class A roof assembly are recommended and effective in reducing vulnerability to wildfire damage in all fire severity zones. However, other roof coverings such as fire-retardant-treated wood shingles, if combined with the appropriate **underlayment** and decking to prevent the penetration of flames to the building interior, can also be used (see Section A.2) to achieve a Class A rating.

Design Issues: When installing a different roof covering material than that used in the pre-disaster design, it may be necessary to replace components of the roof deck to accommodate the new material (see Section A.2).

Birdstops or mortar should be installed at the open ends of tile roof coverings to prevent the accumulation of debris and entry of embers under the tiles (see Section A.3.b).

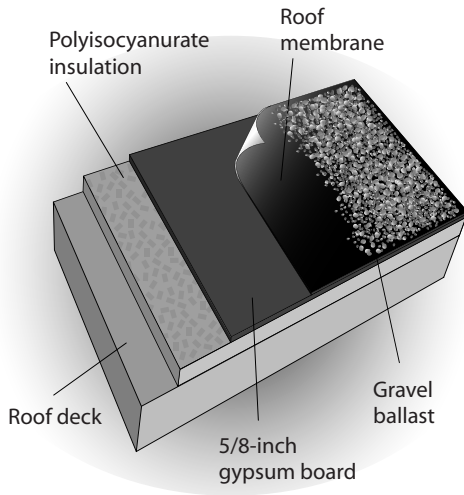
Limitations: Metal roofing may conduct heat or melt (depending on the metal type and exposure) and may ignite the roof substrate underneath it.

Considerations:



A.1.b Install an Appropriate Roof Covering on a Low-sloped Roof to Achieve a Class A Rated Roof Assembly

Description of Mitigation Measure: Install a *noncombustible* roof covering such as metal roofing or gravel ballast. A wide range of proprietary products for membrane roofs, built-up roofs, and hybrids of these two types of roofs are available, some of which include noncombustible coverings or are included in Class A rated roof assemblies.



Effectiveness: Specifying a Class A rated roof assembly is recommended and is effective in reducing the potential for ignition of the roof covering and for reducing heat transfer and fire penetration to the deck from the exterior.

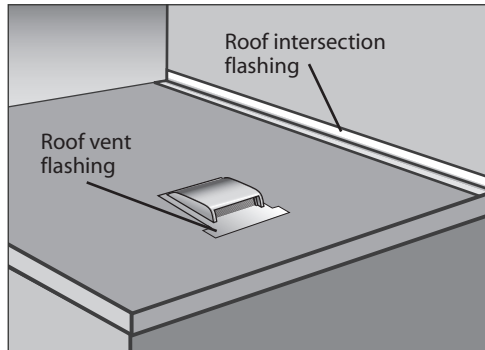
Design Issues: When installing a different roof covering material than that used in the pre-disaster design, it may be necessary to replace components of the roof deck to accommodate the new material (see Section A.2). For membrane and built-up roofing systems, the manufacturer's specifications and testing data should be consulted to determine whether the roof covering or roof assembly meets desired requirements.

Considerations:



A.1.c Install Flashing at Roof Valleys and Intersections with Roof Vents, Walls, and Chimneys

Description of Mitigation Measure: Install metal *flashing* and *fire-resistant underlayment* below flashing in areas on the roof that may accumulate debris. Areas that commonly accumulate debris are roof valleys, roof edges, intersections with exterior walls, and penetrations in the roof covering, such as chimneys, through-roof vents, and skylights.



Effectiveness: Effective at reducing vulnerability to wildfire in all fire severity zones.

Design Issues: Installation of fire-resistant underlayment may be a component of mitigation for the entire roof (see Section A.2.b).

Considerations:



A.2 Roof Deck

Problem: During wildfire exposure, the roof deck is the last line of defense in reducing the potential for transfer of heat and spread of flames from the roof into the interior of a building.

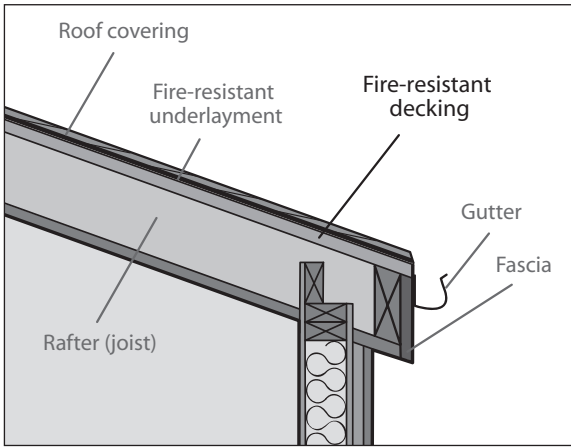
Mitigation Objective: Prevent the transfer of heat and spread of flames from the roof into the interior of the building by installing a Class A rated roof assembly.

Mitigation measures to protect the roof deck from damage by wildfire damage include:

- A.2.a Install an Appropriate Roof Deck 11
- A.2.b Install an Appropriate Underlayment . . . 12

A.2.a Install an Appropriate Roof Deck to Achieve a Class A Rated Roof Assembly

Description of Mitigation Measure: Use a **noncombustible** deck such as steel, concrete, or concrete over steel decking, or use a **fire-retardant-treated** wood deck to achieve a Class A rated roof assembly.



Effectiveness: Noncombustible roof decks that are part of a Class A rated roof assembly are recommended. In all fire severity zones, concrete decks and concrete topping over steel decks are effective in preventing intrusion of high heat, embers, and flames into the building.

Although steel decks and fire-retardant-treated wood decks offer greater protection than combustible decks, they are not as effective as concrete decks. Heat can readily transfer through steel decks, and embers can enter the interior of the building between steel and wood deck joints. Steel and fire-retardant-treated decks can be effective in reducing vulnerability to wildfire damage if other roof assembly enhancements are incorporated as recommended in other sections of this Handbook.

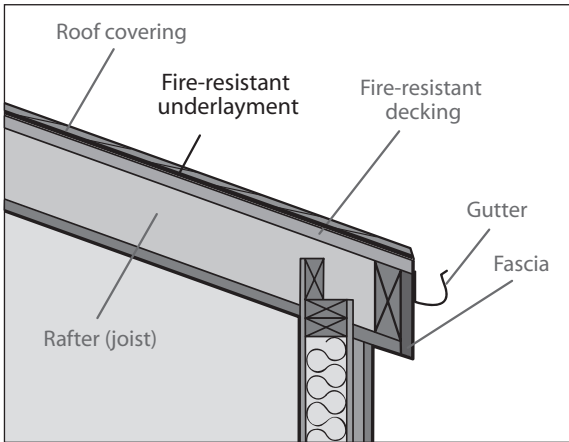
Design Issues: If the existing roof deck is to be removed because it is damaged, an evaluation must be conducted to determine whether the existing deck framing members have adequate structural capacity to support the new deck.

Considerations:



A.2.b Install an Appropriate Underlayment to Achieve a Class A Rated Roof Assembly

Description of Mitigation Measure: Install a **fire-resistant underlayment** to prevent wildfire exposures from reaching the roof deck. Examples include a mineral-surface cap sheet rated for use in a Class A rated roof assembly and exterior grade **Type X gypsum** sheathing products.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones if used in a Class A rated roof assembly.

Design Issues: Gypsum board is specified as Type X if it is 5/8-inch thick and complies with ASTM C 1177.

Limitations: Fire-resistant underlayments cannot prevent ignition to a roof that does not have a Class A rated roof assembly.

Considerations:



A.3 Roof Edges

Problem: Combustible debris such as leaf litter and pine needles may accumulate along the edges of the roof, either in gutters or in the gaps beneath the edges of clay tiles. This debris can ignite and spread flames to the roof covering or deck.

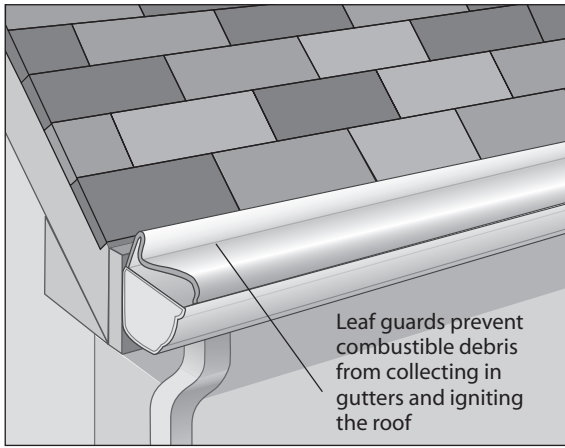
Mitigation Objective: Reduce the potential for the accumulation of combustible debris.

Mitigation measures to prevent ignition of debris on roofs include:

- A.3.a Install Noncombustible Gutters 14
- A.3.b Install Birdstops 15

A.3.a Install Noncombustible Gutters

Description of Mitigation Measure: Install gutters constructed with **noncombustible** material such as aluminum, galvanized steel, or copper. Install leaf guards to provide a cover over gutter openings and help resist debris from accumulating in the gutter.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Mesh leaf guards are not effective in preventing the accumulation of pine needles. Solid leaf guards as shown in the figure are therefore recommended.

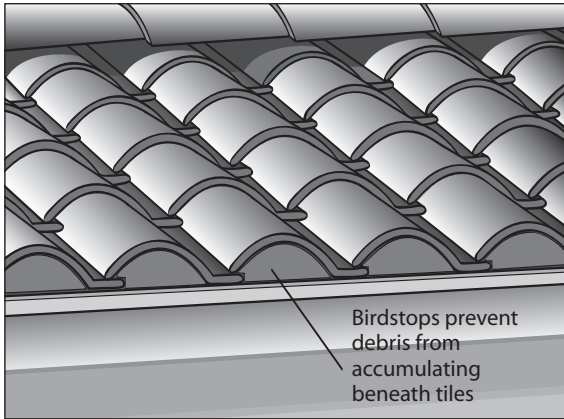
Limitations: Leaf guards may become dislodged over time, allowing debris to accumulate between the leaf guard and the roof. In this instance, the leaf guard must be reinstalled.

Considerations:



A.3.b Install Birdstops

Description of Mitigation Measure: Install *noncombustible* birdstops at eaves to prevent debris from accumulating and to prevent birds from building nests.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Quality of construction must eliminate all openings that may allow embers into roof assembly.

Limitations: Birdstops may become dislodged over time and must be reinstalled when it occurs.

Considerations:



A.4 Eaves and Overhangs

Problem: Embers and hot gases may be trapped by eaves and overhangs during a wildfire. The eaves, overhangs, and soffits, as well as the adjacent exterior wall, may ignite if not constructed of **fire-resistant** or **noncombustible** materials. Additionally, eave vents under the overhang where hot gases are often trapped may allow embers to enter the attic space where they can quickly ignite surrounding materials.

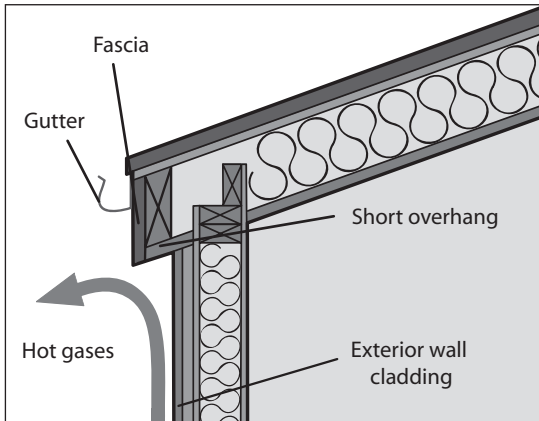
Mitigation Objective: Reduce or prevent the trapping of hot gases and embers that can cause ignition of building components and prevent the intrusion of embers into the building interior.

Mitigation measures to protect eaves and overhangs from wildfire damage include:

- A.4.a Reduce or Eliminate Overhangs 17
- A.4.b Construct Eave Assembly to Reduce Vulnerability to Wildfire Damage 18

A.4.a Reduce or Eliminate Overhangs

Description of Mitigation Measure: Design the building without overhangs, or if an overhang is designed, minimize the width of the overhang and use **fire-resistant** materials to enclose exposed eaves (see Section A.4.b).



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

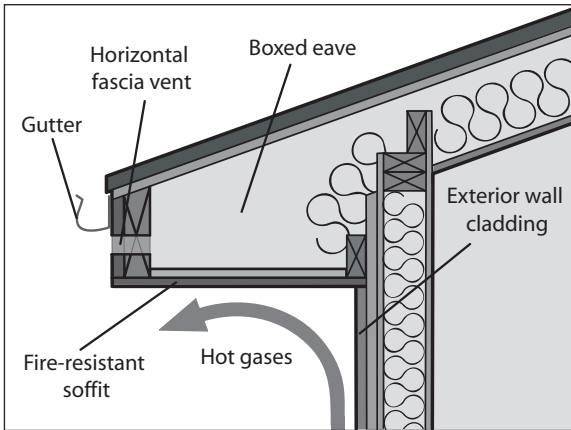
Design Issues: The effect of eliminating the roof overhang, in terms of protection from weather, must be considered. Overhangs protect walls from rain and windows from sun. If this mitigation measure is not acceptable due to local weather conditions, use the mitigation measure outlined in Section A.4.b.

Considerations:



A.4.b Construct Eave Assembly to Reduce Vulnerability to Wildfire Damage

Description of Mitigation Measure: Reduce the potential for trapping hot gases and embers by constructing boxed eaves. Prevent hot gases and embers from entering the attic by properly placing vents and screens in the fascia away from areas where gases and embers are trapped by the eave and using a flat soffit, as shown below. Reduce the potential for ignition by using **fire-resistant** materials for the fascia and soffit. Materials should have a minimum 1-hour **fire-resistance rating**.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Use baffled vent design to deflect debris and protect vent openings. Vents must provide required ventilation as required by design or code.

Considerations:



B. Exterior Walls

Introduction: The design and composition of exterior walls, and consequently their vulnerability to wildfire damage, vary depending on the type of building.

- The exterior of wood-frame and steel-stud buildings consists of exterior wall cladding (such as brick, stone, stucco, wood siding, wood shingles, or vinyl siding) that is placed over sheathing (such as plywood, Oriented Strand Board, particle board, or gypsum board).
- Buildings with solid load-bearing walls may be constructed of brick, stone, or concrete block.
- Steel frame and concrete frame buildings may incorporate a wide range of materials for exterior walls depending on their design, including metal panels; glazing; fiberglass or cementitious panels; in-fill brick, concrete, or hollow clay tile masonry; and pre-cast or cast-in-place concrete panels.
- The exterior of tilt-up buildings consists of pre-cast concrete panels.

