BIOENGINEERED WILDFIRE MITIGATION

Audience: The intended audience for this Job Aid is state, tribal, and local governments; emergency managers; and first responders. This audience does not have an in-depth technical background or experience with bioengineering techniques pertaining to wildfire mitigation. The audience may consider incorporating bioengineered wildfire mitigation techniques into their hazard mitigation planning or implementing these techniques with the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Assistance (HMA) planning and project grants.

Further, the audience may consider using HMA funded planning-related activities to advance certain elements of the hazard mitigation plan, integrate information with other planning efforts, build capabilities, or evaluate adoption and/or implementation of codes and ordinances. As appropriate, HMA funded activities should be coordinated with activities funded under other FEMA programs, such as Public Assistance (PA) and other federal grant programs to make effective use of federal funds.

DEFINITION

Bioengineered wildfire mitigation uses aspects of the natural environment to mitigate the risk of wildfire to the community, including residential and commercial property, utilities, and infrastructure.

While various wildfire mitigation methods exist, this Job Aid addresses methods applicable to the relevant HMA programs (i.e., Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM)).

BENEFITS*

TECHNICAL BENEFITS:

1. Enhances the resistance of structures and their immediate surroundings (i.e., the ignition zone) to ember threats
2. Reduces debris and other objects that might ignite around a structure
3. Uses natural barriers to mitigate ignition risk
4. Increases likelihood of infrastructure resilience following a fire event
5. Increases accessibility for emergency personnel and first responders to address ignition situations

ECONOMIC BENEFITS:

1. Reduces landscape treatment and maintenance costs because native plants require less water and upkeep
2. Decreases wildfire threat to infrastructure
3. Potentially decreases insurance costs

ECOLOGICAL BENEFITS:

1. Promotes the use of native plants and non-invasive exotic, ignition-resistant plants
2. Decreases the spread of invasive species
3. Promotes plant health and diversity of natural and cultivated landscapes
4. Conserves soils and prevents soil erosion and landslides
5. Maintains and restores wildlife habitat
6. Improves air quality
7. Decreases impacts from other natural phenomena (floods, wind-downed debris)
8. Allows habitats and wildlife to recover from damage

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* Benefits are discussed in general terms, not in the context of BCA

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SOCIAL AND CULTURAL BENEFITS:

1. Promotes resilience and fosters adaptation in a changing climate
2. Builds and promotes a community knowledgeable about the Firewise USA® program of the National Fire Protection Association (NFPA) ("Firewise USA®")
3. Enhances community safety and neighborhood collaboration

KEY CONCEPTS AND TERMINOLOGY

TERMINOLOGY

Firescaping refers to landscape design with the intent to mitigate against, and hinder the progression of, wildfires in a structure's ignition zone (Figure 1).[1]

Firewise USA® is a program that serves residential communities in an effort to reduce wildfire risks from embers and small flames that can lead to home ignition. Firewise USA® advocates for homeowners and communities to prepare their structures and mitigate against the threat of embers through a variety of mitigation techniques in an identified "ignition zone".[2]

Silviculture is the growing and cultivation of trees.

Figure 1. Example of firescaping using succulents. (Photo by Debra Lee Baldwin; used with permission.)

CONCEPTS

The Wildland-Urban Interface (WUI) was a term coined in the 1960s to describe an area where the built environment is at risk for ignition from wildland fire. Structures are often ignited solely by embers that can travel great distances from a wildfire. While geographic location (the WUI) can be the primary indicator of ignition risk, a more precise way of assessing all-encompassing wildfire risk is the vulnerability of individual structures, their immediate surroundings, and valuable community resources to ignition.

Built environments vulnerable to wildfire and other fire hazards include:

- Vacation properties
- Residential subdivisions
- Commercial developments
- Municipal buildings
- Agricultural facilities and other rural land uses
- Utilities
- Bridges
- Power line and communication corridors
- Roadways
- Other public infrastructure
- Industrial uses

Ignitable structures continue to be developed in areas vulnerable to wildfire flames and embers.

Natural grasses, brush, and surface fuels increase the risk of natural wildland fires in susceptible areas. The built environment is often exposed to ignitions, making effective pre-event mitigation and preparedness necessary to reduce damage and loss to communities and natural resources from wildfires.

Fuel is any biomass that may contribute to a wildfire.[3] Fuels differ in their biomass makeup, moisture content, and how they affect wildfire behavior, fire intensity, and burn severity.[4]

- <u>Biomass</u> is composed of living and dead vegetation at a site.

- Surface Fuels are vegetative materials on or near the ground such as leaves, needles, logs, branches, brush, and grasses.[5] Surface fuels can ignite both ground fuels and large woody biomass such as trees, and can transition into crown fires.[6]
- Ground Fuels lie below surface fuels and include biomass such as organic soils, roots, decomposing litter, buried logs, and stumps, as well as duff (decaying vegetation covering the ground under trees).[7]
- Canopy Fuel comes from the crowns of trees. The quantity of canopy fuel is estimated by analyzing the tree canopy structure, which includes the canopy's bulk density, height, fuel weight, and base weight. These factors, along with the distance and separation between canopies, impact the spread and intensity of a wildfire should it have access to ladder fuels and reach the tops of the trees.[8]
- Ladder Fuels are live or dead vegetation, including tall grasses, shrubs, and tree branches, that serve to connect surface fuels to canopy fuels, allowing fire to spread from near the ground surface to the tree canopy.[9]

Fire Types include three general forms of wildfire spread.

- Ground Fire burns organic matter in the soil beneath leaf litter on the surface.
- Surface Fire burns fuel on the surface level of the ground, including leaf litter, fallen branches, duff, brush, grasses, shrubs, and a variety of other potential fuels.
- Crown Fire burns the top layer of foliage in the canopy of trees. Sometimes referred to as a canopy fire, these wildfires are the most intense, hottest, and are difficult to control and contain.

Wildfire Behavior begins with the ignition triangle, the three elements crucial for a fire to start: oxygen, which starts and sustains combustion; heat, which raises fuel to its ignition point; and fuel, which sustains and carries flames.[10]

Weather, topography, and fuel all impact where a wildfire can occur and how it behaves, burns, and spreads.

