Wahikuli-Honokōwai Wildfire Mitigation Plan

Reducing Wildfire Hazards and Impacts in the Wahikuli-Honokōwai Watersheds

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Developed by:
Hawaii Wildfire Management Organization, a 501(c)3 nonprofit organization dedicated to protecting Hawaii's communities and natural resources from wildfire.

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Section 1- Introduction

Section 1- Introduction

Introduction

Due to dense and unmanaged vegetative fuel loads, high likelihood of fire ignition, strong winds, frequent periods of drought, and historic and nearby wildfire events, the Wahikuli-Honokōwai watersheds are at high risk of wildfire. They also have steep slopes that make post-fire erosion impacts a significant threat to downslope, riparian, and nearshore resources.

Volume 2 Section 3.7 (pg. 47) of the Wahikuli-Honokōwai Watershed Management Plan prioritizes the completion of a BAER (Bare Area Emergency Response) plan to address wildfire impacts in the watersheds and to be prepared ahead of time for dealing with the after-effects of wildfire. Wildfire and watershed management experts within the Hawaii Wildfire Management Organization are in strong agreement that preparing for fire, reducing its impacts, and quickly stabilizing lands after a fire are essential management tasks for Wahikuli-Honokōwai.

Purpose

This Wahikuli-Honokōwai Wildfire Mitigation Plan was written to provide resource managers and landowners with a comprehensive wildfire readiness plan. It provides an overview of pre-fire hazard reduction recommendations and outlines the preparation needed to ensure a strong during-fire and post-fire response.

Table 1 below details the categories of activities that can be implemented to reduce wildfire occurrence and minimize fire impacts. The scope of activities that is necessary for a comprehensive fire protection plan is heavily weighted toward prevention and risk reduction. It is well documented that the costs of implementing pre-fire mitigation activities are much less than the costs of suppressing fires, preventing post-fire erosion, and rehabilitating lands after fire. They also avoid fire-caused damage to the landscape in the first place rather than trying to repair damage caused by unmitigated wildfires without a pre-defined

Why a Wildfire Mitigation Plan and not a BAER plan for Wahikuli-Honokōwai?

Various agencies use different planning tools to address wildfire issues. Traditionally, a team of experts creates a BAER plan ***during and immediately after a large wildfire***, usually on Federal Forest lands. It is specific not just to an area, ***but to a particular fire event and its specific details*** (size, intensity, suppression damages such as bulldozer lines and new road cuts, etc.) It is not appropriate to develop a BAER plan ahead of time because of its specificity to a particular fire event. These plans also only cover the period of time at the end of an actively burning fire and the days following it.

The work of minimizing the impacts of fire doesn't just occur after a fire has taken place. Reducing the likelihood of wildfire and keeping fires that do occur small and quickly contained are essential up-front management tasks that have a higher likelihood of success than waiting until a fire has already ravaged the landscape and working after-the-fact to offset its impacts.

HWMO would be remiss if we provided any specific measures in anticipation of a speculated fire event with speculated boundaries, burn severity, and suppression impact details. We would also be remiss if we provided a plan that deals only with the short-term after-effects of a fire without minimizing the underlying causative risks and hazards, and planning for the long-term. These additional considerations and their corresponding recommended actions can reduce the number, size, and damage from wildfires in the first place, and set in place actions that will better protect natural, cultural, and community resources in the area. It is with this intent that the Wahikuli-Honokōwai Wildfire Mitigation Plan was written. Chapter 5 does, however, provide important action steps that can be taken to pre-organize a BAER-type team of experts who can create an appropriately specific plan to stabilize soil immediately after a specific wildfire has occurred.

Inset 1. Why a fire mitigation plan instead of a BAER plan?

fire management plan or adequate resources.

A Three-Pronged Approach To Reducing Fire Risk and Impacts

For the above reasons, HWMO recommends a three-pronged approach to dealing with the wildfire issue in Wahikuli-Honokōwai watersheds:

1. Implement pre-fire measures to:
    - Reduce ignitions
    - Manage vegetative fuels
    - Maximize firefighting access
2. Ensure firefighting is efficient, effective, and minimally impacting by:
    - Developing a fire management plan
    - Maximizing firefighting resources
    - Ensuring any firefighting effort uses minimal impact suppression techniques
3. Prepare in advance for post-fire response by:
    - Developing ready-to-go post-fire response teams (to conduct assessment and treatment plans)
    - Being prepared to stabilize soil immediately after wildfire
    - Developing longer-term restoration and rehabilitation plans for various parcels ahead of time to recover from wildfire and take advantage of any post-fire opportunities

The following table (Table 1, Page 8) provides an overview of the components of a comprehensive wildfire mitigation plan. Each of the actions listed has a corresponding chapter in this plan that lays out the necessary background information and provides recommended actions.