Causes of Damage: In general, exterior walls with combustible cladding are the most vulnerable to wildfire damage. Cladding composed of combustible materials, such as wood siding, may ignite when exposed to flames, radiant heat, or airborne embers and firebrands. Once the cladding ignites, fire may burn through the cladding to the sheathing or interior, spread vertically to the eaves and roof, or transmit heat to the interior. Vinyl cladding may deform, exposing the underlying sheathing or interior directly to flames and heat.

Laps in siding represent weak points where flames can quickly burn through to the sheathing or interior. Additionally, openings for wall penetrations (such as for utilities), may allow heat, hot gases, and embers to intrude, causing ignition of combustible materials in the building interior.

Mitigation measures for common wildfire damage to exterior walls are discussed in the following sections:

B.1 Wall Cladding	20
B.2 Wall Penetrations	24

B.1 Wall Cladding

Problem: Combustible cladding is vulnerable to ignition or melting due to flames, radiant heat, and contact with airborne embers and firebrands. Once ignited, flames can spread to the roof or interior. Heat may also pass through the cladding and ignite underlying wall components.

Mitigation Objective: Prevent the ignition of exterior wall cladding and reduce the potential for transfer of heat and spread of flames to the building interior.

Mitigation measures to protect wall cladding from wildfire and prevent the spread of heat and flames include:

- B.1.a Install Fire-Resistant or Noncombustible Cladding 21
- B.1.b Install Siding with Less Penetrable Joints 22
- B.1.c Install Type X Gypsum Board Between Studs and Covering 23

B.1.a Install Fire-Resistant or Noncombustible Cladding

Description of Mitigation Measure: Install cladding that is **fire-resistant** or **noncombustible**. Examples include stucco, metal siding, **fiber-cement** siding, masonry, and concrete. Fire-resistant materials should be approved for a minimum **fire-resistance rating** of 1 hour.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: The fire-resistance rating should be tested in accordance with ASTM E119.

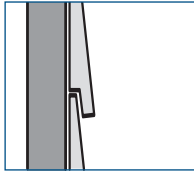
Limitations: The choice of exterior cladding systems may affect the sheathing requirements.

Considerations:

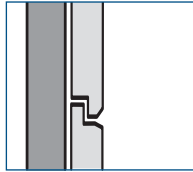


B.1.b Install Siding with Less Penetrable Joints

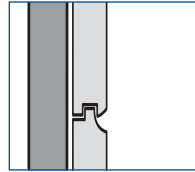
Description of Mitigation Measure: If siding is specified, install **fire-resistant** or **noncombustible** siding with rabbetted, shiplap, or tongue and groove joints. These types of joints hinder the passage of wildfire elements past the exterior wall surface.



Rabbetted joint



Shiplap joint



Tongue and groove joint

Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

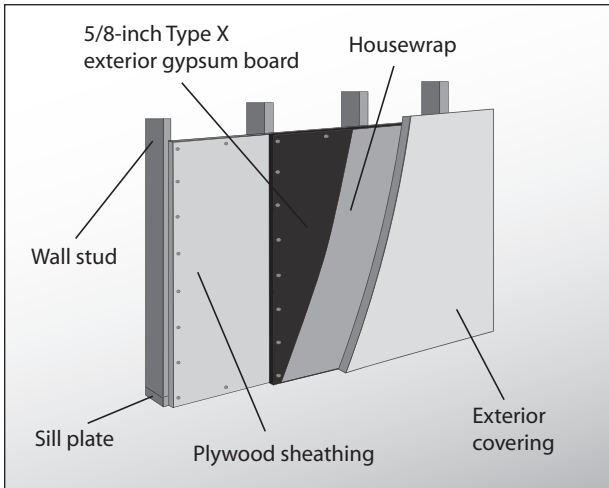
Design Issues: The addition of exterior grade **Type X gypsum board** can increase the fire resistance of the wall assembly (see Section B.1.c). Gypsum board is specified as Type X if it is 5/8-inch thick and complies with ASTM C 1177.

Considerations:



B.1.c Install Type X Gypsum Board Between Studs and Covering

Description of Mitigation Measure: Install a 5/8-inch thick exterior **Type X gypsum board** compliant with ASTM C 1177 between the studs and wall covering to reduce the potential for transfer of heat and spread of flames to the interior.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Fire-rated Type X gypsum board is economical, easy to install, and available in many sizes.

Considerations:



B.2 Wall Penetrations

Problem: Exterior wall penetrations, such as those for utilities, create gaps in the building exterior through which heat, hot gases, and embers can intrude.

Mitigation Objective: Eliminate the potential for intrusion of heat, hot gases, and embers.

Mitigation measures to eliminate the risk of intrusion at wall penetrations include:

B.2.a Eliminate Gaps Due to Exterior Wall Penetrations	25
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B.2.a Eliminate Gaps Due to Exterior Wall Penetrations

Description of Mitigation Measure: Seal gaps around wall penetrations or if possible, remove above-ground exterior wall penetrations, relocate the utility entry to an underground location, and seal the gaps in the wall. Small gaps may be filled with **fire-resistant** caulk or mortar or with fire-rated expanding foam; large gaps may be filled with **intumescent** or fire-protective sheets or pillows. Fire-resistant wrap may be used around ventilation features such as air conditioners that are built into and penetrate exterior walls.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Replacing pipes, cables, and other installations can damage sealants. Fire-resistant caulk or mortar must be removed and replaced each time a cable or pipe is reinstalled.

Considerations:



C. Vents

Introduction: Vents are designed to allow airflow into enclosed spaces, such as attics, and allow the removal of excess moisture and heat from those spaces. They may be installed in a variety of locations, depending on the design of the building. Common locations for vents are soffits, gables, and ridgelines of roofs. They may also be installed in foundations to allow ventilation of crawl spaces. Vents are generally required by code, which may also prescribe a mesh covering to keep debris out.

Causes of Damage: Vents may allow heat and embers to intrude into the building. Additionally, debris that collects at vent openings can be ignited and spread flames and hot gases to both the interior and exterior of the building.

Mitigation measures for common wildfire damage to vents are discussed in the following section:

C.1 Vent Openings 27

C.1 Vent Openings

Problem: Embers may intrude through vent openings. Screens and louvers attached to vent openings may ignite.

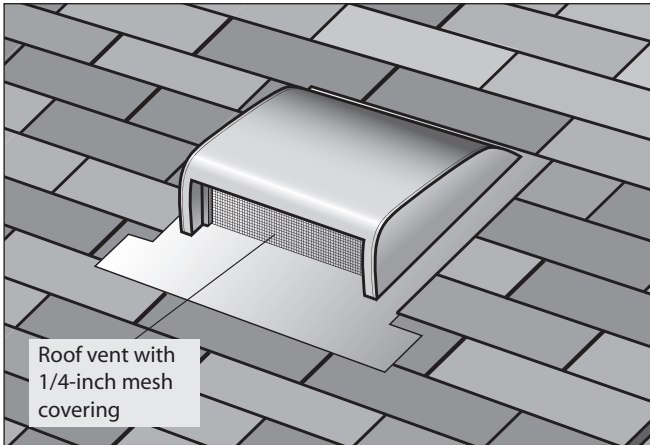
Mitigation Objective: Protect vent openings from embers.

Mitigation measures to protect vent openings from intrusion of embers include:

- C.1.a Install Noncombustible Screens with Small Openings 28
- C.1.b Install Noncombustible Louvers with Adjustable Slats 29

C.1.a Install Noncombustible Screens with Small Openings

Description of Mitigation Measure: Install *noncombustible*, corrosive-resistant metal screens with maximum 1/4-inch openings. Vent openings should not exceed 144 square inches each.



Effectiveness: Effective for reducing vulnerability to wildfire damage in moderate fire severity zones.

Design Issues: Vent screens must maintain their original function of allowing airflow for a building.

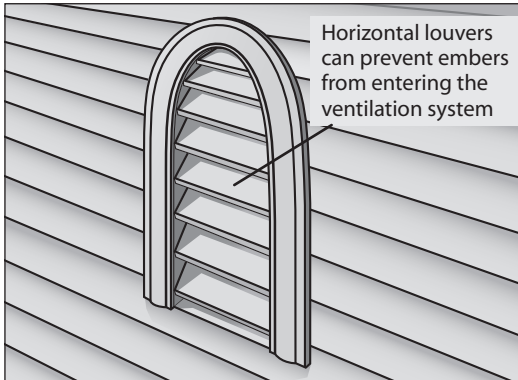
Limitations: Metal screens with 1/4-inch openings will not prevent flames, gases, or embers smaller than a 1/4-inch from entering the vent system.

Considerations:



C.1.b Install Noncombustible Louvers with Adjustable Slats

Description of Mitigation Measure: When practical, install **noncombustible** horizontal louvers with adjustable slats that can seal the vent opening during a wildfire.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Louvers must maintain their original function of allowing airflow for a building.

Limitations: Louvers may require human intervention at the onset of a wildfire.

Considerations:



D. Exterior Doors

Introduction: Exterior doors include sectional and rolling doors, such as garage doors. Doors with a **noncombustible**, solid mineral core are classified as fire-rated by Underwriters Laboratories (UL) based on the period of time a door can resist a fire (UL Standard 10C).

Causes of Damage: During a wildfire, exterior doors are vulnerable to ignition due to radiant heat, direct contact with flames, and contact with airborne firebrands and embers. Heat, flames, and embers can also penetrate gaps in the exterior door assembly, such as between the door and the ground, and ignite combustible material in the building interior. Glass in doors can break due to heat or airborne debris, allowing intrusion of hot gases and embers.

Mitigation measures for common wildfire damage to exterior doors and frames are discussed in the following sections:

- D.1 Exterior Doors and Frames 31
- D.2 Sectional and Rolling Doors 33

D.1 Exterior Doors and Frames

Problem: Radiant heat or direct contact with flames can ignite combustible exterior doors, break glass in the exterior door, and penetrate the building through the gaps around the exterior door perimeter.

Mitigation Objective: Protect exterior doors and prevent wildfire elements from spreading into the building interior.

Mitigation measures to protect exterior doors and frames from wildfire damage include:

D.1.a	Install Fire-Resistant Door Assemblies	32
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D.1.a Install Fire-Resistant Door Assemblies

Description of Mitigation Measure: Install fire-rated exterior door assemblies in compliance with UL Standard 10C. As part of an assembly, door frames must also comply with the exterior door's **fire-resistance rating**. The fire-resistance rating should not be less than 20 minutes. Fire-rated door assemblies may include doors manufactured from wood, metal, or fiberglass.



Effectiveness: Exterior doors with a fire-resistance rating higher than 90 minutes are effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: For windows in doors, tempered glass with a low-emissivity or proprietary reflective coating are recommended. For glazed doors, follow the guidance in Section F.

The fire-resistance rating for exterior doors is intended to equal 3/4 of the fire-resistance rating of the surrounding wall (see Section B.1.a).

Considerations:



D.2 Sectional and Rolling Doors

Problem: Sectional and rolling doors and frames, which are often used for garages, are susceptible to ignition when constructed of combustible materials such as wood or vinyl panels. If the gap around the perimeter of the door is not properly sealed, hot gases, flames, and embers can circumvent the door and ignite material in the building interior.

Mitigation Objective: Protect exterior doors and prevent wildfire elements from spreading into the building interior.

Mitigation measures to protect sectional and rolling doors and frames from wildfire damage include:

D.2.a	Install Noncombustible Insulated Doors and Frames	34
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D.2.a Install Noncombustible Insulated Doors and Frames

Description of Mitigation Measure: Install doors and frames with steel, aluminum, or other applicable **noncombustible** materials. Doors should also be insulated to protect against radiant heat. Seal the gap between the pavement and the garage door and the gap between the framing and the garage door with weatherstripping in accordance with UL Standard 10C.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: For windows in garage doors, tempered glass with a low-emissivity or proprietary reflective coating are recommended.

Limitations: Weatherstripping should be replaced after being exposed to a fire.

Considerations:



E. Ramps, Decks, and Other Attached Exterior Structures

Introduction: Ramps, decks, and other exterior structures may be attached to a building. They are frequently constructed of wood and constructed in locations with a high probability of exposure to wildfire elements.

Causes of Damage: Ramps, decks, and other attached exterior structures constructed of combustible materials are prone to ignition. Additionally, if these features are elevated above grade, embers, firebrands, and hot gases can become trapped beneath them. Once the structure ignites, the fire may come into contact with the building, causing the building to ignite.

Mitigation measures for common wildfire damage to attached exterior structures are discussed in the following section:

E.1 Ramps, Decks, and Other Attached Exterior Structures	36
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E.1 Ramps, Decks, and Other Attached Exterior Structures

Problem: Damage to structures attached to the exterior of buildings is caused by exposure to firebrands and embers. In addition, debris that accumulates at the gaps in decking and at the railing edges increases the risk of combustible material igniting. Embers and debris can also threaten the underside of the structure.

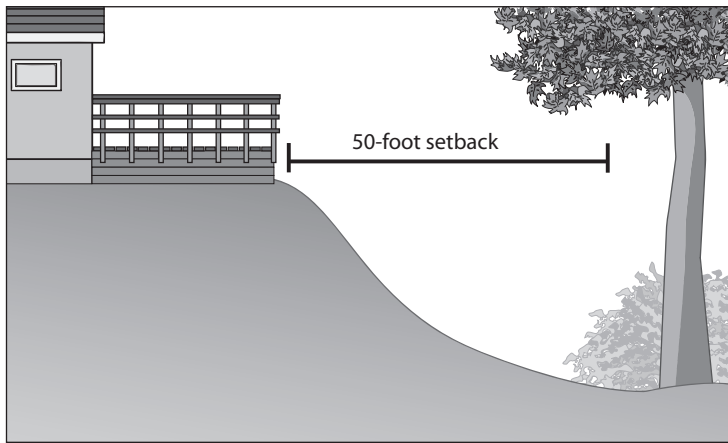
Mitigation Objective: To protect attached exterior structures from ignition.