- Weather impacts wildfire movement and ember ignitions. Wind speed and direction, temperature, moisture, air pressure, and numerous other weather conditions feed into the behavior of a wildfire and distribute embers that can initiate more ignitions.
- Topography also has a role to play, as the terrain of an area, including slope and elevation, impacts how quickly a fire moves. For example, south and west facing slopes in the northern hemisphere have greater sun exposure, which can result in drier fuels.[11]
- The Fuel that is available to be consumed by the wildfire is another vital element that helps to explain the behavior of a fire. Fuels can enhance or hinder fire's spread and intensity depending on their moisture content, flammability, and ability to serve as a ladder.

Fuels are the one component that community members, property owners, and homeowners can control to some degree by implementing the mitigation measures described in this job aid.

The Ignition Zone

The Firewise USA® program's Home Ignition Zone (HIZ) concept is based on the Ignition Zone. First developed by retired U.S. Department of Agriculture (USDA) Forest Service fire scientist Jack Cohen in the late 1990s, this concept has become a general best practice for mitigating structural wildfire ignitions and providing guidance for reducing the vulnerability of the built environment in areas exposed to wildfire flames and embers.[12] This Job Aid uses Firewise USA's® ignition zone distance recommendations.

The ignition zone is broken into three zones that radiate out from any structure, as shown in Figure 2 below. Although the ignition zone in neighborhoods and communities might overlap, the ignition zone principle can be applied at the neighborhood and/or community level. In these cases, coordination on the creation of defensible space between adjacent property owners is highly encouraged.

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Figure 2. The Ignition Zone radiates up to 200 feet from a structure and includes an Immediate Zone (Zone 1), Intermediate Zone (Zone 2), and Extended Zone (Zone 3).

Zone 1 – *Immediate Zone*, which is the zone closest to the structure, includes the structure itself and extends five feet from the furthest attached exterior point. This includes the landscaped area immediately surrounding the structure. The immediate zone also includes anything that is attached to the structure, such as garages, carports, decks, and patios. This is the area has been identified by NFPA as critical to protect and it's also the most susceptible to embers.[13]

Zone 2 – *Intermediate Zone* is five to 30 feet from the furthest exterior point of the structure. This zone should employ a mix of fire-safe structural elements and ignition-resistant plants to create fire breaks, reduce fuel, and prevent flames from reaching the structure.[14]

Zone 3 – *Extended Zone* is 30 to 100 feet and up to 200 feet from the structure. Firewise USA® asserts that the goal is not to prevent wildfire, but to interrupt the fire's path and keep flames low and on the ground, which will prevent ignition of both ladder and canopy fuels.[15] In the extended zone, which often expands into wildlands (i.e., undeveloped areas), appropriate mitigation techniques are vital, including tree thinning and debris cleanup.

COMMONLY USED MITIGATION MEASURES

Using common measures, mitigation is critical to addressing numerous threats to infrastructure and property (both private and public), communities (their economic vitality, health, and safety), and reducing the loss of human lives during wildfire events. Wildfires do not discriminate; they affect residential and commercial properties, public and municipal buildings, community infrastructure, and utilities with equal measure. Intense wildfires not only harm the built environment, but can have a detrimental impact on industry and economic vitality. The impact of wildfires on silviculture, rangeland, agriculture, and farming can be widespread and devastating to livelihoods. Wildfires can also make soils more impermeable, which can result in increased potential for flooding in some watersheds.

Three commonly used mitigation measures to reduce wildfire risk to the built environment are:

1. **Wildfire Hazard Reduction in the Ignition Zone:** The use of ignition-resistant building components and materials in the construction of the structure itself, debris reduction on and around the structure, and surface fuel management within the ignition zone.

2. **Firescape and Landscape Mitigation Techniques in the Ignition Zone:** The use of various biological and design elements that reduce wildfire risk or intensity.

3. **Post-Wildfire Recovery and Mitigation Techniques:** A focus on landscape stabilization, forest regeneration, and invasive species prevention to mitigate against flood, erosion, and landslides.

These measures align with HMA eligible wildfire activities: Defensible Space, Structural Protection through Ignition-Resistant Construction, and Hazardous Fuels Reduction.

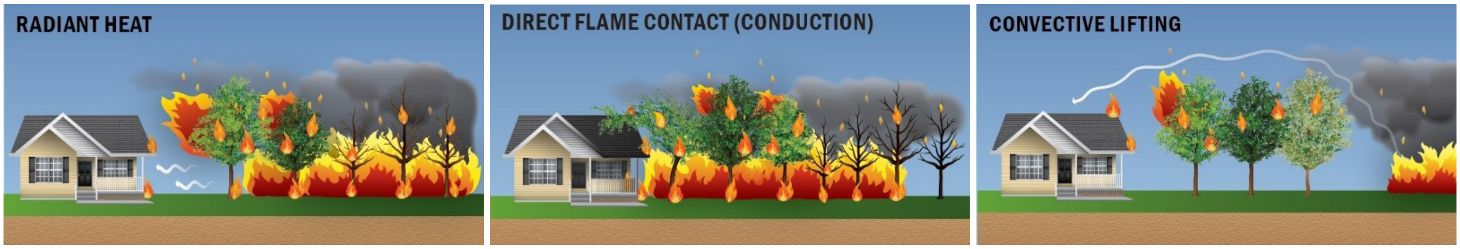

Figure 3. Heat transfer methods, such as radiant heat, direct flame contact (conduction), and convective lifting, can ignite structures in the WUI.

REDUCING WILDFIRE HAZARDS IN THE IGNITION ZONE

The ignition zone can extend up to 200 feet around the built environment and includes the structure(s) of concern. The goal in the ignition zone is to reduce ignition vulnerabilities and increase the probability that the built environment will survive a wildfire event without emergency response. Support structures ignite through several methods of heat transfer, including radiant heating, direct flame contact, and convective lifting that results in embers landing on flammable surfaces (see Figure 3).[16]

Building Design Techniques and Standards

Ignition-resistant construction is an important part of the overall approach to wildfire hazard mitigation. Community planners, developers, and building code officials play important roles in mitigation success in the ignition zone and should help educate others in the community about the benefits of incorporating wildfire mitigation techniques into infrastructure design and construction. Community planning and development must be considered from the perspective of, and in conjunction with, the threat of wildfire risk. Hazard mitigation plans should be used to inform the development, adoption, and enforcement of wildfire-specific zoning and building codes to promote effective mitigation activities. Development in lower-risk topographies promotes safer communities, which can further be paired with stringent wildfire-focused building codes that require materials such as Class A roofing and ignition-resistant siding. Mitigation plans can also be used to track the implementation of wildfire bioengineering mitigation actions.