Actions that minimize wildfire impacts	Reduce Ignitions	Manage fuel	Maximize firefighting access	Maximize firefighting resources and preparation	Minimize firefighting impacts	Emergency post-fire stabilization [Bare Area Emergency Response (BAER)]	Long-term rehabilitation or restoration of burned area toward desired land use goals
Why is this important	1. Reduces number of fires. 2. Alters fire behavior to keep fire smaller. 3. Maximizes firefighters strategic options for containing fires. Fewer fires + faster and more effective fire suppression → smaller fires → reduced fire severity → reduced impacts → greater chance for stable soils → decreased erosion potential			Ensures efficient and effective firefighting.	Reduces impacts caused by wildland firefighting, which is the largest contributor to post-fire erosion.	Stabilizes soil to reduce erosion during next large rain event.	Works to recover from wildfire impacts on a greater scale, and to prevent/reduce future impacts. Often long-term rehabilitation is used to direct ecological community composition toward one that is more desirable to landowner for future land use.
When can these actions be taken?	Before a wildfire occurs.				Prepare/train ahead of time for actions that take place during a fire event.	Prepare/train ahead of time for actions that take place in the final days of a fire event and immediately after fire.	From weeks to years after the fire event.
Details in:	Section 2					Sections 2, 3, 4	Section 5

Table 1. Overview of Wildfire Mitigation Strategies

Section 2- Before Fire:
Pre-Fire Mitigation and Preparedness for During-Fire and Post-Fire Response

Section 2

Before Fire: Pre-Fire Mitigation and Preparedness for During-Fire and Post-Fire Response

Pre-Fire Mitigation

Fire is possible only when oxygen, fuel, and heat/ignition are all present. This is known as the fire triangle. The fire triangle is a simple way of understanding the factors of fire. Each side of the triangle represents one of the three ingredients needed to have a fire, demonstrating the interdependence of these ingredients in creating and sustaining fire. When there is not enough heat generated to ignite or sustain the process, when the fuel is exhausted, removed, or isolated, or when oxygen supply is limited, a side of the triangle is broken and the fire will not start (or if it is already burning it will die). Limiting oxygen supply is the last option to be taken— this is the part of the fire triangle that firefighters are addressing through the application of water or retardant on flames. For pre-fire mitigation purposes, land managers should focus on removing ignition sources and managing fuel (vegetation and combustible materials). Reducing the likelihood of ignition can prevent and/or reduce the occurrence of wildfire. Managing vegetation and combustible materials will reduce the potential for fires to ignite and spread across landscapes and structures. Both are considered to be wildfire mitigation actions, and both are detailed below.