Mitigation measures to protect attached exterior structures from wildfire damage include:

E.1.a	Use Proper Siting and Setbacks	37
E.1.b	Use Fire-Resistant or Noncombustible Material	38
E.1.c	Install Flashing or Screens at Intersection with Building	39
E.1.d	Cover Underside of Joists with Fire-Resistant Panels	40
E.1.e	Enclose Underside of Structure with Screens	41
E.2.f	Enclose Underside of Structure with Skirting	42
E.1.g	Construct Noncombustible Patio Around Footprint	43

E.1.a Use Proper Siting and Setbacks

Description of Mitigation Measure: Avoid constructing ramps, decks, and other attached exterior structures near heavily vegetated areas and topographic features such as gullies, canyons, saddles, ridgetops, and narrow mountain passes. If the structure is perched on a hillside, choose a site or remove vegetation to ensure a 50-foot setback from wildland vegetation on the downslope side. Increase setbacks in heavily forested environments.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

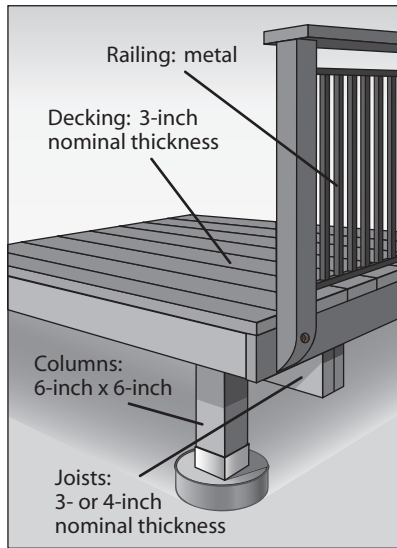
Design Issues: If the structure is constructed over a slope, protect the area below the structure (see Sections E.1.d–f).

Considerations:



E.1.b Use Fire-Resistant or Noncombustible Material

Description of Mitigation Measure: Construct ramps, decks, and other attached exterior structures using **noncombustible** materials such as steel or concrete or using heavy timber construction such as 3-inch nominal thickness **fire-retardant-treated wood** for the decking and railing, and 6-inch x 6-inch timber support columns.



Effectiveness: Noncombustible materials are effective for reducing vulnerability to wildfire damage in all fire severity zones. Heavy timber construction is effective for medium- and high-risk fire severity zones.

Design Issues. Replacing existing decking material with new material could increase the weight of the deck, and the support structure may require strengthening.

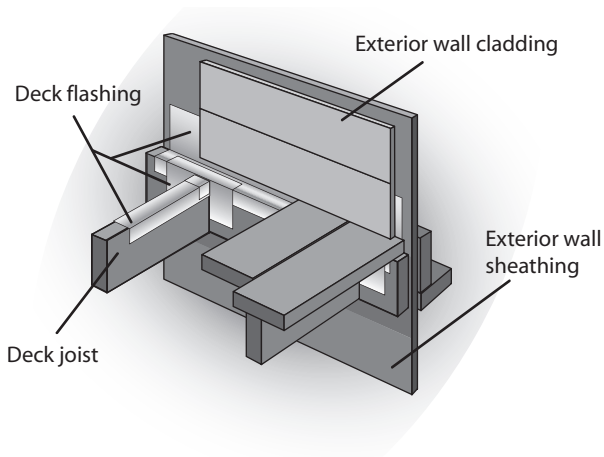
Limitations: Because metals get extremely hot in a wildfire, metal ramps and decks should not be relied upon as an escape route.

Considerations:



E.1.c Install Flashing or Screens at Intersection with Building

Description of Mitigation Measure: Protect the gap where a ramp, deck, or other attached exterior structure meets the building using metal **flashing**. Although debris may still accumulate, the debris will not be lodged in the framing and the flashing would facilitate debris removal from the gap.



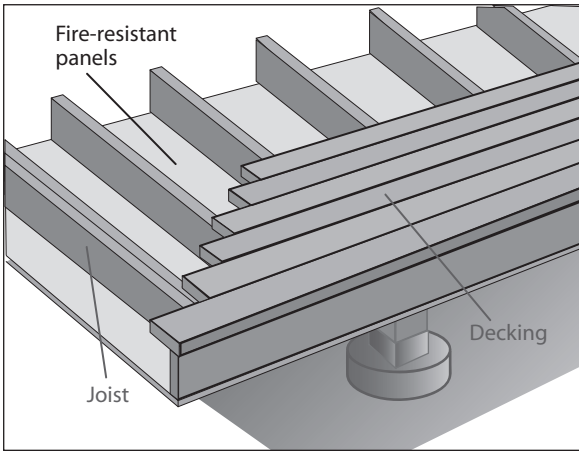
Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Considerations:



E.1.d Cover Underside of Joists with Fire-Resistant Panels

Description of Mitigation Measure: To avoid ignition from embers, firebrands, and hot gases trapped under the structure, cover the underside of the joists with **fire-resistant** panels, such as **fiber-cement** panels.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

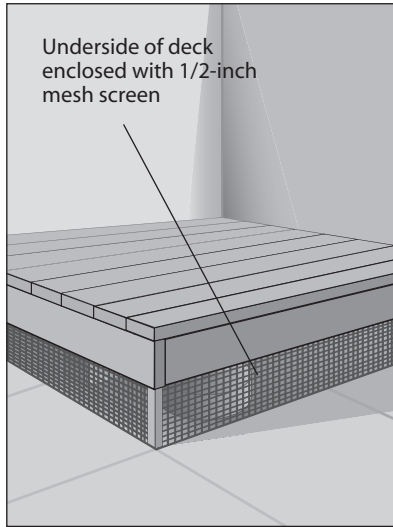
Design Issues: The ability of the deck to drain water must be considered.

Considerations:



E.1.e Enclose Underside of Structure with Screens

Description of Mitigation Measure: For ramps, decks, and other attached exterior structures that are elevated less than 6 inches above-grade, enclose the vertical opening to the underside of the structure with a 1/2-inch or smaller mesh screen. The screen will prevent firebrands and most embers from penetrating the underside of the structure.



Effectiveness: Effective at preventing fire damage in moderate fire severity zones.

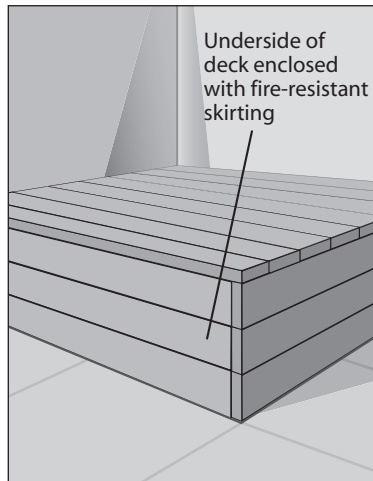
Limitations: Mesh screens will not prevent hot gases, flames, or small embers from penetrating the underside of the structure.

Considerations:



E.1.f Enclose Underside of Structure with Skirting

Description of Mitigation Measure: Enclose all underfloor areas with materials approved for a minimum **fire-resistance rating** of 1 hour.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

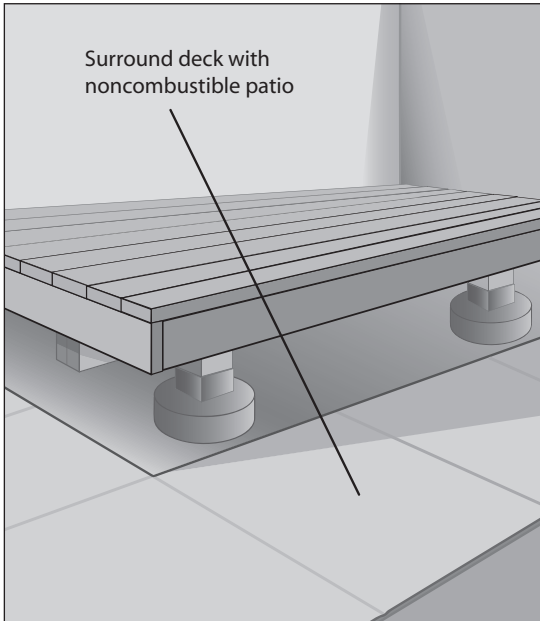
Design Issues: Structures enclosed with **fire-resistant** skirting must be vented for proper moisture control.

Considerations:



E.1.g Construct Noncombustible Patio Around Footprint

Description of Mitigation Measure: Construct a stone, concrete, or masonry patio beyond the footprint of exterior structures. The patio will create a firebreak for exterior structures.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Considerations:



F. Windows and Skylights

Introduction: During a wildfire, windows and skylights are often the weakest part of the building due to their susceptibility to failure. If a window or skylight fails, the wildfire has a direct access point into the building interior.

Causes of Damage: Windows and skylights commonly fail during wildfires when the glazing breaks. Window or skylight glazing can break due to a differential between indoor and outdoor temperatures during a wildfire. The heat differential stresses the glazing and eventually causes cracking.

During a wildfire, glazing can also become dislodged and fall out of place. For example, vinyl frames warp and then melt until the window fails. Firebrands can be blown with enough force to break window and skylight glazing. Radiant heat can also pass through unbroken windows and skylights and ignite combustible materials inside a building.

Mitigation measures for common wildfire damage to windows and skylights are discussed in the following sections:

F.1	Windows and Frames	45
F.2	Skylights and Frames	50

F.1 Windows and Frames

Problem: Wildfire elements can break window glazing or ignite or melt the window framing. Damage can be caused to the interior by the passage of radiant heat through the window.

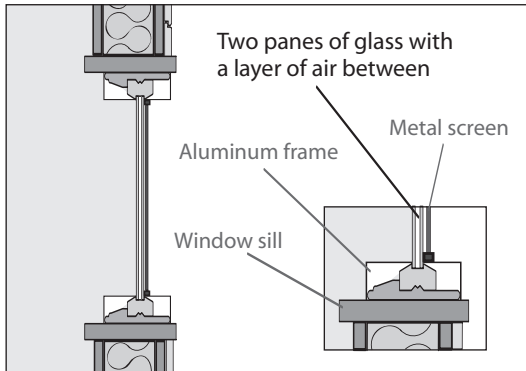
Mitigation Objective: Protect the interior of a building by preventing windows and frames from failing.

Mitigation measures to protect windows and frames from wildfire damage include:

F.1.a	Install Fire-Resistant Glazed Window Panels	46
F.1.b	Install Fire-Resistant Framing	47
F.1.c	Install Permanent or Temporary Fire-Resistant Shutters	48
F.1.d	Install Fire-Resistant Screens	49

F.1.a Install Fire-Resistant Glazed Window Panels

Description of Mitigation Measure: Install an insulated glazing unit (IGU), which consists of two or three panes of glass that are separated by a sealed air space. Laminated glass, tempered glass, and glass with a low-emissivity coating are recommended and can be combined in various ways in an IGU. IGUs that can resist a fire for at least 20 minutes are recommended.



Effectiveness: IGUs are effective for reducing vulnerability in all fire severity zones. However, using a **fire-resistant** window panel is only effective if fire-resistant framing is also used (see Section F. 1 .b).

Design Issues: If a **fire-resistance rated** wall is specified (see Section B.1.a), window assemblies with a fire-resistance rating of 3/4 the wall rating should be specified. For example, a 3/4-hour window assembly rating should be used in conjunction with a 1-hour rated wall assembly.

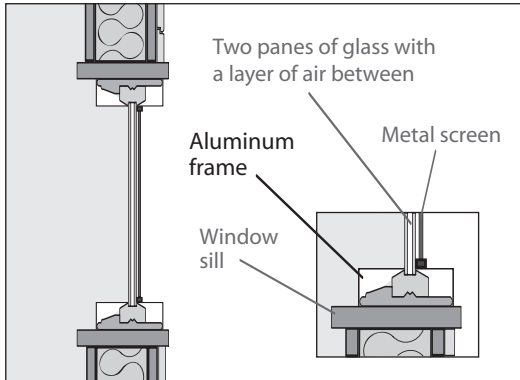
Limitations: Large, tempered glass panes may require custom manufacturing.

Considerations:



F.1.b Install Fire-Resistant Framing

Description of Mitigation Measure: Framing for windows should be constructed with **fire-resistant** or **noncombustible** materials such as steel, aluminum, or wood frames with aluminum cladding.



Effectiveness: Noncombustible framing is effective for reducing vulnerability to wildfire damage in all fire severity zones.

Limitations: Metal and metal clad frames still transmit heat but delay damage.

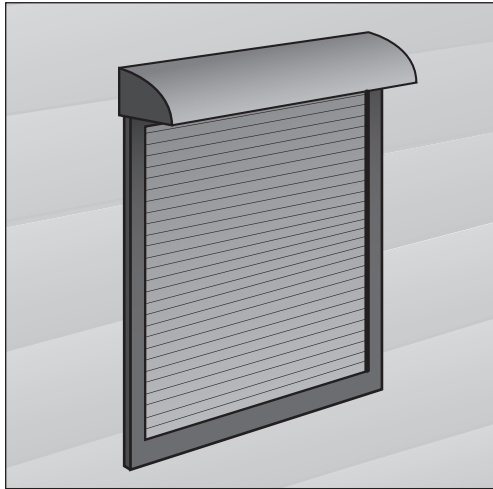
Aluminum frames have no combustible components but melt at 1,200° F.

Considerations:



F.1.c Install Permanent or Temporary Fire-Resistant Shutters

Description of Mitigation Measure: Install temporary or permanently attached metal shutters, including roll-down window covers. Metal shutters installed prior to a wildfire are better than metal screens (see Section F.1.d) at preventing intrusion of embers and firebrands.



Effectiveness: Metal shutters are effective for reducing vulnerability to wildfire damage in all fire severity zones.

Shutters are useful in other extreme weather conditions such as windstorms and hurricanes.

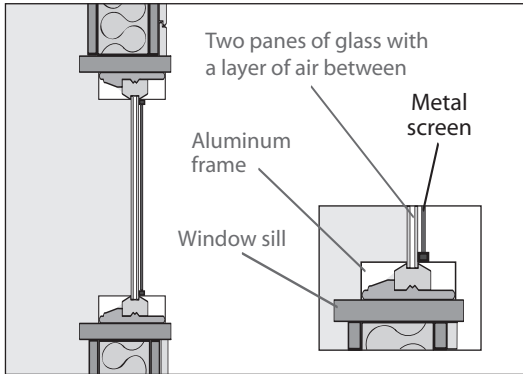
Limitations: Metal shutters require human intervention to ensure effectiveness; sufficient warning time is critical.

Considerations:



F.1.d Install Fire-Resistant Screens

Description of Mitigation Measure: Install permanent metal screens set over the window to deflect flying embers and absorb some of the radiant and convective energy.



Effectiveness: Metal screens are effective for reducing vulnerability to wildfire damage in moderate fire severity zones; however, metal screens are not as effective as metal shutters (see Section F. 1 .c).

Design Issues: Metal screens cannot be used on some window types, such as windows that open outwardly.

Considerations:



F.2 Skylights and Frames

Problem: Skylights have the same problems as windows except that skylights are commonly made with polycarbonate glazing and during wildfires, polycarbonate can melt under intense heat.