Additionally, building materials and design techniques can be used to decrease vulnerability to wildfires. For more information regarding building materials, building codes to meet ignition-resistant standards, and structure ignitability, please visit the following sites:

National Fire Protection Association/Firewise USA, Research Fact Sheet Series, available at https://www.nfpa.org/Public-Education/By-topic/Wildfire/Firewise-USA/Firewise-USA-Resources/Research-Fact-Sheet-Series

Home Survival in Wildfire-Prone Areas: Building Materials and Design Considerations (University of California, Agriculture and Natural Resources), available at https://anrcatalog.ucanr.edu/pdf/8393.pdf

Hazardous Fuels Reduction

In addition to using building design techniques and standards, fuel management and debris reduction techniques can also effectively slow a wildfire's progression. These techniques can be used for both the ignition zone and the wildlands that surround the built environment.

Fuel management in the ignition zone and wildlands begins with site-specific analysis, including an inventory of vulnerable land uses close to vulnerable structures. Once these susceptible areas are identified, fuel management techniques can be used to reduce potential ignitability:

- Dense areas of trees and other growth in wilderness and forest areas that border the built environment can be selectively thinned to reduce and prevent crown fires, which can quickly spread to properties, communities, and infrastructure.

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- Managing and maintaining ladder fuels and clearing the forest understory reduces the threat of surface fires evolving into crown fires.
- Removing dead and dying trees can also reduce the risk of high intensity wildfires. For example, in October 2010 the Church's Park Fire in Colorado burned over 85 percent of the overstory where lodgepole pines had been killed by a bark beetle infestation. A similar recent infestation has prompted the Forest Service to selectively remove dead and dying lodgepole pines.[17]

Vegetation and vegetative debris that are removed during the fuel management process should be properly disposed. Each jurisdiction has a different method for disposing of vegetative debris. To find out information on your jurisdiction's method, check with your local natural resources or solid waste department for information regarding their policies and procedures.

Ignition zone fuel management begins with individual structures, radiates outward, and is crucial to reducing ignition vulnerability. Risk reduction measures can and should be used in conjunction with each other to the extent possible and practicable.

- Zone 1, in order to reduce vulnerability structural components, must be ignition resistant and debris must be managed to prevent embers from causing ignitions. Fuels (plants, mulches, walkways, furniture, etc.) adjacent to the structure (0-5 feet) must be resistant to ignition from falling embers.
- Zone 2 (5-30 feet) fuels must be selected, located, and maintained to ensure that, if ignited, their flames will not contact or provide a continuous fuel path to structures or flammable attachments.
- Zone 3 (30-200 feet) fuels must be placed and maintained to prevent large flames from approaching structures.

Vegetative fuel management in all ignition zones is critical to reducing structure ignitions.

- Grasses should be cut and kept short. Dead vegetation accumulations should be completely removed from the property (grass clippings/leaf piles).
- Fallen and dead branches, brush, and timber should be collected and removed from the ignition zone.
- Combustible materials, such as wood piles, should not be kept near the home or structure.

Particular attention should be paid to the areas on or around the home where fuel may accumulate. This includes under deck structures and in gutters where embers might ignite the fuel and quickly move to the structure. Local governments, homeowners' associations, and others can serve to enforce both home ignition zone management, maintenance, and debris removal in and near wildfire-prone communities.

In addition to reducing the ignition potential of individual properties, communities also need to consider a holistic approach. Mitigation done to multiple, contiguous properties will be more effective at reducing risk than mitigating individual properties using a "checkerboard" type of approach in which mitigated and non-mitigated properties are intermingled.

FIRESCAPING AND LANDSCAPE MITIGATION TECHNIQUES IN THE IGNITION ZONE

Firescaping uses the natural environment to reduce the vulnerability of the built environment to wildfire. Landscaping for wildfire mitigation involves a combination of both landscape design and yard/ground maintenance that will prevent the spread of fire in the ignition zone. Through firescaping, the yard, grounds, outbuildings, and property surrounding the built environment can be used as a buffer zone from wildfires and significantly reduce the structures' vulnerability (Figure 4).

Figure 4. Use of ignition-resistant plants can help protect structures from wildfire. (Photo by Debra Lee Baldwin; used with permission.)

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Plants can either contribute to or reduce structure ignition potential. For example:

1. Trees/shrubs near structures may reduce problematic radiant heat from large flames, but their leaf litter on roofs or near structures requires removal and regular maintenance so they don't become fuel for ember-driven fires.

2. Flammable plants in problematic locations, or overgrown plants, can often be made ignition-resistant by trimming the branches from their stems upward from the ground, removing dead branches, and removing combustible litter and mulches near their bases.

Built environments can have abundant and attractive plant designs and landscapes that resist propagating fire. In different regions of the country, different plant species and arrangements can be selected to design ignition-resistant yards, landscapes, and natural environments. To effectively design, retrofit, and mitigate these situations for ignition resistance, local fire experts should be consulted to determine what vegetative fuel arrangements constitute an ignition-resistant landscape.

Plant Selection

The ideal plants for firescaping generally have high moisture content and don't have oils, resins, or waxes. Evergreen shrubs like juniper and other conifers contain oils and resins that burn with greater intensity and have the potential to ignite as ladder fuels.[18] A focus on deciduous trees and shrubs instead of evergreens, and planting herbaceous instead of woody plants, decreases available fuel and reduces plants' potential as ladder fuels that increase risk to structures and surrounding wildlands.[19]

Figure 5. Four-point Evening Primrose

Plant selection should vary depending on the ecoregion in which the built environment is located (see page 12). Plant selection should lean towards native species rather than non-native.

Ignition-resistant plants include succulents like stone crops, hens & chicks, aloe, cactus, and jade; ground covers like verbena, ornamental strawberry, and winter creeper; perennials like evening primrose (Figure 5), yarrow (Figure 6), and chives; and low shrubs like azaleas, California redbud, butterfly bush, and lilac. Avoid plants that shed combustible materials such as needles or branches.