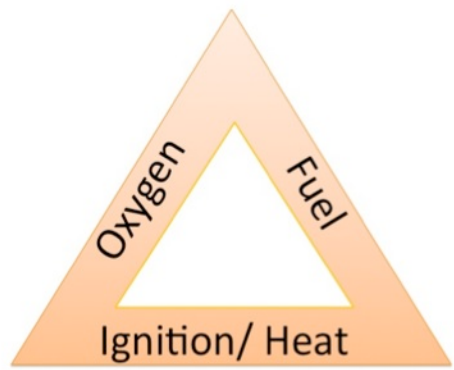


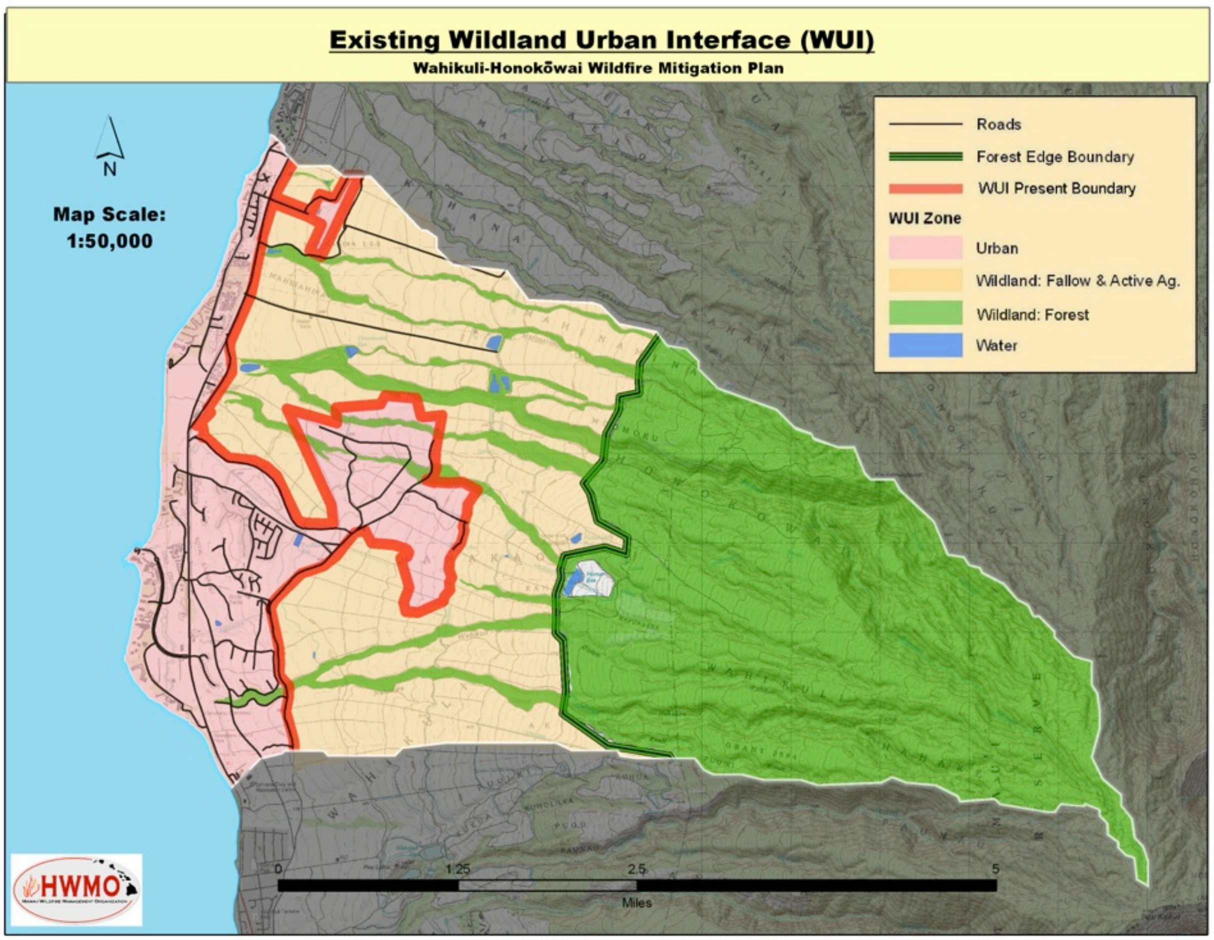
Figure 1. Fire Triangle

'Wildfire Mitigation' is a term used to describe any action taken to reduce or eliminate the long-term impacts that wildfires can have on people, property, structures, and natural areas. A number of mitigation objectives can be achieved through pre-fire planning (adapting to wildfire), ignition reduction (preventing the hazard), and vegetative fuels reduction and management (averting the hazard). The key to successful mitigation lies in breaking the cycle of destruction, rebuilding, and destruction again. Typically, only after the cost of responding to repeated incidents involving loss of life, property, or ecosystem function becomes unacceptable does attention turn toward mitigation. Preparing a mitigation plan as early as possible provides the best protection toward loss prevention and wildfire-caused damage to infrastructure and ecosystems. This is critical for areas like native forests that do not usually recover to their former state after wildfire. Mitigation measures should be based on the most current identification of hazards and threats.

Mitigation in the Wildland Urban Interface

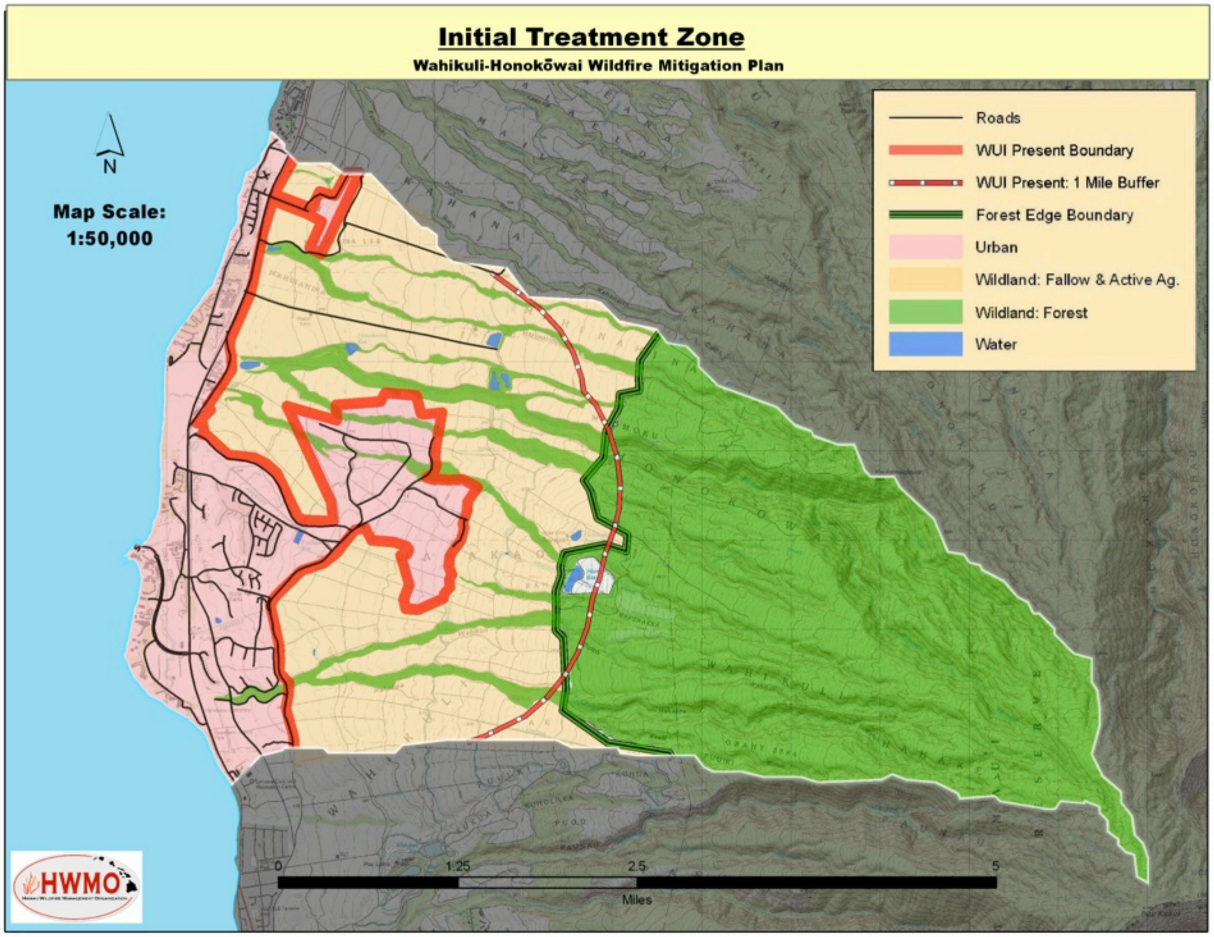
Pre-fire mitigation measures are extremely important in the wildland-urban interface, or WUI. The WUI is defined as the area where homes or roads are built near or among undeveloped lands that are prone to fire. The post-agricultural fallow grass-shrub areas in the lower elevations of Wahikuli-Honokōwai are considered a fire-prone wildland environment. The forested and riparian areas are also part of the wildland. The community subdivisions, paved roads, highway, and coastal developments in the Wahikuli-Honokōwai watersheds make up the "urban" component of the Wahikuli-Honokōwai WUI. These watersheds experience classic wildland-urban interface wildfire threats. The recommended pre-fire mitigation treatments, therefore, are aligned with routine prescriptions for risk reduction in the WUI.