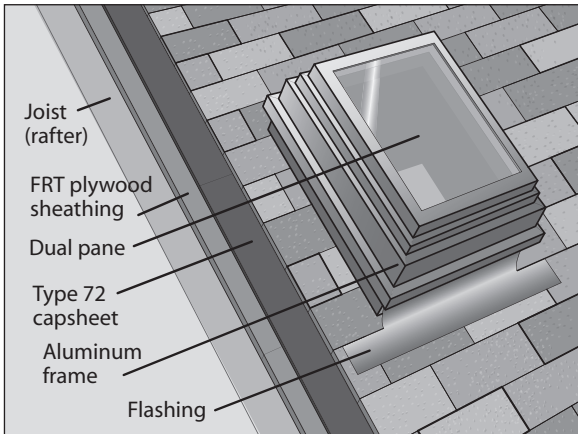
Mitigation Objective: Prevent skylights from failing and protect the interior of the building from ember, firebrand, and heat intrusion.

Mitigation measures to protect skylights and frames from wildfire damage include:

F.2.a Install Fire-Resistant-Rated Skylights and Framing 51

F.2.a Install Fire-Resistant-Rated Skylights and Framing

Description of Mitigation Measure: Follow guidelines described in Section F.1. In addition, consider using wired glazing for the skylight. When attached to the roof of a building, install proper **flashing** around the frame (see Section A.1.c).



Effectiveness: IGUs are effective at preventing fire damage in all fire severity zones.

Design Issues: Metal and metal clad frames still transmit heat but delay damage from the wildfire.

Limitations: Skylights will eventually fail under continuous exposure to fire.

Considerations:



G. Foundations

Introduction: Foundations vary widely based on building type and design. Many types of foundations, such as concrete slab-on-grade foundations and foundations that are entirely below-grade, are not at risk of damage from wildfires. Other types of foundations that are susceptible to damage in a wildfire are:

- Closed foundations, in which the foundation walls are typically load-bearing. The below-grade portion of the foundation walls are usually constructed of concrete or masonry. The above-grade portion can also be constructed of concrete or masonry or constructed of a stud wall, commonly called a cripple wall. The wall encloses a basement or crawl space, and the cripple wall often has vents to allow air circulation in the crawl space or basement.
- Open foundations, in which the building rests on piers or piles and the underside of the first floor is exposed.

Causes of Damage: Radiant heat, flames, embers, and firebrands can enter foundations through damaged windows, wall penetrations, or cripple wall vents or, in the case of open foundations, may directly affect the piers or piles, framing, and subflooring of the building. Wildfire elements can ignite columns, subflooring, and combustible materials, such as contents of a basement within the foundation. For buildings with cripple walls, the cripple wall may ignite if it is composed of combustible materials.

For mitigation measures associated with vents, wall penetrations, and windows, see Sections B, C, and F.

Mitigation measures for common wildfire damage to foundations are discussed in the following sections:

G.1 Closed Foundations	53
G.2 Open Foundations	55

G.1 Closed Foundations

Problem: Wildfire elements can breach the building envelope through vents, windows, and exterior wall penetrations in the foundation walls. Wildfire elements can gain access to combustible construction material, such as the first floor framing or combustible wall materials, through the crawl space or basement. In addition, combustible contents are often stored in closed foundations.

Mitigation Objective: Prevent wildfire elements from entering the foundation. Prevent combustible material in the closed foundation from igniting.

Mitigation measures to protect closed foundations from wildfire damage include:

G.1.a Enclose Crawl Space with
Fire-Resistant Cripple Wall 54

G.1.a Enclose Crawl Space with Fire-Resistant Cripple Wall

Description of Mitigation Measure: Construct the cripple wall surrounding the crawl space with **fire-resistant** or **noncombustible** materials. See Section B.1 for information regarding fire-resistant and noncombustible walls.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Modifications to cripple walls require an engineering analysis.

If the building is located in a floodplain, as designated by FEMA's National Flood Insurance Program, regulations in 44 CFR Part 60 should be considered.

Considerations:



G.2 Open Foundations

Problem: In an open foundation, the building piers or piles, framing, and subflooring are exposed. Radiant heat, flames, embers, and firebrands can directly affect these components, igniting the framing and subfloor.

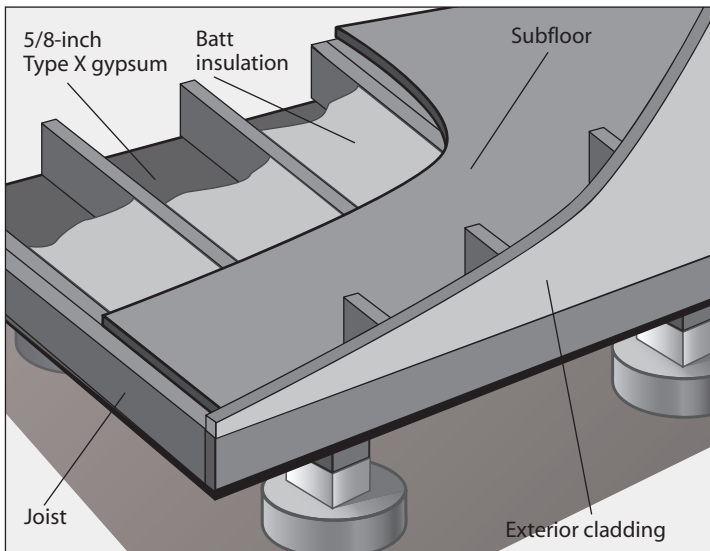
Mitigation Objective: Prevent wildfire elements from directly affecting piers or piles, framing, and subflooring.

Mitigation measures to protect open foundations from wildfire include:

- G.2.a Protect Underside of Exposed Floor
Framing with Fire-Resistant Panels 56
- G.2.b Install Fire-Resistant Skirting 57

G.2.a Protect Underside of Exposed Floor Framing with Fire-Resistant Panels

Description of Mitigation Measure: Protect the underside of the exposed floor framing with 5/8-inch **Type X gypsum board**. Attach **fire-retardant-treated** wood panels, **fiber-cement** panels, or metal panels over the gypsum board.



Effectiveness: Effective for reducing vulnerability to wildfire damage in moderate fire severity zones.

Design Issues: Exposed columns should be constructed with **fire-resistant** materials such as heavy timbers or posts encased in gypsum board.

In areas where dry rot is a concern, do not use fire-retardant-treated wood panels because these panels cannot be treated with a preservative.

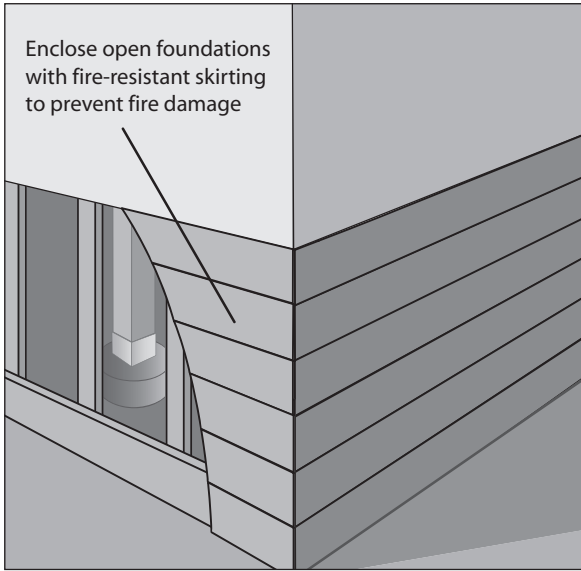
Limitations: Placing the panels around the existing plumbing, electrical, and ventilation systems and structural elements could be time-consuming and difficult in a confined space.

Considerations:



G.2.b Install Fire-Resistant Skirting

Description of Mitigation Measure: To prevent the intrusion of fire elements underneath the building, install **fire-resistant** skirting around the perimeter of the building.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Structures enclosed with fire-resistant skirting must be vented for proper moisture control.

If the building is located in a floodplain, as designated by FEMA's National Flood Insurance Program, regulations in 44 CFR Part 60 should be considered.

Considerations:



H. Building Contents

Introduction: The term “contents” refers to items in the building interior that are not part of the structure or the mechanical, electrical, heating, ventilation, or air conditioning systems.

Causes of Damage: Building contents may ignite after fire elements have penetrated the building envelope. In general, contents will contribute to the spread of the fire throughout the interior of a building.

This section describes wildfire mitigation measures for general contents:

H.1 General Contents 59

H.1 General Contents

Problem: The building interior typically contains combustible materials. After wildfire elements have breached the building envelope, building contents are prone to ignition.

Mitigation Objective: Prevent the fire from spreading throughout the interior of a building.

Mitigation measures to protect general contents from wildfire damage include:

H.1.a	Install an Automatic Sprinkler System	60
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H.1.a Install an Automatic Sprinkler System

Description of Mitigation Measure: Install an automatic fire sprinkler system. Installing sprinklers in enclosed spaces such as attics should be considered for added protection when a fire penetrates the exterior of the building. The automatic sprinkler system will focus suppression efforts only on areas affected by fire.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: All sprinkler heads must function properly. Specialized suppressant systems are required in commercial cooking areas, radio vaults, and computer network rooms.

Limitations: Water pressure and supply must both be adequate for an interior sprinkler system to be effective. A pressurized holding tank may be necessary because the municipal water supply is used for fire suppression efforts during wildfire events.

Considerations:



I. Building Equipment

Introduction: Building equipment such as mechanical, electrical, and heating, ventilation, and air conditioning systems is often installed at the exterior of a building. Equipment can be mounted on the rooftop, on ground-level pads, or on exterior walls. The equipment connections often penetrate the building envelope.

Causes of Damage: Building equipment is vulnerable to damage when exposed to wildfire. The equipment can have highly combustible components, such as fuel tanks, that are vulnerable to ignition from radiant heat, direct contact with flames, and ember intrusion. Once these components ignite, the resulting fire may ignite the building. Sensitive instruments and wiring are examples of components that can be damaged by wildfires. Additionally, electronic equipment that requires a consistent power source is also vulnerable to operational failure during a wildfire.

Building equipment commonly damaged in a wildfire includes:

- I.1 Exterior-Mounted Equipment 62
- I.2 Electronics Equipment 64

I.1 Exterior-Mounted Equipment

Problem: Equipment mounted on the exterior of a building, such as transformers and heating, ventilation, and air conditioning units, is openly exposed to wildfire elements. A frequent problem with exterior-mounted equipment is the possibility of components igniting or being damaged by hot gases. Firebrands and embers can enter the interior of a building through exterior building penetrations required for anchorage and feed pipes.

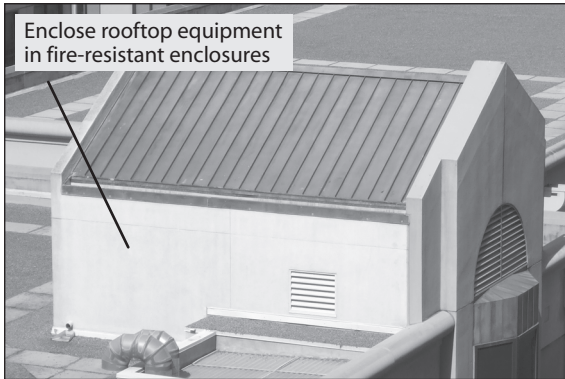
Mitigation Objective: Prevent damage to exterior-mounted equipment and prevent firebrands and embers from passing through exterior building penetrations.

Mitigation measures to protect exterior mounted equipment from wildfire damage include:

I.1.a	Protect Exterior-Mounted Equipment with Enclosures	63
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I.1.a Protect Exterior-Mounted Equipment with Enclosures

Description of Mitigation Measure: Protect exterior-mounted equipment with enclosures constructed of **fire-resistant** or **noncombustible** materials. See Sections I.A–I.D for **ignition-resistant construction standards** for roofs, walls, vents, and doors. For roof penetrations, appropriate sealants are described in Section B.2.a.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Exterior-mounted equipment in fire-resistant enclosures must continue to operate at capacity and may have certain ventilation and accessibility requirements.

Adding fire-resistant enclosures can increase the load on a building. The support structure may require strengthening.

Considerations:



I.2 Electronics Equipment

Problem: When it is essential for electronic building equipment to have a continuous power supply, wildfires are problematic. Wildfires frequently destroy power lines and create fluctuations, including power surges and power outages. Both destroyed power lines and fluctuations may damage building equipment.

Mitigation Objective: Prevent electronic equipment from being damaged by wildfire-induced power fluctuations.

Mitigation measures to protect electronic equipment from wildfire damage include:

- I.2.a Install Surge Protection 65
- I.2.b Install Backup Power Supplies 66

I.2.a Install Surge Protection

Description of Mitigation Measure: Electronic building equipment that is sensitive to power surges can be protected by properly grounding equipment and installing devices rated to provide surge protection.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Surge protection must be adequate for the power load demand of electronic equipment.

Limitations: Surge protection will protect the integrity of electronic equipment but will not maintain the power supply.

Considerations:



I.2.b Install Backup Power Supplies

Description of Mitigation Measure: There are several methods to provide a backup power supply for electronics. One option is to install an Uninterruptible Power Supply (UPS).



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Limitations: If the ambient temperature exceeds the manufacturer's recommendations, the generator can be damaged and the power supply interrupted.

UPS devices provide power for a limited time.

Considerations:



II. UTILITIES

Introduction: Utilities include systems that are related to power, water, waste management, and communications. The greatest risk of fire damage is to above-grade utilities. Underground systems (storm drains, sewer and water lines and in some cases power lines), by virtue of the insulating capacity of the earth, generally have a low risk of damage from wildfire. In power distribution and communication systems, however, the portions of the equipment that must remain above-ground may be subject to damage.

Utility components vulnerable to wildfire damage may include:

- Utility station buildings used to house equipment such as pump houses.
- Above-ground utility equipment that is exposed to the elements. Examples are tanks, meters, pumps, telemetry equipment, utility risers, pole- or pad-mounted transformers, electrical substations, and cell phone and radio towers.
- Utility distribution systems such as pipes used for drinking water and sewage treatment and wires and cables mounted on poles for power and communication systems.
- Stored materials such as chemicals. Municipal treatment plants, commercial operations and industrial operations often use and store toxic chemicals that can ignite and be released into the environment.

Causes of Damage: Typical wildfire damage to utilities is described below.

Water storage and distribution systems: Storage facilities include reservoirs and tanks. Distribution systems include pipes, pumping stations, treatment facilities, and wells. Chemicals used in treatment are volatile, are subject to explosion, and can emit toxic gases. Intense heat has the potential to damage pipes and pumping equipment that lie above-grade and facilities such as wood storage tanks. Wildfires can also damage the power supply to pumping stations and equipment used to control and monitor system operations.

Power plants and transmission lines: The primary risk is to transmission towers and the lines that carry the electricity. High winds that often accompany wildfires can cause contact between energized conductors, resulting in power disruption.