Figure 6. Mission Blue butterfly rests on a Yarrow plant

While plant choice can reduce the spread of wildfire, it is important to note that ignition-resistant does not mean fire-proof. All plants will burn at hot enough temperatures. In addition, not all ideal ignition-resistant plants will be native to the region they are planted in, but non-native, non-invasive exotic plants can serve a vital purpose in the defense of a structure or property.

When designing ignition-resistant landscaping, particular attention should be paid to decorative yard enhancements such as flower beds and mulching. Railroad ties and wood accents should not be used in the ignition zone to create or outline flower beds or gardens. In addition, wood-based mulches should be avoided in Zone 1 and replaced with an inorganic compound or rock.

Landscape Strategies

The selection of appropriate plants for a yard is vital, but so is their physical arrangement. Planting under eaves, vents, trees and decks; and adjacent to siding should be avoided. Appropriate heights and trimming requirements for trees, brush, and shrubs should be maintained, as well as the appropriate spacing and distance between the plant, trees, and shrubs themselves.

Natural fire barriers and breaks can enhance the wildfire buffer around a structure and reduce vulnerability in the ignition zone. Natural rock outcroppings, mineral or bare soils, wetlands, streams, lakes, and fish ponds can all serve as fire breaks. Concrete sidewalks, patios, and driveways can also stop the progression of flames. Ideally, there would be

Pre-Wildfire Mitigation Case Study

Cold Springs Fire, Nederland, Colorado

The residents of the town of Nederland, Colorado, are no strangers to wildfire. Living in an environment that is regularly exposed to wildfire, residents, business owners, and the Town work diligently to mitigate against the ever-present threat. Wildfire Partners, a program funded by Boulder County and a $1.125 million grant from FEMA, helps residential property owners mitigate against wildfire and has worked closely with the residents of Nederland to analyze, assess, and aid in wildfire mitigation on their properties.

In July 2016, two individuals camping in the forest near Nederland failed to extinguish their campfire properly. This oversight started a fire that quickly spread due to the availability of fuel nearby, which included a variety of Lodgepole Pine, Ponderosa Pine, and Douglas Fir. The readily available fuel, paired with wind conditions, escalated the wildfire into a rapidly expanding crown fire. The "Cold Springs Fire" quickly spread towards residential properties near Nederland and ultimately burned over 500 acres and destroyed eight homes.

Homeowner Wildfire Mitigation

Mr. Robert Lanham, an area resident, had been in the Wildfire Partners Program since 2014 and had, for the last decade, undertaken extensive measures to mitigate against potential wildfire threats to his property. Over a period of ten years, Mr. Lanham completely transformed his neglected property into a model for wildfire mitigation. He cleared Lodgepole stands, thinned trees in the ignition zone, replaced the siding of his house and his roof with more fire resistant materials, created open spaces, and encouraged growths of Aspens and other deciduous trees.

Mr. Lanham's dedication paid off in July 2016, when his property survived the Cold Springs Fire with only the loss of a small outbuilding, despite the final analysis showing heavy ember activity in the vicinity of his property. The closest surface fire impingement burned within 55 feet of his garage.

In an interview with Wildfire Partners after the fire, Mr. Lanham said the "multiple lines of defense" he had created in his ignition zone had all been tested. He added that the survival of his home was due to a combination of tree thinning, tree species conversion, aggressive surface fuel reduction, diligence in grass and yard maintenance, and structural mitigation.

This multi-layered defense was vital to the success of Mr. Lanham's wildfire mitigation and underscores the importance of fuel and debris management, firescaping, and structural fireproofing in reducing the risk and vulnerability of the built environment in a wildfire susceptible area.

Case Study Courtesy of Wildfire Partners and Boulder County

numerous areas and objects in the ignition zone to break up the movement and path of a wildfire, minimizing available fuels and providing natural barriers to fire progression.

IMPLEMENTATION OF POST-WILDFIRE RECOVERY AND MITIGATION TECHNIQUES

Following a wildfire, there is increased vulnerability to secondary threats, such as floods and mudslides. Slope-stabilizing erosion control practices and forest regeneration can help to mitigate flood and landslide. The focus of wildfire bioengineering shifts to address landscape stabilization for erosion control, overall soil stabilization, stream valley slope stabilization, and flood control. Post-wildfire mitigation techniques address the need to enable soil infiltration, stabilize slopes, regenerate the forest, and control non-native invasive plant colonization. Slope stabilization and forest regeneration should be prioritized, especially in the recharge areas of streams that often lead to developed areas at risk for flooding and landslide. A variety of methods can mitigate threats to vulnerable topography after a wildfire incident, but proper placement and implementation of the mitigation technique is vital to the success of the project.

Landscape Stabilization

Landscape or soil stabilization following a wildfire event is of utmost importance due to the increased threat of soil erosion following the destruction of the plant material and litter layer on the ground. In an effort to control erosion and provide soil stabilization, numerous techniques can be used (Figure 7). Soil stabilization is eligible under HMA. Short term stabilization methods include:

- Mulching covers the area with a protective straw layer. Straw helps to prevent soil erosion, protects the mineral soils that have been exposed, absorbs humidity, and breaks down swiftly in many landscapes, adding nutrients back into the soil to promote new plant growth (or potentially grass after reseeding). Mulch should be covered with plastic netting or adhered to the soil with a tacking agent to minimize loss of straw to adverse weather.
- Hydraulic mulch forms a barrier or crust and prevents water and wind erosion, is also an option to prevent soil erosion.
- Erosion control mats or blankets, a blanket of fibers, straw, or other plant material that protects the soil from precipitation can be used on hillsides and along valleys.
- Log terraces can stem the flow of water and subsequent soil movement. Dead trees can be placed on the contour, opposite the direction of the slope in an alternating fashion, preventing water from finding a direct path downslope.[20]

Figure 7. Post-wildfire erosion control methods include mulching, erosion control mats, log terraces, fiber rolls, and silt fences. (Sources: Minnesota Pollution Control Agency, Afterwildfirenm.org, Colorado State Extension, and Moscow Forestry Science Laboratory of Washington State University)