The current boundaries of the WUI in Wahikuli-Honokōwai are represented in Map 1 below. The red WUI boundary line represents the interface between the urban/developed region and the wildland environment. It is at this interface that the hazard of ignition is highest. It is also the area that can be treated to create defensible space around communities to protect lives and homes from wildland fire and to provide greater firefighter access to wildland areas adjacent to subdivisions. The wildland is divided into two types: fallow/active agriculture and forest. Mitigation measures will vary based on this distinction. Active agriculture is much less of a wildfire hazard than fallow, unmanaged post-agriculture lands.



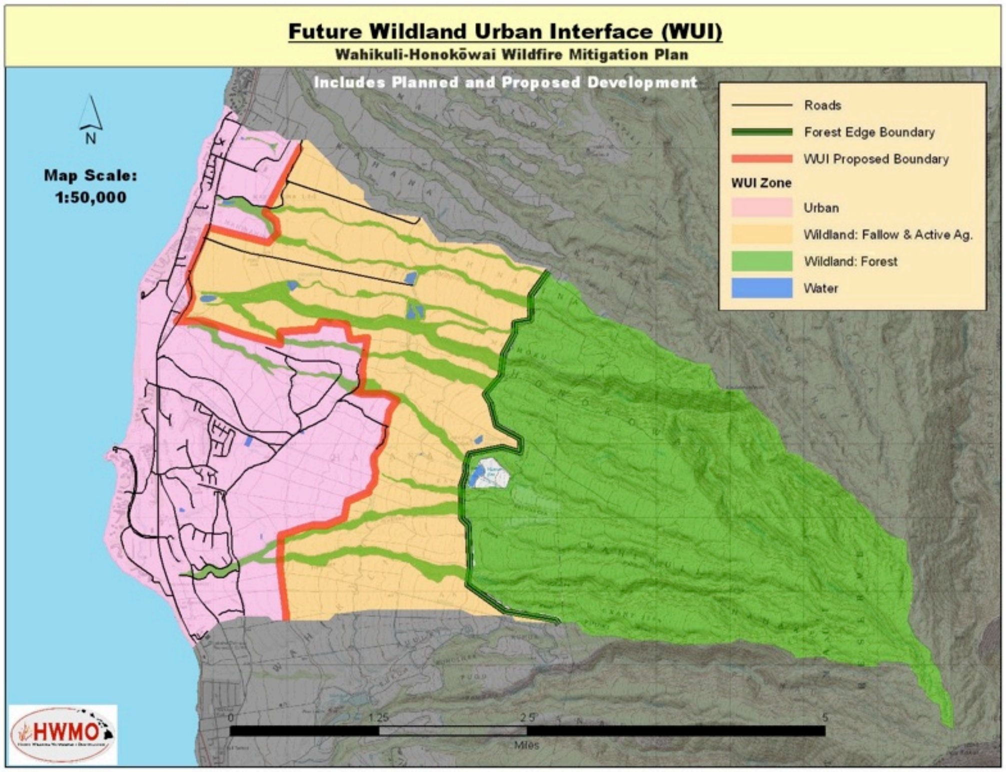
Map 1. Exisiting Wildland-Urban (WUI) Interface.