Radio and communications systems: Systems typically contain heat-sensitive components such as transfer panels and insulated cables.

Utility poles and lines: Utility (electric, telephone, or cable) equipment is often installed on poles. Poles and lines can be damaged by falling debris during a fire. Poles are made primarily from pressure-treated wood that is resistant to ignition but will burn under intense heat. Power outages and power surges caused by wind and fire can damage electrically powered equipment miles away.

Electrical transformers: Electrical transformers are devices used to change the voltage of an alternating current in one circuit to a different voltage in a second circuit. Transformers can be mounted on a pole or on the ground. Most transformers contain oil that can burn under intense heat. Explosions can result when the transformers are exposed to wildfires. Although most transformers containing polychlorinated biphenyls (PCBs) are being phased out, some transformer failure can release potentially harmful chemicals.

Utility risers and service drops: Electrical, telephone, and cable can run overhead or underground to individual buildings. Overhead utilities can be damaged by flames, heat, or falling limbs. Most portions of underground utilities are less vulnerable, but the riser poles where the utility transitions from overhead to underground remain vulnerable, particularly when non-metallic conduit (such as polyvinyl chlorides [PVC]) or nonmetallic guards are used.

Mitigation measures for common wildfire damage to utilities are discussed in the following sections:	
A.1	Enclose Equipment or Chemicals in Fire- or Heat-Resistant Building or Enclosure 69
A.2	Install Equipment or Store Chemicals Underground. 70
A.3	Treat with Fire Retardant or Use Fire-Resistant Material 71
A.4	Shield Electrical Components with Fire-Resistant Flashing 72
A.5	Install Transfer Switches 73

A.1 Enclose Equipment or Chemicals in Fire- or Heat-Resistant Building or Enclosure

Description of Mitigation Measure: For larger equipment, construct a **fire-resistant** building to house the equipment using **ignition-resistant construction standards** (see Section I). For smaller equipment and the storage of hazardous materials, use pre-fabricated or custom-made enclosures made of heat- or fire-resistant material to completely enclose these items. Install a concrete pad at the base or build a **noncombustible** wall around the equipment to create **defensible space**.



Effectiveness: For the effectiveness of fire-resistant buildings, refer to Sections I.A–I.D. Above-ground systems enclosed in appropriate metal or concrete enclosures are effective in moderate and high fire severity zones.

Design Issues: Equipment in fire-resistant enclosures must continue to operate at capacity and may have certain ventilation and accessibility requirements.

Limitations: Radiant heat can still cause damage to sensitive components if the components have not been properly insulated or constructed. Wire in conduits in the exterior walls are vulnerable to melting and failing if not insulated from radiant heat.

Considerations:



A.2 Install Equipment or Store Chemicals Underground

Description of Mitigation Measure: Meters and other equipment can be installed underground along with the distribution system such as water pipes and power lines. It may be possible to store chemicals and other hazardous materials in underground storage areas.



Effectiveness: Underground facilities are effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Movement of systems underground will require planning, engineering, and design, including geotechnical and environmental evaluations. Accessibility should be considered for continued ease of maintenance.

Limitations: May be difficult to implement in urban or environmentally sensitive areas.

Considerations:



A.3 Treat with Fire Retardant or Use Fire-Resistant Material

Description of Mitigation Measure: Use **fire-resistant** materials for equipment, such as a tower or a tank, that may be impossible to place underground or in a fire-resistant enclosure. For example, treat a wood pole with **fire retardant** or replace it with **noncombustible** steel or spun concrete material. A wooden tank can be replaced with one made of fire-resistant material such as ferrocement. Install a concrete pad at the base or construct a fire-resistant wall (see Section IV) around the facility to create **defensible space**.



Effectiveness: Using fire-resistant materials is effective for reducing vulnerability to wildfire damage in all fire severity zones. Fire-retardant treatments may not be as effective in extreme or high fire severity zones. Defensible space increases effectiveness.

Limitations: The fire-retardant coating must be re-applied often to be effective.

Considerations:



A.4 Shield Electrical Components with Fire-Resistant Flashing

Description of Mitigation Measure: Shield exposed electrical components and conduits on riser poles with metallic conduits or other **fire-resistant** materials such as **flashing** to reduce the possibility of damage.



Effectiveness: Electrical components that are shielded with fire-resistant material are effective in moderate and high fire severity zones.

Limitations: Maintenance and inspection of metallic conduits should be performed regularly.

Considerations:



A.5 Install Transfer Switches

Description of Mitigation Measure: To mitigate for electrical failures to critical equipment such as pumps and treatment facilities, install transfer switches that facilitate the use of a backup generator.



Effectiveness: Transfer switches are effective for reducing vulnerability to wildfire damage in all fire severity zones.

Limitations: The mitigation measure may require human intervention; sufficient warning time is critical.

Considerations:



III. RECREATIONAL FACILITIES

Introduction: Recreational facilities include non-buildings such as benches and buildings such as restroom facilities. Recreational facilities are often constructed of wood or other combustible materials and are often located in parks and other areas with heavy vegetation, which can fuel a wildfire.

Causes of Damage: Combustible materials used in the construction of recreational facilities are vulnerable to ignition. Ignition may result from contact with blowing embers and firebrands, radiant heat due to combustion of nearby vegetation and structures, and direct contact with flames.

Mitigation measures for common wildfire damage to recreational equipment are discussed in the following sections:

- A. Recreational Facilities (Non-buildings) 75
- B. Recreational Facilities (Buildings) 77

A. Recreational Facilities (Non-buildings)

Problem: Recreational facilities that are not considered buildings include, but are not limited to, benches, playground equipment, picnic tables, lifeguard stations, trash receptacles, bleachers, and dugouts. These facilities often have wooden components and are therefore vulnerable to damage during a wildfire. Additionally, they are often installed in parks or other areas with vegetation that poses a wildfire risk.

Causes of Damage: Non-building recreational equipment composed of combustible material typically has a small chance of survival once ignited.

Mitigation measures to protect recreational facilities from wildfire damage include:

- A.1. Use Noncombustible Materials or
Treat with Fire-Retardant Coating 76

A.1 Use Noncombustible Materials or Treat with Fire-Retardant Coating

Description of Mitigation Measure: Replace wooden equipment or components with **noncombustible** materials such as steel, concrete, or masonry. If the damage does not require replacement, wooden components may also be treated with a **fire-retardant** coating. A concrete pad can also be placed under the facility to create some **defensible space**.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones. The fire-retardant coating provides minimal fire resistance for wooden equipment.

Limitations: Fire-retardant coating must be re-applied often to be effective.

Considerations:



B. Recreational Facilities (Buildings)

Introduction: Recreational areas often include buildings or similar structures such as picnic shelters, restroom facilities, and pavilions. The structures are typically constructed of combustible materials such as wooden studs, posts, and other framing. Additionally, they are often constructed in parks or other areas with vegetation that poses a wildfire risk.

Causes of Damage: Combustible exterior materials can ignite, leading to total destruction of the structure.

Mitigation measures to protect recreational facilities similar to buildings from wildfire damage include:

Refer to Section I, Buildings 1

IV. FENCES AND WALLS

Introduction: Fences and walls function as physical or visual barriers or architectural statements. Fences and walls are constructed from a wide range of materials and often include combustible components such as wooded posts and railings or materials that can melt, such as vinyl.

Causes of Damage: Wildfire damage is typically the result of ignition or melting of the fence or wall construction materials. Ignition or melting may result from radiant heat, direct contact with flames, or contact with blowing embers and firebrands. Fences and walls have large surface areas that often contain cracks, openings, and rough areas, or are wire barriers. All of these characteristics increase the risk that fences and walls will trap fire elements. The potential for ignition is also related to the condition of the fence or wall: its age, the amount of debris accumulated adjacent to or on the fence, and the proximity to combustible vegetation or general landscaping.

If the fence or wall is connected or adjacent to a building, it may provide a path for the spread of flames to that building. Conversely, **noncombustible** walls can function as a flame deflector and thus add to the fire defense of an adjacent building.

Wildfire mitigation measures for fences and walls are discussed in the following section:

A. Fences and Walls 79

A. Fences and Walls

Problem: Wooden fences and fences with wooden components are those most vulnerable to fire damage. Vinyl fences are durable, stable, and in most cases stronger than wooden fences. If exposed to enough heat, however, vinyl is subject to deformation and melting. Other fence materials, such as masonry and concrete, chain-link, barbed-wired, aluminum, and full metal generally perform much better than wooden fences in wildfires. However, metal may melt if exposed to long periods of extremely high temperatures.

Mitigation Objective: Reduce damage to fencing through the use of **noncombustible** materials.

Mitigation measures to protect fences and walls from wildfire damage caused by use of combustible materials include:

- A.1. Use Noncombustible Materials 80
- A.2. Treat Fences and Walls with
Fire-Retardant Coating 81

A.1 Use Noncombustible Materials

Description of Mitigation Measure: Replace combustible fences and walls with **noncombustible** materials such as steel, concrete, masonry, or fireproof fiberglass.



Effectiveness: Steel, masonry, and concrete fences and walls are the most effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Masonry and concrete walls are visually obstructive but may act as flame barriers or deflection walls for adjacent buildings.

Limitations: Chain-link and barbed-wire fences allow the fire to pass through and do not act as protective barriers. Melting may occur if the metal is exposed to long periods of extremely high temperatures.

If ignited, a vinyl fence will self-extinguish. However, melting may occur if exposed to enough heat.

Considerations:



A.2 Treat Fences and Walls with Fire-Retardant Coating

Description of Mitigation Measure: Treat wooden fences and walls with a *fire-retardant* coating.



Effectiveness: Fire-retardant coatings applied to wooden fences are effective only in moderate fire severity zones because they provide minimal fire resistance.

Limitations: The fire-retardant coating must be re-applied often to be effective.

Considerations:



V. SURFACE TRANSPORTATION SAFETY FACILITIES

Introduction: This section includes surface transportation safety facilities such as guardrails, signage, traffic control systems, and lighting systems. It does not include roadways, which generally have a low risk of damage during a wildfire.

Causes of Damage: These features often include combustible components such as wooden posts and heat-sensitive equipment that is vulnerable to wildfire damage. Typically, combustible components of roadside facilities are ignited and damaged or destroyed. Flames, blowing embers and firebrands, and radiant heat may make direct contact with the facility or nearby vegetation or debris and cause ignition.

Mitigation measures for common wildfire damage to surface transportation safety features are discussed in the following sections:

- A. Guardrails 83
- B. Traffic and Light Systems 85

A. Guardrails

Problem: Guardrails can contain posts that are made of combustible material. Wooden posts are often treated with creosote. Although creosote protects the wood from decay, the wood is highly combustible and will ignite when exposed to fire.

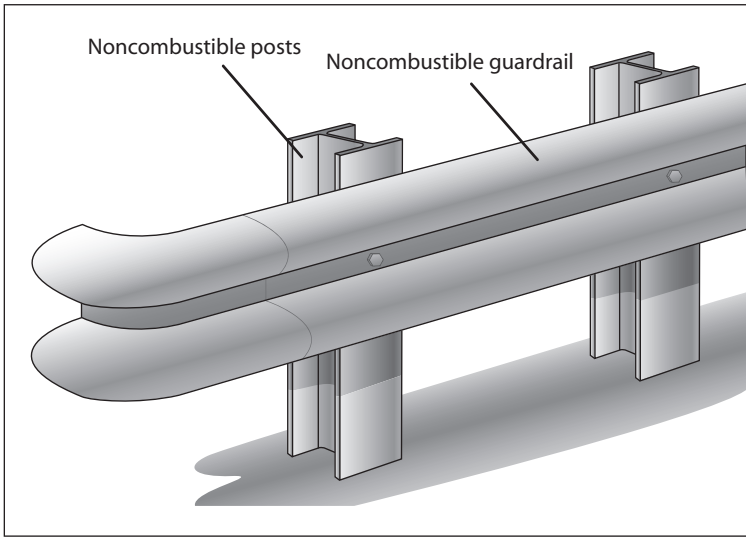
Mitigation Objective: Reduce the possibility of damage by limiting the amount of combustible material used in guardrail construction.

Mitigation measures to protect guardrails from wildfire damage include:

A.1 Use Noncombustible Materials 84

A.1 Use Noncombustible Materials

Description of Mitigation Measure: To prevent damage to posts and to maintain the effectiveness of guardrails, replace systems reliant on combustible materials with concrete barrier systems, steel posts, or high-tension cable barriers.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Considerations:



B. Traffic and Light Systems

Problem: Although poles typically have thick cross sections, poles made of combustible materials will eventually ignite. Also, wooden poles may be treated with creosote. Although creosote protects the wood from decay, the wood is highly combustible and will ignite when exposed to fire.

Span wire is typically thin and left exposed to the elements. Span wire fails due to a reduction in strength when exposed to wildfire temperatures.

Mitigation Objective: Reduce damage to light and traffic poles by using **noncombustible** materials.

Mitigation measures to protect traffic and light systems from wildfire damage include:

- B.1 Replace Wooden Poles and Signs with Noncombustible Materials 86
- B.2 Replace Span Wire with Noncombustible Material 87

B.1 Replace Wooden Poles and Signs with Noncombustible Materials

Description of Mitigation Measure: Use steel poles, concrete poles, or poles encased with flame-retardant PVC for traffic signs and light systems.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Steel poles are lighter and easier to install than wooden or concrete poles. Unlike wood, steel and concrete poles do not require treatment to extend lifespan.

Considerations:



B.2 Replace Span Wire with Noncombustible Material

Description of Mitigation Measure: Traffic signals that use span wire are prone to damage during a wildfire. To prevent damage, replace the span wire system with **noncombustible** poles. Traffic signals are supported either by cantilevered beams or a beam connected to two poles. Noncombustible support poles, such as steel or concrete, should be used.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Considerations:



VI. BRIDGES

Introduction: Bridges are constructed with a wide range of designs. In general, they are constructed of wood, timber, steel, concrete, or a combination of these materials. Bridges have a critical function during a wildfire to facilitate evacuation and provide access for firefighters. Once a bridge becomes structurally unsound, evacuation and firefighter access are curtailed. The result is a loss of access through an area for as long as several months.

Causes of Damage: Wildfire damage to bridges is typically the result of the ignition of bridge construction materials. The **fire resistance** of a bridge is dependent on the material and methods that were used to construct it.

The structural components of a bridge are exposed to the environment. Additionally, bridges often span vegetated areas or areas where debris has accumulated or are adjacent to vegetated areas, increasing exposure to wildfire elements. Large, flat surfaces such as decking provide exposure to wildfire elements, and blowing embers and firebrands may be trapped in open structural elements or underneath the bridge.