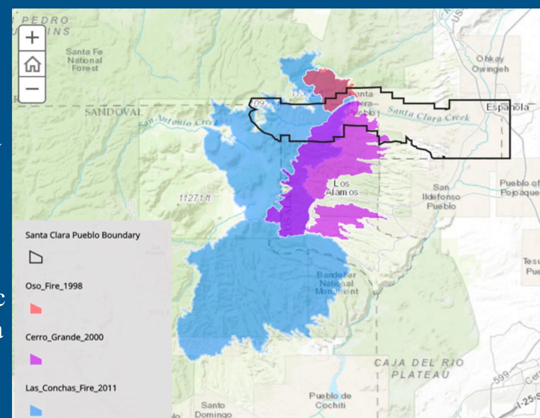
- Fiber rolls can be used as a temporary fix to control sediment and soil surface runoff and erosion. These are particularly useful to protect against sedimentation of water sources near burn sites. Fiber rolls are made from materials such as straw or coconut fiber and are rolled into a tube.
- Hydroseeding involves a slurry of seed and mulch mixed with water and fertilizer to promote growth of native grasses. Grasses help reduce soil erosion because they have an extensive root system to hold soil in place. The seed slurry is held in a tank and applied by spraying it on the ground in a uniform layer. The application process lends itself to covering large areas quickly. Hydroseeding is most effective on short, steep slopes.
- Silt fences can also prevent erosion. Woven wire and fabric filter cloth acts as a fence to trap sediment from runoff.

A Tribe's Collaborative Journey Toward Establishing Forest Resilience Post-Wildfire

Santa Clara Pueblo Forestry

Background

Santa Clara Pueblo (Kha'p'o Owinge) is a federally recognized Native American tribe located on the Rio Grande in Northern New Mexico. The Pueblo encompasses 90 square miles of tribal land and is home to 2,600 residents who rely on these lands for food, medicine, recreation, and spiritual sanctuary. Central to Santa Clara Pueblo is the east-west trending Santa Clara Canyon and Creek. This sacred watershed has provided spiritual sanctuary to Santa Clara peoples for millennia. In addition, the 26-mile wide tribal boundary encompasses 5,000 feet of elevation gradient, from an altitude of 6,000 feet in the Rio Grande Valley in the east, to 11,000 feet in the Jemez Mountains to the west. The elevation variation has resulted in diverse climatic zones that consist of mixed conifer forests, alpine meadows, aspen, ponderosa pine, scrub oak, pinon-juniper woodlands, high desert grasslands, and cottonwood bosque.

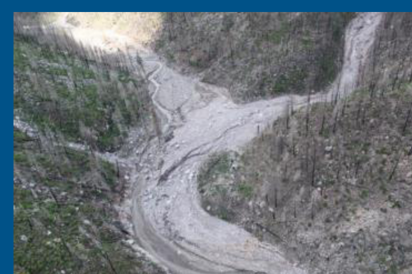


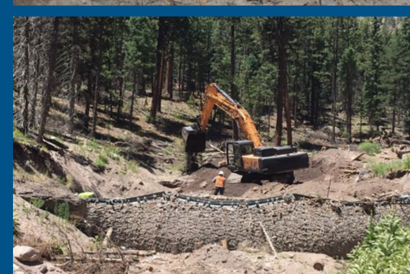
The magnitude of the Oso, Cerro Grande, and Las Conchas fires resulted in five Presidential Disaster Declarations for the Santa Clara Pueblo

Since 1998, three severe wildfires have originated outside tribal boundaries, yet burned over 80% of Santa Clara forested lands. Following the fires, Santa Clara Creek and Canyon were further devastated by seasonal rains which resulted in debris flow, resulting in combined damages of roughly $250 million.

Erosion Control and Flood Mitigation Post-Fire

These severe fires resulted in the removal of vegetation and organic matter withholding forest soils. In addition, New Mexico is prone to an annual monsoon season that results in high-intensity precipitation from July through early September. These factors, combined with geologic substrate comprised of poorly consolidated volcanic sediment, created conditions prime for catastrophic erosion in fire impacted watersheds. Post-fire debris flows inundated nearly all tributaries and the main stem of Santa Clara Creek. These flood events breached four dams and severely damaged roadways, recreation sites, and natural areas.





Post-fire resilience strategies have focused on a combination of bioengineering with natural materials, erosion control, and bank stabilization. Erosion control structures were constructed in tributaries to reduce sediment transport. The structures were cost-effective, built by hand and used on-site materials. Over 5,300 structures have been built in 26 tributaries since 2014 and include a diverse mix mitigation techniques such as zuni bowls, log mats, contour felling, jack strawing, mastication/mulching, riprap with vegetation, log drops, picket baffles, and wicker weirs.

In addition the Pueblo has undertaken a variety of hazardous fuel reductions (selective thinning and pile burns of debris) combined with reforestation. Santa Clara Forestry has set an annual goal to plant 200,000 commercially viable seedlings from locally sourced seed. As restoration efforts expand into riparian areas, planning efforts will include willow/shrub planting and herbaceous grass propagation techniques.

Case Study courtesy of Santa Clara Pueblo

The Path Forward

These efforts will serve to mitigate both the direct threat of future wildfires, and the secondary impacts such as flooding, erosion, and streambank destruction that result from high intensity fires. For more information please visit: https://www.arcgis.com/apps/Cascade/index.html?appid=23463ab7bf624b478e5553e27299d7e5

Reforestation is a long-term stabilization method that involves replanting trees and selecting seedlings to restore forest health and reduce erosion. Typically native species are selected for planting, although forests can also be re-established through natural seeding. In addition to improving soil health and reducing erosion, reforestation can improve air and water quality, enhance wildlife habitat, and increase biodiversity. The effectiveness of reforestation depends in part on the rate of forest establishment and appropriate maintenance accomplished during establishment to control invasive species.

In terms of flooding, diversion channels or deflection walls can be used to slow and redirect the flow and movement of water across a slope rather than directly downward to a stream or wetland. Water bars (berms of soil/bedded logs) and culverts can also be used to channel water off of burn regions.[21] Reducing the risk of flood and erosion after a fire through the implementation of soil stabilization, flood diversion, and reforestation efforts is important to protecting nearby communities.