Map 2 below displays an approximate one-mile buffer around the wildland-urban interface. This is the standard area for the application of mitigation measures in wildland-urban interface situations. In Wahikuli-Honokōwai, the approximate one-mile buffer is primarily comprised of fallow post-agricultural land containing a grass-shrub complex. Mitigating wildfire through the reduction of ignitions and vegetative fuel in this area and at the interface boundaries should be the primary focus of mitigation efforts as a way to protect lives, homes, and forests. Additional discussion and area-specific recommendations for mitigation treatments can be found in subsequent sections of this chapter.

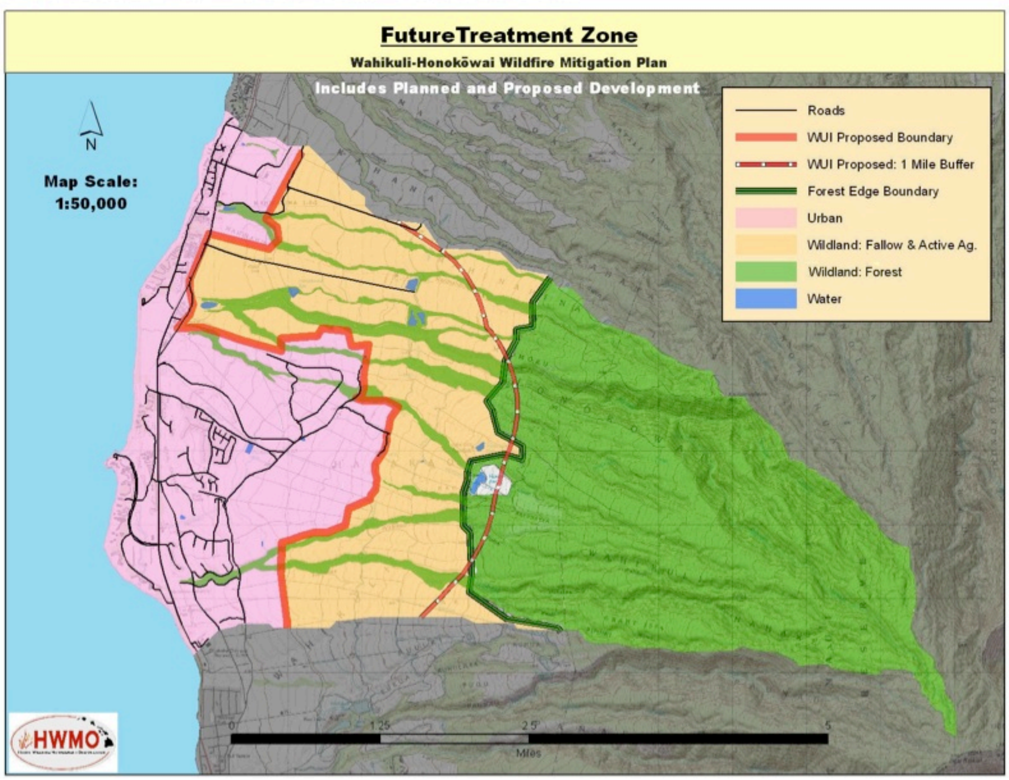


Map 2. Initial WUI Treatment Focus. Approximate one-mile buffer from interface.

Nationwide, people are moving farther into "natural" areas to take advantage of undeveloped lands, privacy, and natural beauty. Wahikuli-Honokōwai is no exception. With additional areas slated for new development, the focal area for WUI mitigation activities will shift over time. Map 3 below displays the most recent update (2014) to proposed and planned development that is set to take place in the Wahikuli-Honokōwai watersheds. Map 4 below demonstrates how that one-mile WUI treatment buffer will shift when the development takes place. With the development plans available at the time of writing, there will be only moderate changes to WUI boundaries. However, these plans are frequently modified and updated. It is important to keep future WUI boundaries in mind so that treatments recommended in this plan (based on current land uses and boundaries) can be adjusted to changing land uses, circumstances, and interface boundaries.