Wildfires typically cause the following types of damages in bridges:

- Decking made of combustible material is ignited and damaged. As a result, the decking may no longer be able to carry the required loading.
- Combustible framing in the superstructure or substructure is damaged by a wildfire and compromises the structural integrity of the bridge.
- Guardrails with combustible posts or railing ignite.

Mitigation measures for common wildfire damage to bridges are discussed in the following sections:

- A. Superstructure 89
- B. Substructure 93

A. Superstructure

Problem: Damage is caused when combustible superstructure elements are exposed to a wildfire.

Mitigation Objective: Reduce damage to the superstructure of a bridge and ensure that the road surface is functioning during and after a wildfire.

Mitigation measures to protect the superstructure from wildfire damage include:

- A.1 Use Noncombustible Material 90
- A.2 Treat Superstructure with
Fire-Retardant Coating 91
- A.3 Install Noncombustible Guardrails
or Barriers 92

A.1. Use Noncombustible Material

Description of Mitigation Measure: Replace combustible superstructure materials with **noncombustible** materials such as steel or concrete.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Steel and concrete tend to be more durable than wood.

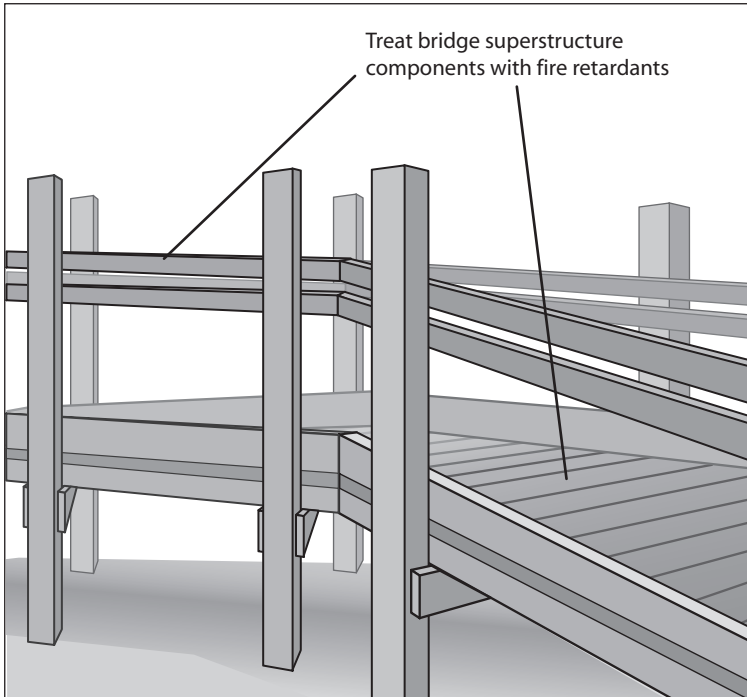
Limitations: New structural components require a loading engineering study including load-path considerations.

Considerations:



A.2 Treat Superstructure with Fire-Retardant Coating

Description of Mitigation Measure: When wooden elements cannot be replaced, treat exposed wooden superstructure components with **fire retardants** such as cementitious fireproofing or **intumescent**.



Effectiveness: Effective in moderate fire severity zones.

Limitations: Post-manufacturing fire-retardant treatment has a limited lifespan. The bridge should be retreated as directed by the product label.

Considerations:



A.3 Install Noncombustible Guardrails or Barriers

Description of Mitigation Measure: For guardrails or barriers to continue to function properly during and after a wildfire, replace combustible materials with **noncombustible** materials such as steel and concrete.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Limitations on available space should be considered.

Limitations: Each type of barrier is engineered to perform differently. Added weight on the structure requires a loading engineering study including load-path considerations.

Considerations:



B. Substructure

Problem: Damage is caused when combustible substructure elements are exposed to a wildfire.

Mitigation Objective: Reduce damage to the substructure of a bridge and ensure that the bridge is functioning during and after a wildfire.

Mitigation measures to protect the substructure from wildfire damage include:

- B.1 Use Noncombustible Materials 94
- B.2 Treat Substructure with Fire-Retardant Coating 95

B.1 Use Noncombustible Material

Description of Mitigation Measure: Replace combustible substructure materials with **noncombustible** materials such as steel or concrete.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Design Issues: Steel and concrete tend to be more durable than wood.

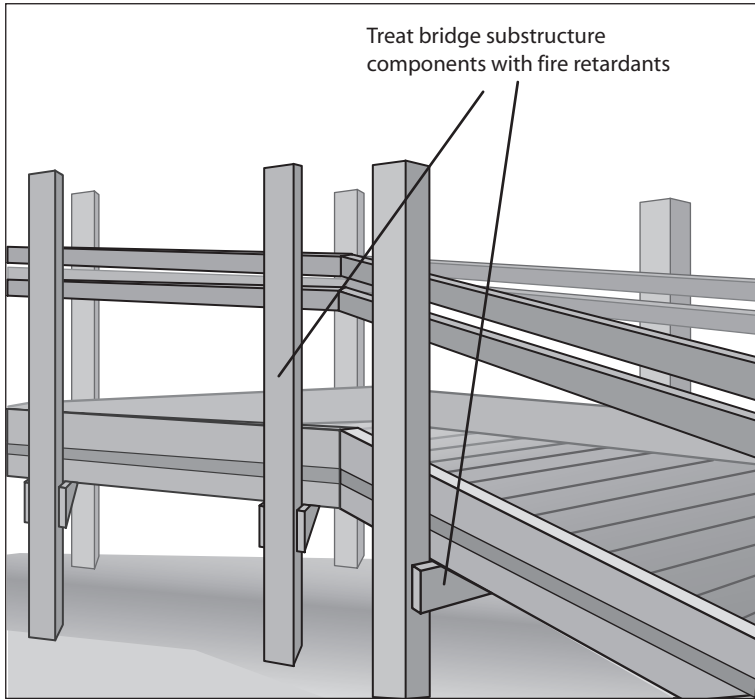
Limitations: New structural components require a loading engineering study including load-path considerations.

Considerations:



B.2 Treat Substructure with Fire-Retardant Coating

Description of Mitigation Measure: When wooden elements cannot be replaced, treat exposed substructure components with **fire retardants** such as cementitious fireproofing or **intumescent**.



Effectiveness: Effective for reducing vulnerability to wildfire damage in moderate fire severity zones.

Limitations: Post-manufacturing fire retardant has a limited lifespan. The bridge will require retreatment as directed by the product label.

Considerations:



VII. RETAINING WALLS AND EROSION-CONTROL STRUCTURES

Introduction: Retaining walls include structures designed to stabilize slopes. Erosion-control structures include facilities designed to control the movement of water and sediment on slopes or in drainages. This section does not include a discussion of post-fire measures to stabilize burned slopes and prevent erosion, excessive runoff, or debris flows.

Causes of Damage: Retaining walls and erosion-control structures are often constructed:

- Of combustible materials, such as wood and timbers
- In heavily vegetated areas and areas where vegetative debris accumulates
- On slopes and are consequently often in the direct path of an approaching wildfire

Nearby vegetation and accumulated debris may ignite and provide a path for flames to come into contact with the facility. Large, flat surfaces, exposed structural components, and cracks and gaps in walls increase the potential for contact with, or trapping of, blowing embers and firebrands. Once ignited, the structure itself may become an additional source of fuel and pose a threat to nearby buildings and other facilities.

Mitigation measures for retaining walls and erosion-control structures from common wildfire damage are discussed in the following section:

- A. Retaining Walls and Erosion-Control Structures 97

A. Retaining Walls and Erosion-Control Structures

Problem: Retaining walls and erosion-control structures are often constructed with combustible materials such as wood. These structures are often constructed on slopes and consequently may be in the direct path of an approaching wildfire. Once a wood retaining wall or erosion-control structure ignites, its capability to hold or control soil and eliminate erosion is reduced.

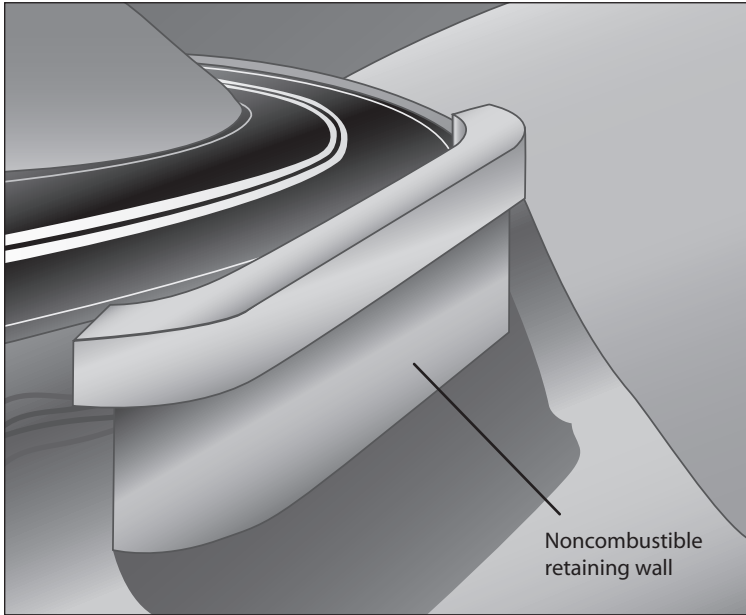
Mitigation Objective: Reduce damage and maintain the structural stability of retaining walls and erosion-control structures during and after a wildfire by using **noncombustible** materials.

Mitigation measures to protect retaining walls and erosion-control structures from wildfire damage caused by use of combustible materials include:

A.1. Use Noncombustible Materials 98

A.1 Use Noncombustible Materials

Description of Mitigation Measure: Reconstruct combustible retaining structures or erosion-control structures with **noncombustible** materials such as steel, concrete, or masonry. For example, retaining walls made with timber lagging or railroad ties can be replaced with a masonry or concrete block wall. Also, wood revetments used for erosion control can be replaced with riprap or gabion baskets.



Effectiveness: Effective for reducing vulnerability to wildfire damage in all fire severity zones.

Limitations: Construction on embankments near streams may have added environmental concerns.

Considerations:



APPENDIX A
Disaster Assistance Policy 9526.1
Hazard Mitigation Funding under Section 406 (Stafford Act)

I. TITLE:

Hazard Mitigation Funding Under Section 406 (Stafford Act)

II. DATE:

July 30, 2007

III. PURPOSE:

Provide guidance on the appropriate use of hazard mitigation discretionary funding available under Section 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), 42 U.S.C. 5121-5206. This will ensure national consistency in the use of Section 406 mitigation funds and promote measures that reduce future loss to life and property, protect the federal investment in public infrastructure and ultimately, help build disaster resistant communities.

IV. SCOPE AND AUDIENCE:

This policy applies to all disasters declared after publication of this document. It is intended to guide all personnel responsible for the administration of the FEMA Public Assistance Grant Program.

V. AUTHORITIES AND REFERENCES:

Section 406 (e) of the Stafford Act and Title 44 Code of Federal Regulations (CFR) § 206.226.

VI. BACKGROUND:

- A. The Robert T. Stafford Disaster Relief and Emergency Assistance Act provides FEMA the authority to fund the restoration of eligible facilities that have sustained damage due to a Presidentially declared disaster. Section 406 of the Stafford Act contains a provision for the consideration of funding additional measures (further described in 44 CFR § 206.226) that will enhance a facility's ability to resist similar damage in future events.
 1. In providing discretionary authority for the addition of hazard mitigation measures to permanent work restoration, Congress recognized that during the repair of damaged components

of facilities there would be a unique opportunity to prevent recurrence of similar damage from future, similar disaster events. Such measures are in addition to any measures undertaken to comply with applicable codes and standards, although such compliance, itself, could be considered a form of mitigation.

2. Section 406 hazard mitigation funding and Section 404 hazard mitigation funding are distinct. Section 406 is applied on the parts of the facility that were actually damaged by the disaster and the mitigation measure provides protection from subsequent events. The mitigation work must be cost effective and be reasonably performed as part of the work or measure which will reduce the potential for damage to a facility from a disaster event. Sometimes, a combination of Section 406 and 404 funding may be appropriate, where Section 406 hazard mitigation funding is used to provide protection to the parts of the facility that were damaged and Section 404 hazard mitigation funding is used to provide protection to the undamaged parts of the facility. In these instances, the application for Section 404 hazard mitigation funding must be submitted in a timely manner, consistent with State and local hazard mitigation plans, and approved by the State Hazard Mitigation Officer.
3. FEMA may provide discretionary hazard mitigation funding under Section 406 of the Stafford Act. FEMA, Grantee and subgrantee's interests in disaster resistance must be balanced with the supplemental nature of disaster assistance and FEMA's obligation for the prudent stewardship of Federal disaster funds.
4. Only FEMA is authorized to interpret and implement the Stafford Act and regulations issued pursuant to the Stafford Act. Accordingly, only FEMA has the authority to determine which hazard mitigation measures it will fund. The Stafford Act and applicable regulations do not authorize State or local building officials or agencies to determine the amount of hazard mitigation funding FEMA will contribute to a project.

VII. POLICY:

- A. Section 406 provides discretionary authority to fund mitigation measures in conjunction with the repair of the disaster-damaged facilities. These opportunities usually present themselves during

the repair efforts. The mitigation measures must be related to eligible disaster-related damages and must directly reduce the potential of future, similar disaster damages to the eligible facility. This work is performed on the parts of the facility that were actually damaged by the disaster and the mitigation measure provides protection from subsequent events. **Exceptions to this provision will be reviewed on a case-by-case basis.**

- B. Mitigation measures must be determined to be cost-effective. Any one of the following means may be used to determine cost-effectiveness:
1. Mitigation measures may amount to up to 15% of the total eligible cost of the eligible repair work on a particular project.
 2. Certain mitigation measures (see Appendix A) determined cost-effective, as long as the mitigation measure does not exceed 100% of the eligible cost of the eligible repair work on the project.
 3. For measures that exceed the above costs, the Grantee or subgrantee must demonstrate through an acceptable benefit/cost analysis methodology that the measure is cost-effective. FEMA's Benefit Cost Analysis (BCA) software provides appropriate benefit/cost analysis methodologies. You can obtain the software from FEMA by contacting the BCA helpline at 1-866-222-3580, e-mail (bchelpine@dhs.gov), or the applicable FEMA Regional Office. Alternative benefit/cost methodologies will only be considered acceptable if the Grantee or subgrantee receives and submits written approval from the FEMA Regional Office and FEMA Headquarters prior to the submission of the mitigation proposal. The benefit/cost analysis will be based on a comparison of the total project cost to the total cost of the following benefits: 1) damage to the facility and its damaged contents, 2) emergency protective measures required as a result of that damage, and 3) temporary facilities required due to the damage.
- C. If a facility has Section 406 hazard mitigation funding included in the approved scope of work (SOW) and the subgrantee wishes to restore the facility to its pre-disaster condition and function **without** the Section 406 hazard mitigation SOW, then the subgrantee must request a change of SOW prior to completion of the project. Section 406 hazard mitigation funds must be de-obligated when the subgrantee does not use the funds as approved in the SOW.