Soil Structure

Wildfires cause widespread changes to the soil makeup and burn some, or all, of the dead plant material that covers the ground and adds nutrients to the soil. Fires have the potential to change the mineral composition in different soil layers and potentially create or enhance a water-repellent layer, slowing or preventing infiltration and increasing surface runoff, resulting soil erosion.[22] Plowing can be used to break up the soil and enable infiltration to counter surface runoff.

Ash deposited during a wildfire will usually mix or absorb water, but can sometimes be repellent.[23] In order to combat the soil's inability to absorb water after a wildfire, techniques such as plowing using a rototiller to break up the charred, compacted surface soil are sometimes used, as are watering and irrigation methods. It is important to control opportunistic pioneer plant species, which are often non-native invasive species, from taking root in the vulnerable soil. Aggressive, invasive exotic plants reduce opportunity for growth of stabilizing and ignition-resistant native plants. Invasive insect species and plant diseases should also be addressed and already-stressed woodland vegetation should be removed to prevent further ignition potential. Large-scale seeding paired with planting perennial plants that will help to foster recovery is recommended in the post wildfire-environment.

Additional Tools and Resources for Post-Wildfire

Please visit the Hazard Mitigation Grant Program Post fire web page at https://www.fema.gov/hazard-mitigation-grant-program-post-fire. Valuable resources are located here, including additional detail regarding the Post-wildfire pre-calculated benefits. Pre-calculated benefits of $5,250 per acre are available for the following post-wildfire mitigation project types:

- Soil stabilization
- Flood diversion
- Reforestation projects

Figure 8. EPA's ecological regions of North America

REGIONAL DIFFERENCES: AN OVERVIEW OF WILDFIRE IN LEVEL I EPA ECO-REGIONS

Wildfire bioengineering techniques should be appropriate to regional conditions. The U.S. Environmental Protection Agency (EPA) uses ecoregions to identify areas where ecosystems are generally similar, allowing organizations to structure and implement ecosystem management strategies.[24] The EPA identifies 15 Level I ecoregions in North America (Figure 8). For the purposes of this job aid, and the focus on bioengineering for mitigating wildfire in the United States, ecoregions 5-13 and 15 are highlighted in the table below.

ECOREGION	DESCRIPTION	WILDFIRE SUSCEPTIBILITY	FIRE SAFE PLANT CHOICES
FIVE Northern Forests	The Northern Forest region offers extensive boreal forest and a high density of lakes that encompasses the northern portion of Minnesota, Wisconsin, and Michigan. Despite the large urban areas that this land is home to, much of it remains relative wilderness, which can be problematic in terms of wildfire mitigation and the large swaths of forests adjacent to rural, urban, and recreational developments. [25]	MEDIUM	Northern Forest Plants[26] • Nannyberry • Moss phlox • Columbine • Wild geranium • Ninebark • Bearberry • Wintergreen
SIX Northwestern Forested Mountains	The Northwestern Forested Mountains extend from Alaska through Northern California and into Nevada. This region contains some of the highest mountains in North America and boasts ecosystems that range from alpine tundra to dense conifer forests, to dry sagebrush and grasslands. The climate is variable with arid and mild climates in the southern lower valleys, humid and cold climates at higher elevations, and cold and sub-arid climates in the northern reaches of the region. Much like the breadth of climates in the Northern Forested Mountains, the region boasts a diverse offering of vegetative cover in both alpine and sub-alpine environments, ranging from shrubs and lichen, to lodgepole pine, firs, and Englemann spruce.[27]	HIGH	Northwestern Forested Mountains Plants[28, 29] • Sulfur Buckwheat • Desert 4 o'clock • Squaw carpet • Basket-of-gold • Blue flax • Lupine • Lamb's ear
SEVEN Marine West Coast Forests	The Marine West Coast Forests region spans from the mainland and offshore islands in the Pacific Coast to Alaska and down south into Northern California. This region is home to some of the wettest climates in North America. The topography is mountainous and bordered by coastal plains. The region's proximity to the Pacific Ocean deeply impacts the climate and is responsible for a high level of precipitation and fairly moderate temperatures. The altitude variation results in widely diverse ecological zones in this region. It includes temperate coastal forests playing host to cedar, hemlock, Douglas fir, spruce, and redwood.[30]	LOW	No Data is available for this region due to the wet climate and minimal wildfire risk
EIGHT Eastern Temperate Forests	The Eastern Temperate Forests span from the Great Lakes to the Gulf of Mexico, and from the Atlantic Coast into Oklahoma, Missouri, Iowa, Minnesota, and sections Eastern Texas. The climate ranges from moderate to mildly humid with a broad variety of forest cover, and a high density of human inhabitants. The forest canopy in this region consists of mostly broadleaf, deciduous trees and needle-leaf conifers. Tree species include ashes, elms, black cherry, yellow popular, dogwood, along with oak, hickory, beech and maple.[31]	MEDIUM to HIGH	Eastern Temperate Forest Plants[32, 33] • American Beautyberry • Elderberry • Pyracantha • Witch Hazel • St. John's Wort
NINE Great Plains	The Great Plains covers the central part of the continent and has the widest latitudinal range of any North American ecoregion. The region covers roughly 3.5 million square kilometers and extends from Canada down to southern Texas and into Mexico. This area boasts grasslands, very few forests, and a sub-humid to semiarid climate. The region was once covered with natural grasslands, but due to numerous factors including development, extractive industries, and agriculture, much of the native prairie has been drastically altered. Now the area is home to wheat, corn, and soy beans. The remaining native vegetation includes grama grass, wheatgrass, and bluestem prairie as well as shrub/grassland and grassland/forest combinations. Today there are very few remaining native deciduous trees, except in the eastern portion of the region or in protected locations.[34]	MEDIUM	Great Plains Plants[35] • Yarrow • Monkshood • Bugleweed • Pussytoes • Nodding Onion • Hosta