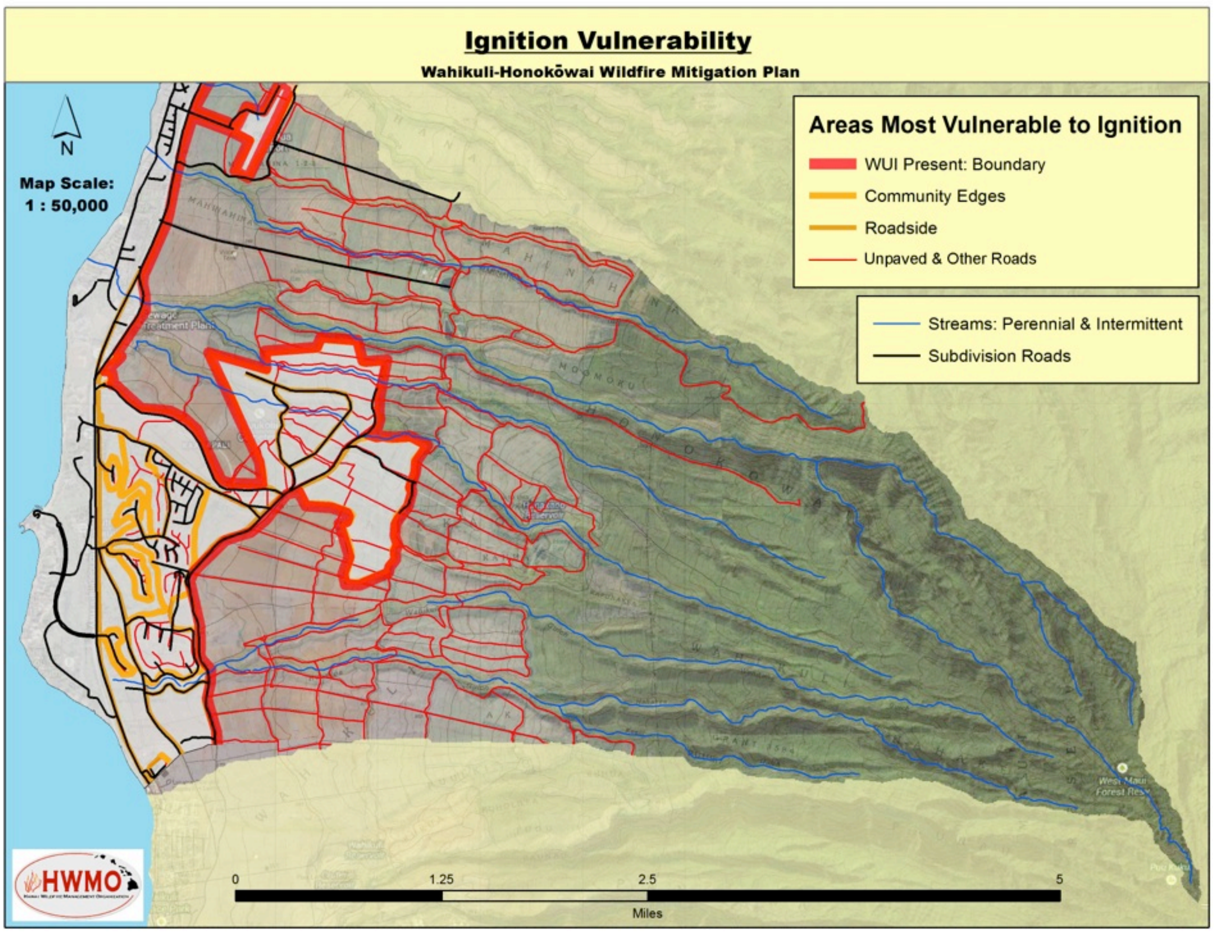
Map 3. Future Wildland-Urban Interface, based on planned and proposed development as of August 2014.[1]



Map 4. Future WUI Treatment Focus. Approximate one-mile from interface of proposed and planned development.[1]