- D. Proposed hazard mitigation projects must be approved by FEMA prior to funding. They will be evaluated for cost effectiveness, technical feasibility, and compliance with statutory, regulatory, and executive order requirements. In addition, the evaluation must ensure that the mitigation measures do not cause a negative impact to the facility's operation, surrounding areas, or susceptibility to damage from another hazard.
- E. The costs of meeting applicable codes/standards in accordance with 44 CFR § 206.226 (d) and minimum National Flood Insurance Program requirements are regulatory requirements that are distinct from hazard mitigation. Funding for these costs is considered separately.
- F. When the cost of proposed replacement material for a damaged component is more than the original material, the proposed material must be shown to be cost effective.
- G. There may be no duplication in hazard mitigation funding between Sections 404 and 406. Therefore, the Grantee and subgrantee must be able to identify specific hazard mitigation work that will be accomplished with funding through Section 406. Section 404 funding may not duplicate that work, although Section 404 may be additive and accomplished on Section 406 facilities. The appropriate split on a project between funds under Sections 404 and 406 is a FEMA decision. Sections 404 and 406 funding cannot be used to meet the non-federal cost share of the other grant.
- H. Funds recommended for mitigation measures may be approved for an improved project if the original facility and its function will be restored and the mitigation work is still needed, is technically feasible, and will be performed as part of the overall project. Facilities eligible for replacement under 44 CFR 206.226(f) - *Repair vs. replacement* are not eligible for mitigation measures.
 - 1. If mitigation measures are approved for the repair of a disaster-damaged facility and the subgrantee requests an improved project which will instead involve the replacement of the facility, on the same site or an alternate site, the cost of the mitigation measures is not eligible.
 - 2. The cost of mitigation measures approved under Section 406 for the repair of a facility may not be applied towards an Alternate Project.
- I. Early in a disaster the FEMA and State PA Officers, in consultation with the Hazard Mitigation Group Supervisor, should issue a

Memorandum of Understanding outlining how 406 mitigation will be addressed for the disaster, including what measures will be emphasized, making linkages to codes and standards and availability and integration of other mitigation programs.

VIII. RESPONSIBLE OFFICE:

Disaster Assistance Directorate (Public Assistance Division).

IX. SUPERSESION:

This policy updates and replaces RP9526.1, Hazard Mitigation Funding Under Section 406 (Stafford Act), published August 13, 1998.

X. REVIEW DATE:

Five years from date of publication.

//signed//

Carlos J. Castillo
Assistant Administrator
Disaster Assistance Directorate

**Appendix A [of Disaster Assistance Policy 9526.1]:
Potential Mitigation Measures
That Are Pre-Determined to Be Cost Effective**

The following potential mitigation measures (reference: paragraph VII.B.2) are determined to be cost-effective if they:

- do not exceed 100% of project cost,
- are appropriate to the disaster damage,
- will prevent future similar damage,
- are directly related to the eligible damaged elements,
- do not increase risks or cause adverse effects to the property or elsewhere,
- are technically feasible for the hazard and location, and
- otherwise meet requirements stipulated in this policy, including environmental, historic, and mitigation planning considerations.

This list will continue to be evaluated and will evolve over time as new information becomes available.

I. General

A. Drainage/crossings and bridges

1. Drainage structures – When drainage structures are destroyed, replacing the structure with multiple structures or a larger structure. Sizing of replacement culverts can be made using in-place state/local drainage criteria (nomographs). However, structures need to be considered with regard to a total drainage system and should not be upgraded without a watershed hydrology study with an emphasis on downstream effects and NFIP [National Flood Insurance Program] regulations.
2. Culverts – Where the alignment of culverts is inconsistent with streams flowing through them (because it has been blown-out), realign or relocate the culverts to improve hydraulics and minimize erosion. However, realignment of structures must be considered in regard to a total drainage system and shall not be replaced without a hydrology study with an emphasis on downstream erosion effects.
3. Headwalls and wing walls – Installation to control erosion.
4. Low-water crossings – When bridges are destroyed and where traffic counts are low, replacing bridges with carefully placed low-water crossings.

5. Gabion baskets, riprap, sheet-piling, and geotextile fabric installation – Installation to control erosion.
 6. Roadways – Where roadways shoulders are damaged by overflow from adjacent water courses, stabilize shoulders and embankments with geotextile fabric.
 7. Restraining cables on bridges – Installation of cables to restrain a bridge from being knocked off piers or abutments during floods or earthquakes. Also, where bridges have been damaged or destroyed when girders, beams and decking system are displaced by storm surges or earthquakes, install girder and deck uplift tie-downs to prevent their displacement from the substructure.
- B. Sanitary and storm sewer systems
1. Access covers – When feasible, access covers can be elevated to the hydraulic grade line. There are a number of devices that prevent infiltration into access holes.
 2. Sewer lines – Repair, lining or encasement of damaged sections to prevent infiltration or structural collapse.
 3. Pump stations –
 - a. Equipment or controls in a pump station that are subject to damage from the 100- year flood can be elevated. Pump station buildings can be dry flood-proofed.
 - b. Installation of camlocks, transfer switches, and electrical panels to facilitate the connection of portable emergency generators.
 - c. Pump stations – If pumps and their attached motors are damaged by storm water inundation, replace them with submersible or inline pumps as appropriate.
 - d. Pump stations – If pump station equipment is damaged as a result of inundation resulting from power failure, install switches, circuit isolation and/quick connect capability to facilitate rapid connection of backup power.
- C. Wastewater treatment plants
1. Elevation of equipment and controls that can be elevated easily.
 2. Dry or wet flood-proofing of buildings.

D. Potable water

1. Well systems –
 - a. Reduction of infiltration and subsequent contamination of the aquifer. Methods include casing the well or raising the elevation of the well head.
 - b. Elevation of controls, mechanical equipment, or electrical service associated with use of the well to protect them from flood damage.
2. Raw water intakes - Buttrressing to prevent damage from erosion, scour, and flood debris.
3. Water treatment plants –
 - a. Elevation of equipment and controls that can be elevated easily.
 - b. Dry flood-proofing.

E. Electric power distribution

1. Pad-mounted transformers – elevating above the base flood elevation.
2. Using multiple poles to support transformers.
3. Anchoring or otherwise protecting fuel tanks from movement in a disaster.
4. Replacing damaged poles with higher-rated poles, of the same or different material such as replacing wood poles with precast concrete or steel.
5. Adding guy wire or additional support to power lines.
6. Removing large diameter lines from poles.
7. Providing looped distribution service or other redundancies in the electrical service to critical facilities.

F. Above ground storage tanks

1. Strengthening or stiffening base connections.
2. Installation of self-initiating disconnects and shut-off valves between tanks and distribution lines to minimize damage and leaks.

G. Underground pipelines – Installation of shut-off valves so that damaged sections of pipeline can be isolated.

II. Buildings:

A. General effects of flood damage –

1. Buildings substantially damaged under NFIP regulations – Repair, dry flood-proofing, or elevation so they are protected to meet minimum NFIP regulations. If the building is replaced, rather than repaired, minimum NFIP requirements are generally in place as codes and standards in participating communities and are applicable in both repair and replacement situation. Section 406 mitigation should be considered in those cases where these standards either fall short or provide no protection against other hazards.
2. Buildings not substantially damaged under NFIP regulations – If technically feasible, dry flood-proofing. Electrical panels, machinery rooms, emergency generators can be elevated above the BFE [Base Flood Elevation] or dry flood-proofed. If dry flood-proofing is not feasible, these buildings should be wet flood-proofed.

B. Roofs – Because the failure of a roof covering can lead to extensive damage to contents and operation, damaged roofing should be evaluated to determine cause of failure.

1. Low slope roofs – Replacement of the entire roof with a roof covering with a secondary membrane and a fully adhered roof covering, such as modified bitumen. Mechanically fastened insulation or membranes are not acceptable.
2. Roof-mounted equipment should be attached to a foundation that will resist expected wind forces.
3. Hurricane clips – Hurricane clips for use in high-wind areas.
4. Roofs – When roof damages are due to wind pressure beneath soffits and overhangs, strengthen the soffit and overhang material and means of attachment to prevent wind pressure adversely affecting the roofing system.
5. Roofs – When there is roof system damage or water intrusion due to damage to roof opening such as hatches and skylights strengthen the openings or the windows to avoid future damage.
6. Roofs – For gable roofs damaged by wind, replace the gable end-framing with hipped roof framing to reduce wind forces (lower edge pressure; reduced projected wind area) and strengthen the roof framing.

- C. Shutters – In areas subject to hurricane winds, shutters are appropriate in the following areas:
 - 1. All damaged windows on critical facilities such as hospitals.
 - 2. The lower floors of buildings with damaged windows most likely to be struck by debris.
 - 3. Damaged windows of buildings with very high value contents that can be damaged by water (such as libraries and document centers).
 - 4. Damaged windows of buildings subject to debris from nearby ballasted roofs, metal buildings, manufactured homes or other structures likely to fail and result in debris.
- D. Anchoring –
 - 1. Anchoring of mechanical and electrical equipment in critical facilities.
 - 2. For small ancillary buildings that have sustained damage and/or have caused damage to other facilities, anchor the buildings to foundations to prevent toppling or becoming missile hazards.
- E. Flexible piping – Installation of flexible piping at pipe/conduit connections to equipment to accommodate expected movement in an earthquake.
- F. Bracing –
 - 1. Bracing of and large diameter pipes and electrical lines to meet seismic loads.
 - 2. Bracing non structural interior walls and partitions.
 - 3. Bracing parapets, anchoring veneer or cladding, and bracing other non-structural elements that could collapse and cause injury or block safe exit of a building during an earthquake.
- G. Replacement of glass – Replacement of glass with impact-resistant material.
- H. General Buildings –
 - 1. Buildings – Where spread footings have been undercut by scour, underpin footings.
 - 2. Siding – if siding has been damage by wind, replace with a stronger siding with stronger attachments to the wall sheathing and structure.

3. Venting – Where there has been water damage caused by water intrusion through venting systems, replace the vents with rain and water resistant vents.
- I. Doors and Windows –
 1. Where damage has resulted from wind and water intrusion around weather stripping on doors and/or windows, upgrade the weather stripping to prevent water infiltration.
 2. Where damage has been caused by wind-induced failure of doors, replace the doors with stronger units. This applies to the door frame, door, hinges, and lock hardware. Both entry and garage doors should be considered.
 - J. Miscellaneous Structures –
 1. Marine Piers – If marine piers ramps that attach to decking have been damaged by storm-surge uplift and buoyancy, install open decking or floating decking with uplift-resistant tie-downs and fasteners.
 2. Signage – If sign panels and their supports have failed, replace with a stronger type of system of supports and panels. Consider using multiple support posts and stronger panels and fasteners.
 3. Gutters and Downspouts – If damaged by either wind and/or water, upgrade the gutter and downspout system to directing water away from the structure and preventing interior or basement water damage.

APPENDIX B

Considerations for Implementation of Mitigation Measures



Project May be Cost-Prohibitive

The cost of actions identified by this symbol may be prohibitively expensive.



Maintenance Required to Maintain Effectiveness

Actions identified by this symbol may require significant and/or continuous maintenance.



Engineer Needed

An engineer should be consulted or hired to develop and/or approve the actions identified by this symbol.



Structural Aesthetics Could be Affected

Actions identified by this symbol may affect the structure's appearance and/or aesthetic value.



Weather Considerations

Actions identified by this symbol may require the local weather climate to be considered.



Local Code Requirements

Actions identified by this symbol may be affected by local code requirements.



Short Lifespan

Actions identified by this symbol may be temporary solutions and require further action in the future.

Environmental and Historic Preservation Considerations

As described in the “How to Use this Handbook” section above, FEMA must consider a range of Federal environmental and historic preservation laws, regulations, and Executive Orders that apply to the use of Federal funds when evaluating proposed mitigation measures under the PA Program. Requirements that commonly apply to PA Program mitigation measures are identified below. For more detailed information on FEMA’s environmental

and historic preservation compliance responsibilities, refer to the FEMA 322, *Public Assistance Guide* (FEMA, 2007) or the FEMA website at www.fema.gov/plan/ehp.

National Environmental Policy Act (NEPA). NEPA requires every Federal agency to follow a specific planning process to ensure that agency decision-makers have considered, and the general public is fully informed about, the environmental consequences of a proposed Federal action, such as the approval of a grant. This review and consultation process is used to evaluate the impact a project, and any possible alternatives, may have on the environment. The process must be completed prior to obligating funds and beginning work. NEPA does not require that FEMA limit the impact of projects on the environment; nor does it require FEMA to fund only the alternative that has the least environmental impact. However, it does require that the decision to fund a project be made in an informed manner. FEMA's regulations regarding NEPA can be found in 44 CFR Part 10.

National Historic Preservation Act (NHPA). The NHPA requires a Federal agency to consider, before approval of funding, the effects of its activities, referred to as "undertakings," on any historic property listed in or eligible for listing in the National Register of Historic Places. The agency funding the undertaking is required to give the Advisory Council on Historic Preservation a reasonable opportunity to comment on that undertaking. Under the NHPA regulations, which can be found in 36 CFR Part 800, PA Program projects are considered undertakings because they are funded in whole or in part by a Federal agency. Historic properties include districts, buildings, structures, objects, landscapes, archaeological sites, and traditional cultural properties that are listed in or eligible for listing in the National Register of Historic Places, a Federally maintained list of recognized historic properties. These properties are not limited to old buildings or well-known historic sites, but include places important in local, State, tribal, or national history. Facilities as diverse as bridges, roads, water treatment plants, and areas once inhabited by Native American populations may be considered historic properties.

Endangered Species Act (ESA). Section 7 of the ESA prohibits Federal actions that cause takings of species listed as threatened or endangered, or the destruction or adverse modification of the habitat for these species. Endangered species include mammals, fish, birds, reptiles, amphibians, plants, and insects. If a project has the potential to affect a threatened or endangered species or its habitat, FEMA must consult with the U.S. Fish and Wildlife Services or the National Marine Fisheries Service, or both, before approving funding for that project. While compliance issues may

arise with projects involving undisturbed sites or sites in or by waterways, they could also arise with relatively minor actions.