ECOREGION	DESCRIPTION	WILDFIRE SUSCEPTIBILITY	FIRE SAFE PLANT CHOICES
TEN North American Deserts	This region spans from Eastern British Columbia down through Baja, California and into North Central Mexico. The North American Desert is composed of shrub and cactus vegetation, with a distinct lack of trees. Grasses and shrubs in this region include sagebrush, shadscale, greasewood, creosote, and tarbush.[36] The desert is not immune to wildfires, particularly in Nevada and Southern California.	MEDIUM	North American Desert Plants[37] • California Fuchsia • Thyme • Barberry • Butterfly bush • Witch hazel
ELEVEN Mediterranean California	Though a smaller ecological region than some of its counterparts, this area of the United States borders the Pacific Ocean on the west and the Sierra Nevada to the east. With a warm and mild Mediterranean climate, vegetation includes shrubland and chaparral mixed in with areas of grassland and open oak woodlands. Common shrubs include chamise, buckbrush, and manzanita.[38]	HIGH	Mediterranean California Plants[39] • French Lavender • Red Monkey Flower • Sage • California Lilac • Society Garlic
TWELVE Southern Semi-Arid Highlands	The Southern Semi-Arid Highlands region encompasses the southernmost parts of Arizona and New Mexico and is bordered by the Temperate Sierras on the west and the North American Deserts on the east. The landscape is composed mostly of hills, bottom valleys, and plains. Much of the region's vegetation is grassland, with various scrublands and forests growing in the transition zones. Dominant grasses include blue-stemmed, threeawn, galleta, muhly grass, along with blue grama. Jalisco, aguascalientes as well as mesquite, oak, and western juniper also make appearances in the region.[40]	HIGH	Southern Semi-Arid Highland Plants[41, 42] • Gambel Oak • Red Osier Dogwood • Wood's Wild Rose • Saltbush • Banana Yucca • Mescal
THIRTEEN Temperate Sierras	The Temperate Sierras comprise the major Mexican mountains, as well as parts of central Arizona and portions of New Mexico. Vegetation is both evergreen and deciduous with a mix of both conifers and oaks.[43]	MEDIUM	Temperate Sierra Plants[44] • Silver Lupine • Bearded iris • Thyme • Monkshood • Native Beebalm • Geyer Onion
FIFTEEN Tropical Humid Forests	The Tropical Humid Forests region includes the southern tip of the Florida Peninsula. This region consists largely of tropical rain forests. Evergreen and semi-deciduous forests are present here, along with a great abundance of air plants. Plants include members of the pea, mulberry, avocado, sapote, and madder families.[45]	HIGH	Tropical Humid Forest Plants[46] • Agave • Aloe • Anise • Coontie • Hydrangea • Pindo Palm • Pygmy Date Palm

PROJECT PLANNING AND EXECUTION – STEPS FOR SUCCESS

Proper bioengineered wildfire mitigation project planning and execution is essential to a successful project. Steps recommended for local, state, and tribal governments, as well as, non-profits are outlined below.

Task 1 - Project Identification: The first step toward project success is clearly and correctly defining the problem or issue to be addressed. For example, the extent of the area threatened or impacted by wildfire and which wildfire mitigation strategies will be implemented. Prioritizing objectives and stakeholder needs will help to define the project.

Reviewing and incorporating information from state, local, and/or tribal mitigation plans can help facilitate development of hazard mitigation project alternatives that align with community priorities.

Task 2 – Project Development: Project development involves collecting data and scoping the project. The information gathered during this task serves as the basis for development of a more technical design, cost estimate, and regulatory compliance project components. For defined spaces and fuels, the project team should conduct a site assessment to evaluate treatment options.

FEMA encourages coordination with Environmental Planning and Historic Preservation (EHP), PA, or HMA staff to determine what data is needed to evaluate the project. EHP coordination during project development can help streamline the EHP review requirements and reduce review time. The project team should collect and review available relevant data such as described in the table below. (Not all data in the table may be available for a given geographic location.)

SUGGESTED DATA	POTENTIAL RESOURCES
Current climatic and vegetation conditions	NCDC Climate Data https://www.ncdc.noaa.gov/cdo-web/ U.S. Climate Resilience Toolkit https://toolkit.climate.gov/ Vegetation Condition Index https://land.copernicus.eu/global/products/vci
Predominant vegetation types	USGS Land Cover Institute https://landcover.usgs.gov/ USDA Economic Research Service https://www.ers.usda.gov/about-ers/partnerships/strengthening-statistics-through-the-icars/land-use-and-land-cover-estimates-for-the-united-states/
Habitat characteristics (current and desired)	Data.gov Data Catalog has many links: https://catalog.data.gov/dataset?vocab_category_all=Biodiversity
Soil types	NRCS Web Soil Survey https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
Topography	USGS Topographic maps https://www.usgs.gov/products/maps/topo-maps
Presence of blight and/or invasive species	USDA Forest Service https://www.fs.fed.us/foresthealth/protecting-forest/forest-health-monitoring/index.shtml State forest, conservation, and natural resources services departments
Community development plans	Local economic development plans, capital investment plans, land use plans
Infrastructure locations (e.g., roads, water lines, hydrants)	Local government GIS departments
Existing building locations and types near wildland fuels	Local building departments, local tax assessor offices
Locations of fire stations	Local government GIS departments, local fire departments
Capability of local first responders	Local hazard mitigation plans, fire and police department long-range plans
Endangered or threatened species	Habitat Conservation Plans, USFWS Field Offices, State Wildlife Offices, USFWS Information for Planning and Consultation https://ecos.fws.gov/ipac/
Wildfire studies and preparedness	Community Wildfire Development Plans, emergency management plans, fire departments, forestry departments, wildfire risk assessment portals online

This data will help inform mitigation activities that can be evaluated and developed.

Like other mitigation projects, wildfire bioengineering projects must meet cost-effectiveness requirements to qualify for FEMA grant funding. Cost-effectiveness is evaluated by FEMA using benefit-cost analysis; cost-effective projects have a benefit-cost ratio greater than 1.0 (https://www.fema.gov/benefit-cost-analysis). FEMA has developed some additional benefit-cost tools (https://www.fema.gov/media-library/assets/documents/110202) to calculate benefits for climate resilient activities, including soil stabilization and reforestation projects in wildfire-impacted areas to support rapid implementation of post-wildfire mitigation activities. FEMA has pre-calculated benefits for benefit-cost analyses, which can expedite grant applications. Additional information about FEMA's post-fire grant program can be found on their post-fire web page (https://www.fema.gov/hazard-mitigation-grant-program-post-fire).