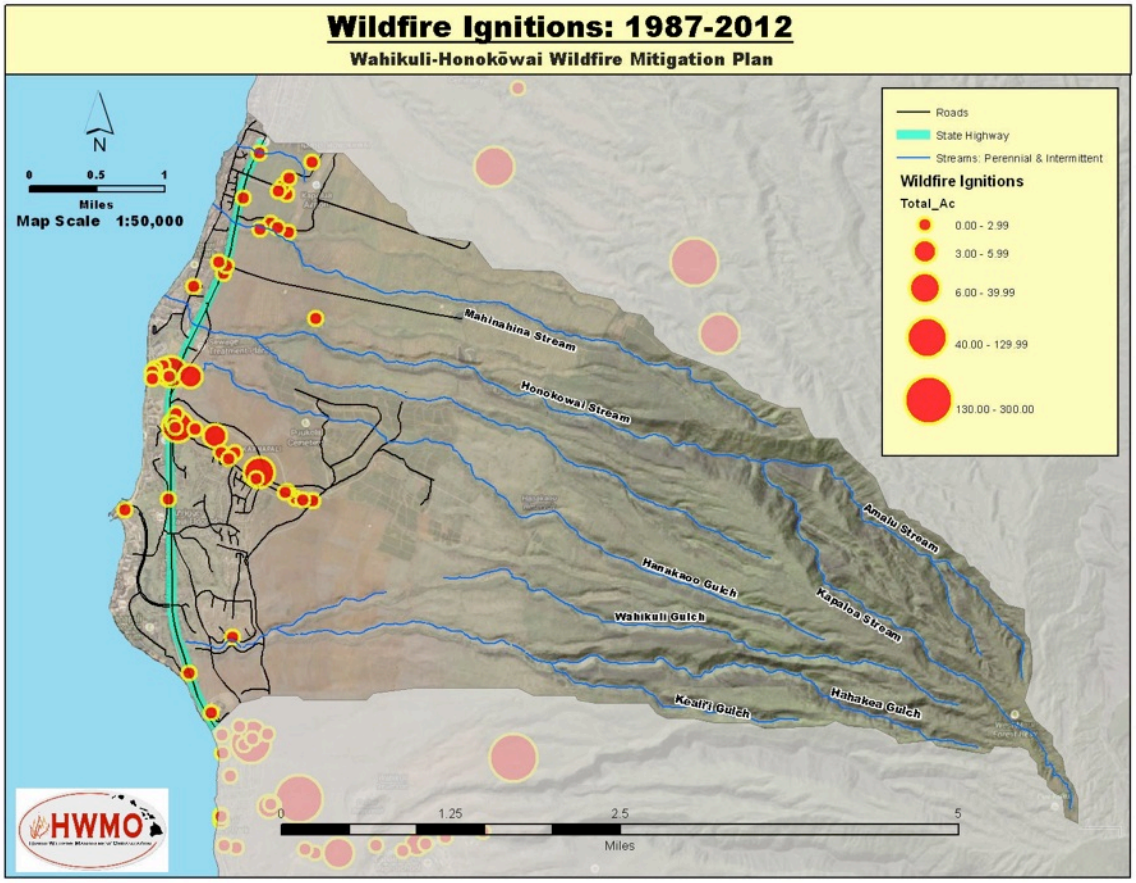
Reducing Ignitions

Reducing the likelihood of ignition is one of the most important components of all wildfire prevention activities, particularly in the WUI area. A heat source is always responsible for the initial ignition of fire, and heat is also needed to maintain the fire and enable it to spread. Heat allows fire to spread by removing the moisture from nearby fuel, warming surrounding air, and preheating the fuel in its path, enabling fire to travel with greater ease. Since humans accidentally or intentionally set most fires in Hawaii, ignition reduction measures focus on human activities and human access areas that are potential ignition sources. The following map (Map 5) demonstrates the areas of high ignition vulnerability. These areas include roadsides and WUI boundaries.



Map 5. WUI Areas Of High Ignition Vulnerability: Roads, WUI Boundaries, And Community Edges.

The Wildfire Ignitions Map (Map 6) below displays the number and approximate location of wildfire ignitions requiring firefighting response from 1987-2012. Some ignitions may be missing due to incomplete source data. However, the available data does provide a general idea of trends and patterns of wildfire starts/ignitions. Note the frequency of ignitions along access roads. Many of the fires occurred during the decades of agricultural production. Many lands have recently been taken out of production, increasing the vegetative fuel hazard but decreasing vehicular traffic on unpaved roads.



Map 6. Wildfire Ignitions 1987-2012 in the Wahikuli-Honōkowai Area.

IGNITION REDUCTION RECOMMENDATIONS:

- **Address wildland-urban interface community sources of ignition.**
  Homes and structures on the wildland-urban interface can be both sources of ignition and casualties of wildfire coming from surrounding environs. For this reason, it is important to protect the landscape from burning homes and roadside ignitions and vice versa. Public outreach is an important focus for ignition reduction, as well as on-the-ground measures to reduce the likelihood of accidental ignition due to human use of an area. Map 5 shows the areas of high ignition hazard for prioritized action. Strategies for reducing WUI ignition sources are as follows:

  1. Develop a wildfire prevention signage plan for publicly accessible areas along the wildland-urban interface during periods of high fire risk.
  2. Manage vegetation around developed areas, community subdivisions, and along roadsides (see below for specific fuels management strategies).
  3. Initiate a process for community education and involvement:
     - Provide educational opportunities for residents and businesses, including power/electricity suppliers, on preventing wildfire ignitions.

- Support the development of community action teams or movement toward becoming certified Firewise or Fire-Adapted Communities.

- **Control equipment-generated wildfire ignitions.**
  1. Ensure that spark arrestors on power tools, mowers, heavy equipment, and welding equipment are functional and regularly maintained.
  2. Educate landowners, land managers, lessees, and field crews about the importance of maintaining equipment to reduce sparking potential.
  3. Develop protocols for limiting or prohibiting equipment operations near or on dry vegetation during high-risk conditions. Implement protocols for acceptable and unacceptable conditions for using combustion engine-based or spark-producing equipment. Unacceptable conditions: dry vegetation during seasons or periods experiencing drought conditions, or midday when vegetation is driest. Equipment use should be limited to early morning or after rain events when fuel moisture is highest.