Executive Order 11988 – Floodplain Management, and Executive Order 11990 – Protection of Wetlands. These Executive Orders require Federal agencies to minimize or avoid activity that adversely affects floodplains and wetlands. Because many PA Program projects are located in these areas, FEMA must review proposed projects for compliance with the requirements of these orders. Through this review, FEMA seeks to:

- Avoid, to the extent possible, short- and long-term adverse impacts associated with the occupancy and modification of floodplains.
- Avoid direct and indirect support of floodplain development wherever there is a practicable alternative.
- Minimize the destruction, loss, or degradation of wetlands.
- FEMA’s regulations for applying these Executive Orders are outlined in 44 CFR Part 9. These regulations describe a specific, eight-step process for conducting floodplain management and wetland reviews before approval of funding.

APPENDIX C

Glossary and Keyword Index

[keywords are underlined]

Asphalt shingles: Roofing felt, saturated with asphalt and coated on the weather side with a harder asphalt and aggregate particles, which has been cut into shingles for application to a sloped roof.

Automatic sprinkler system: A sprinkler system for fire protection purposes, is an integrated system of underground and overhead piping designed in accordance with fire protection engineering standards. The system includes a suitable water supply, and when activated by heat from a fire, discharges water over the fire area.

Building: Any structure used or intended for supporting or sheltering any use or occupancy.

Building envelope: A term used to denote the extreme outside surface and dimensions of a building.

Built-up roofing: Two or more layers of felt cemented together and surfaced with a cap sheet, mineral aggregate, smooth coating or similar surfacing material.

Combustible material: Any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn or will add appreciable heat to an ambient fire.

Cripple wall: A framed stud wall extending from the top of the foundation to the underside of floor framing for the lowest occupied floor level.

Defensible space: An area that is either natural or man-made, where material capable of allowing a fire to spread unchecked has been treated, cleared or modified to slow the rate and intensity of an advancing wildfire and to create an area for fire-suppression operations to occur. (pp. xv, xvi, 1, 69, 71, 76)

Eave: (1) Those portions of a roof that project beyond the outside walls of a building. (2) The bottom edges of a sloping roof.

Ember: A fragment of a material that had been burning, usually with flaming combustion. An ember can be a firebrand.

Fascia: (1) A board used on the outside vertical face of a cornice. (2) The board connecting the top of the siding with the bottom of a soffit. (3) A board nailed across the ends of the rafters at the eaves. (4) The edge beam of a bridge. (5) A flat member or band at the surface of a building.

Fiber-cement: A manufactured, fiber-reinforcing product made with an inorganic hydraulic or calcium silicate binder formed by chemical reaction and reinforced with organic or inorganic nonasbestos fibers or both. Additives that enhance manufacturing or product performance are permitted. Siding products have either smooth or textured faces and are intended for exterior wall. It also comes in sheet form for related applications, such as soffit and eave lining or underlay on decks. (pp. 7, 21, 40, 56)

Firebrand: Detached burning materials (flaming, but usually glowing combustion) that travel beyond the burning vegetation or structures of origin and are potentially capable of producing combustion.

Firebreak: A strip of cleared land that provides a gap in vegetation or other combustible material that is expected to slow or stop the progress of a wildfire.

Fire hazard: A fuel complex, defined by kind, arrangement, volume, condition, and location, that determines the ease of ignition and/or resistance to fire control.

Fire-resistant material: Material that has a property that prevents or retards the passage of excessive heat, hot gases or flames under conditions of use. (pp. xvi, 1, 2, 9, 12, 14, 17, 18, 21, 22, 25, 40, 42, 46, 47, 54, 56, 57, 63, 69, 71, 72, 85)

Fire-resistance rating: The period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by tests, or methods based on tests. (pp. 4, 18, 21, 32, 42, 46, 88)

Fire retardant: A chemical applied to lumber or other wood products to slow combustion and flame spread. (pp. 71, 76, 81, 91, 95)

Fire-retardant-treated wood: Any wood product impregnated with chemicals by a pressure process or other means during manufacture, and which, when tested in accordance with ASTM E 84-05 for a period of 30 minutes shall have a flame spread of not over 25 and show no evidence of progressive combustion. In addition, the flame front shall not progress more than 10½ feet (3200 millimeters) beyond the center line of the burner at any time during the test. Materials that may be exposed to the weather

shall pass the accelerated weathering test and be identified as Exterior type, in accordance, with ASTM D 2898-94 and ASTM D 3201-94. Where material is not directly exposed to rainfall but exposed to high humidity conditions, it shall be subjected to the hygroscopic test and identified as Interior Type A in accordance with ASTM D 2898-94 and ASTM D 3201-94. (pp. 4, 7, 11, 38, 56)

Flashing: A thin, impervious sheet of metal placed in construction to prevent water penetration or direct the flow of water. (pp. 9, 39, 51, 72)

Fuels: All combustible materials within the wildland/urban interface or intermix, including, but not limited to, vegetation and structures.

Gypsum board: The generic name for a family of sheet products consisting of a noncombustible core primarily of gypsum with paper surfacing. Both regular and Type X gypsum board (see definition of “Type X gypsum board” below) are covered under the ASTM C 1396 36, gypsum board standard specification. Regular gypsum has naturally occurring fire resistance due to the presence of gypsum in the core. Type X has special core additives to increase the natural fire resistance.

Human intervention: Any action that a person must take to enable a wildfire protection measure to function as intended. This action must be taken every time a wildfire threatens.

Ignition-resistant construction standards: Construction standards based on use of fire-resistant materials, non-combustible materials, and one-hour fire rated assemblies. (pp. xv, xvi, 2, 63, 69)

Insulated glazing unit (IGU): Window assembly that consist of two or more independently glazed panels installed parallel to each other, having a sealed air gap in between, within a frame designed to fill completely the window or door opening in which the assembly is intended to be installed.

Intumescent: A fire retardant coating that when heated forms a foam produced by non-flammable gases, such as carbon dioxide and ammonia. This results in a thick, highly insulating layer of carbon (about fifty times as thick as the original coating) that serves to protect the coating substrate from fire. (pp. 25, 91, 95)

Membrane roofing: A term that most commonly refers to a roof covering, employing flexible elastomeric plastic materials from 35 to 60 mils thick, that is applied from rolls and has vulcanized joints.

Metal roofing: Metal shingles or sheets for application on solid roof surfaces, and corrugated or otherwise shaped metal sheets of sections for application on roof frameworks or on solid roof surfaces.

Mortar: A mixture of finely divided hydraulic cementitious material, fine aggregate, and water in either the unhardened or hardened state, hydraulic mortar. (pp. 7, 25)

Noncombustible material: As applied to building construction material means a material that, in the form in which it is used, is either one of the following:

- Material of which no part will ignite and burn when subjected to fire. Any material conforming to ASTM E 136 shall be considered noncombustible within the meaning of this section.
- Material having a structural base of noncombustible material as defined in Item 1 above, with a surfacing material not over 1/8 inch (3.2 mm) thick, which has a flame spread rating of 50 or less. Flame spread rating as used herein refers to rating obtained according to tests conducted as specified in ASTM E 84.

“Noncombustible” does not apply to surface finish materials. Material required to be noncombustible for reduced clearances to flues, heating appliances or other sources of high material shall be classed as noncombustible that is subject to increase in combustibility or flame spread rating, beyond the limits herein established, through the effects of age, moisture or other atmospheric condition. (pp. xvi, 1, 2, 4, 7, 8, 11, 14, 15, 16, 21, 22, 28, 29, 30, 34, 38, 47, 54, 63, 69, 71, 76, 78, 79, 80, 87, 90, 92, 94, 97, 98)

Roof assembly: A system designed to provide weather protection and resistance to design loads. The system consists of a roof covering and the roof deck or a single component serving as both the roof covering and the roof deck. A roof assembly includes the roof deck, vapor retarder, substrate or thermal barrier, insulation, vapor retarder and roof covering.

Roof covering: The covering applied to the roof deck for weather resistance, fire classification or appearance.

Roof valley: The place where two planes of a roof meet at a downward, or V, angle.

Sheathing: The material forming the contact face of forms. Plywood, waferboard, oriented strand board, or lumber used to close up side walls, floors, or roofs preparatory to the installation of finish materials on the surface.

Shingle: A roof-covering unit made of asphalt, slate, asbestos, cement, or other material cut into stock sizes and applied on sloping roofs in an overlapping pattern.

Siding: Lumber or panel products intended for use as the exterior wall covering on a house or other building.

Soffit: The underside of a part or member of a structure, such as a beam, stairway, or arch.

Stucco: A Portland cement-aggregate plaster mix designed for use on exterior surfaces.

Tempered glass: Glass that is pre-stressed by heating and then rapidly cooled. It is a process that makes it two to four times stronger than ordinary glass.

Type X gypsum board: Special fire-resistant 5/8-inch thick gypsum board compliant with ASTM C 1177. Gypsum board that is 1/4-inch or 1/2-inch thick are not Type X. (pp. 12, 22, 23, 56)

Underlayment: One or more layers of felt, sheathing paper, nonbituminous saturated felt or other approved material over which a steep-slope roof covering is applied. (pp. 4, 7, 9, 12)

Vinyl cladding: A shaped material, made principally from rigid polyvinyl chloride (PVC) that is used as an exterior wall covering.

Wall cladding: A covering or sheathing usually applied to provide desirable surface properties, such as durability, weathering, corrosion, or impact resistance.

Wildfire: An uncontrolled fire spreading through vegetative fuels, exposing and possibly consuming structures.

Wildland/urban interface area: That geographical area where structures and other human development meets or intermingles with wildland or vegetative fuels.

APPENDIX D

Defensible Space

The Defensible Space Concept

Defensible space refers to the fuel characteristics around a facility and how those characteristics can potentially affect fire behavior. The term is applied generally within the context of wildland fires and to facilities in the wildland/urban interface. The objective of defensible space is to modify fuel characteristics around a facility to reduce the potential for extreme fire behavior, with the goal of providing firefighters an area in which they may operate safely to save the structure from being consumed by an approaching fire.

Defensible space by itself may not save a facility from burning. However, when combined with appropriate structural mitigation, defensible space may decrease the risk to the facility. Without defensible space, firefighters may not even attempt to save a facility from being consumed by an approaching wildfire because the safety risk is too great. Defensible space is one of the components that firefighters assess when deciding whether to attempt to save a facility.

Benefits of Defensible Space

Benefits of creating defensible space around a facility include:

- Reduces hazards for firefighters.
- Firefighters may attempt to save the facility from an approaching fire.
- Greater likelihood that firefighters will succeed in saving the facility from being consumed by fire.
- Greater possibility that the facility will survive an approaching fire without sustaining major damage if fire suppression resources are not available.
- Reduces the burden on fire-suppression resources during an emergency.
- Improves the likelihood that the facility will survive the fire when used in conjunction with appropriate structural mitigation measures.

Code Requirements

Defensible space requirements vary by location and depend on the training of local authorities with jurisdiction. All firefighting agencies are not equipped and trained the same way. A local State lands agency office, local fire department, or county tax assessor's office should be able to provide information about defensible space requirements.

Although there are no national codified requirements for defensible space, there are some general standards. The National Fire Protection Association published the following standards for defensible space (NFPA, 2002):

- Establish a fuel modification area extending 30 feet in all directions from the facility.
- Ground fuels within the defined defensible space shall be treated or removed.
- Live vegetation within the defensible space shall have dead material removed and shall be thinned and pruned.
- Dead and/or downed fuels within the defensible space of facilities shall be removed or treated to maintain the fuel modification area.
- Vegetation under trees within the fuel modification area shall be maintained at a height that will preclude ground fire from spreading into the tree canopy.
- Maintain the defensible space as needed.
- Propane tanks and other combustible liquids storage shall conform to NFPA 30, Flammable and Combustible Liquids Code, NFPA 58, Liquefied Petroleum Gas Code, and the local or State Wildland Fire Risk and Hazard Mitigation Plan.

Specific Practices

In *Protecting and Landscaping Homes in the Wildland/Urban Interface* (Barkley et al., 2005), the authors suggest creating a defensible space by taking the actions listed below in three concentric zones radiating outward from a structure. The measures are focused on structures but can be applied to any facility.

- **Zone 1:** The structure itself. Decrease the ignition potential of the structure by choosing nonflammable roofing materials and siding, enclose decks, soffits and overhangs, and removing debris from roofs and gutters. Cover house vents with wire mesh. See Section I (Buildings) of the Handbook.
- **Zone 2:** The landscape within 100 feet of the structure. Surround the structure by a greenbelt of well watered and maintained plants. Plant perennials, ground cover, and annuals in groups with individual trees and shrubs. Surround these islands of vegetation with rock or brick retaining walls and well-watered turf. Remove overgrowth and dry debris on the ground every three to five years and prune trees. Store firewood on a gravel pad surrounded by well-watered turf.
- **Zone 3:** Beyond 100 feet. Thin native plants. If possible remove highly flammable vegetation and replace with less fire-prone species.

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Glossary

The following definitions apply to this appendix.

Defensible space. An area that is either natural or man-made, where material capable of allowing a fire to spread unchecked has been treated, cleared or modified to slow the rate and intensity of an advancing wildfire and to create an area for fire-suppression operations to occur.

Fire behavior. The physical characteristics of a fire, including flame length (feet); rate of spread (feet per second); and intensity (energy release/ linear feet of flaming front).

Fuel characteristics. The physical characteristics of fuels as they relate to fire including arrangement (vertical/ horizontal continuity), type (e.g., forest; grass; chaparral), loading (pounds per acre), moisture content (weight/dry weight), and toxicity.

Fuel modification. Changing fuel characteristics to reduce combustible fuels, either by replacing highly combustible vegetation with fire-resistant vegetation, or by pruning existing vegetation to create vertical and horizontal separation.

Ground fuels. All combustible materials such as grass, duff, surface litter, tree or shrub roots, rotting wood, leaves, peat, or sawdust that typically support combustion.

Wildland fire. An unplanned and uncontrolled fire spreading through vegetative fuels, at times involving structures.

Wildland/urban interface. An area where improved property and wildland fuels meet at a well-defined boundary.

APPENDIX E

Acronyms

ASTM	Refers to ASTM International; originally known as the American Society for Testing and Materials
CFR	Code of Federal Regulations
FEMA	Federal Emergency Management Agency
FRT	fire-retardant-treated
HMGP	Hazard Mitigation Grant Program
IGU	insulated glazed unit
IWUIC	International Wildland Urban Interface Code
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act
PA	Public Assistance
PCB	polychlorinated biphenyl
PDM	Pre-Disaster Mitigation Program
PVC	polyvinyl chloride
UPS	Uninterruptible Power Supply

APPENDIX F

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APPENDIX G

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