To meet the objectives of Tasks 1 and 2, the appropriate combination of wildfire bioengineering techniques must be incorporated into development of conceptual designs, detailed designs, and implementation plans. It is important to address and comply with all federal, state, and local regulations to obtain necessary permits subsequent to the completion of conceptual design. Depending on the location, impacts, measures selected, and materials employed, various permits, environmental reviews, or certifications may be required before construction/implementation. Starting discussions with permitting agencies early in the project development process – even in the conceptual stages – and keeping documentation will be required by FEMA for award and will likely save time and effort at the project implementation and closeout phases.

BIOENGINEERED WILDFIRE MITIGATION

Task 3 – Project Implementation: Once the appropriate site assessments have been conducted, detailed design has been finalized based on prescribed treatments, permits have been obtained, and FEMA has awarded the project, project implementation can begin in earnest. This includes site preparation, construction, planting, monitoring, and maintenance. For wildfire bioengineering design to be successful, implementation must be closely supervised by someone familiar with the implementation of these types of bioengineering projects. Continuity of an interdisciplinary team involved during the design is highly recommended, and consulting with others who have implemented other wildfire bioengineering projects is encouraged to help ensure the project's success. Scheduling considerations should include appropriate planting seasons and endangered species' nesting seasons.

Task 4 – Project Closeout: Upon project completion, the project owner must document that the project was completed in accordance with the scope of work and that all regulatory compliance grant conditions were implemented to ensure long-term effectiveness. As with any constructed or landscaped project, wildfire bioengineering plans should include maintenance and monitoring to help ensure a successful outcome.

Maintenance activities may be needed more frequently during the first few years for landscaped projects while plants are establishing. The overall need for maintenance and monitoring will depend on the activity, site conditions, climate, and probability of wildfire occurrence. Please reference the HMA Guidance for more information regarding the Operations and Maintenance Plan.

RELEVANT REGULATIONS

FEDERAL REGULATIONS

National Environmental Policy Act (NEPA): The President's Council on Environmental Quality (CEQ) oversees implementation of the National Environmental Policy Act (NEPA). NEPA is the basic national charter for protection of the environment including physical, biological, social, and cultural resources. This law establishes policy, sets goals, and provides a process to review data and information to assess environmental impacts of proposed actions and consider reasonable alternatives to those actions. The NEPA regulations apply to all federally funded or authorized projects.

FEMA evaluates whether wildfire mitigation projects meet DHS's Categorical Exclusions (CATEX) under NEPA, in which case no Environmental Assessment (EA) or Environmental Impact Statement (EIS) is required, and therefore can expedite the EHP process. Application of a CATEX under NEPA does not preclude review and compliance under other relevant EHP laws, regulations, and Executive orders.

Working with FEMA Environmental Planning and Historic Preservation (EHP) staff during project development can help inform whether a project might qualify for a CATEX.

National Historic Preservation Act (NHPA): Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires federal agencies to take into account the effects of their undertakings on historic properties and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. The regulations also place major emphasis on consultation with Indian tribes and Native Hawaiian organizations, in keeping with the 1992 amendments to NHPA. Based on this regulation, if a project impacts historic properties, coordination with the State Historic Preservation Officer is necessary.

Endangered Species Act (ESA): The purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. Under Section 7 of the Endangered Species Act, federal agencies such as FEMA must consult with the U.S. Fish and Wildlife Service on any projects that might affect a federally-listed threatened or endangered plant or animal species on the project site prior to undertaking the project. Other permits could be required as well.

Migratory Bird Treaty Act: The Migratory Bird Treaty Act of 1918 (MBTA) protects more than 1,000 native migratory and certain native non-migratory bird species. The act makes it illegal for anyone to take any of these birds (or their nests or eggs) except under the terms of a valid permit. If there is any native vegetation within the project area that would be removed or affected, potential impacts to migratory birds and the appropriateness of using best management practices should be evaluated.

Bald and Golden Eagle Protection Act: The Bald and Golden Eagle Protection Act (BGEPA) provides for the protection of bald and golden eagles by prohibiting harassment and taking (include disturbing) of these species (including their eggs and active or inactive nests) unless allowed by permit. Wildfire mitigation projects can be subject to these requirements if there are bald or golden eagles or their nests in the vicinity.

Executive Orders: Some Executive Orders, such as 11988 - Floodplain Management and 11990 – Protection of Wetlands, apply to federally-funded projects that affect land use and development in the floodplain. FEMA completes an eight-step decision making process to evaluate projects in the floodplain.

Clean Water Act: This federal law, particularly Section 404, regulates activities in wetlands. It requires permits for the discharge of dredged or fill materials into the waters of the United States, including wetlands. Primary regulatory responsibility falls to the U.S. Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA), which are responsible for permit review and enforcement.

STATE AND LOCAL REGULATIONS

Water Quality Permits: Projects involving work within a stream may require a 401 Water Quality Certification from the state environmental protection agencies. Projects with the potential to affect public drinking supplies through dewatering or other construction activities must contact the state environmental agency to identify regulatory requirements that may apply. Wherever applicable, compliance with the National Pollution Discharge Elimination System (NPDES) permits is required when proposing to, or discharging into any surface water of the state.

Scenic and Historic Preservation: Permits or approvals may be required for projects that require earthmoving and/or demolition of a structure if the projects are within a certain distance from designated state wild, scenic or recreational, archaeological, prehistoric or historical sites or structures.

Protected Species Regulations: State and local laws and regulations related to managing rare or managed fish, wildlife (including migratory birds), plants, and habitats vary. Wildlife, natural resources, and fisheries departments should be consulted to ensure compliance with these requirements.

Water Rights: Each state regulates water rights within its jurisdiction. If a project diverts water or causes changes to a water course, approval or granting of water rights by the state may be required.

Floodplain Management Permits: Floodplain management permits or construction permits may be required by the local floodplain administrator for projects occurring within federally identified special hazard areas (the 1% annual chance floodplain).

Local Water Resources Permits: Local or regional irrigation and water districts are empowered to protect water resources in their jurisdiction; permits may be required for certain projects.

Other: Various agencies, utilities, and authorities should be consulted for projects that depend on specific activities and locations.

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