- **Limit vehicular access during high fire risk conditions.**
  1. Develop protocols for limiting or prohibiting driving near or on dry vegetation during high-risk conditions. Work toward agreements for all parties to avoid driving in dry, high-hazard areas. This includes both the general public and entities with jurisdiction or ownership of the land. Individuals with regular access to fire prone areas and great familiarity with the landscape (landowners, land managers, field crews, regular visitors, etc.) are a common accidental source of vehicle-caused fire ignitions. This can be avoided with strict adherence to conditions-based vehicular access limits.
  2. Develop fire hazard road closure signage and conditions-based installation plan for any access roads or points of entry.
  3. Develop a communication plan with individuals and entities that have access to fire prone areas. Reminders or notifications should be provided about high fire hazard periods, limiting access, and being careful not to idle or drive over dry vegetation.

For the above recommendations, the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) has numerous related standards and specifications that should be consulted for best practices. They include the following Field Office Technical Guides for Maui County, and are included in the Appendix.

- Access Control (Code 472)
- Access Roads (Code 560)
- Trails and Walkways (Code 568)

Vegetative Fuels Management

Fire Behavior and Vegetative Fuels

Unlike the Fire Triangle (ignition/heat, oxygen, fuel), the fire behavior triangle explains how a fire acts after it is already ignited. Comprised of three parts — weather, topography, and fuels — it provides a conceptual basis from which to understand the factors that contribute to how fire moves across a landscape in different ecosystems, seasons, weather, or terrain. These are essential considerations for making decisions on management actions that can reduce the fire spread potential. Weather and topography are components that generally cannot be manipulated to reduce fire risk or spread potential. However, vegetative fuels can be managed in ways that also consider the fire behavior caused by weather and topography. See below for a more detailed weather and topography discussion and relevant maps.

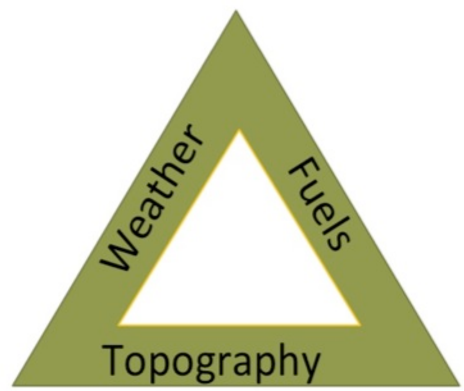
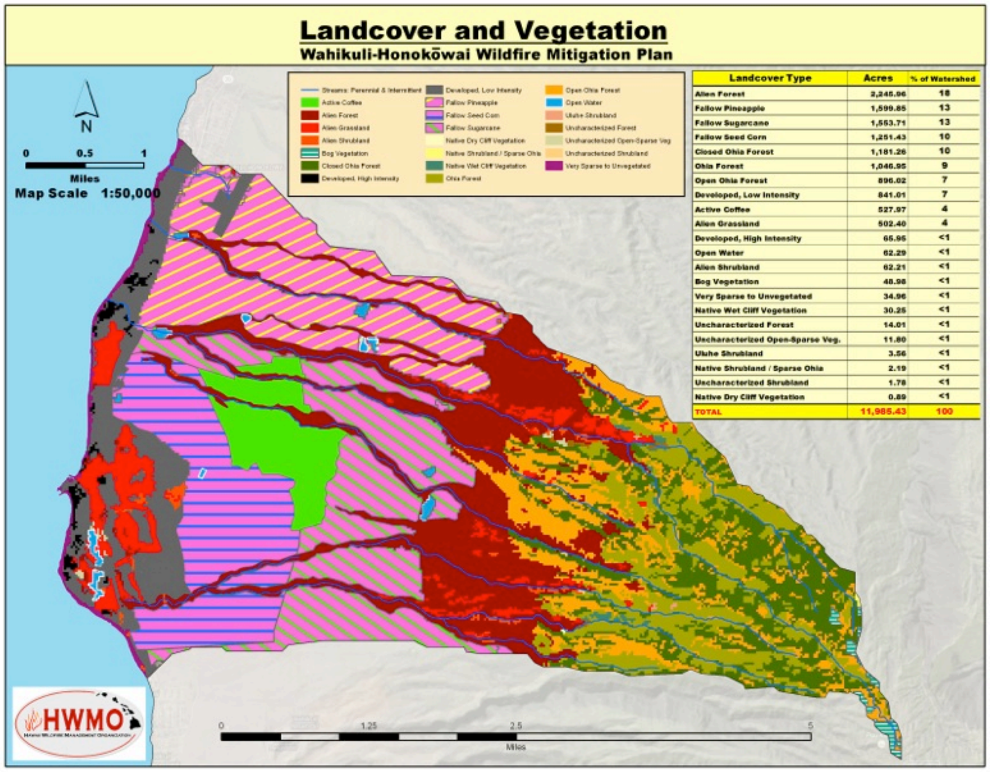


Figure 2. Fire Behavior Triangle

Fuel is the only component that is in both the fire triangle and the fire behavior triangle. For this reason, managing fuel (generally vegetation) works both toward ignition reduction and toward reducing the spread potential of fire if ignition does occur.

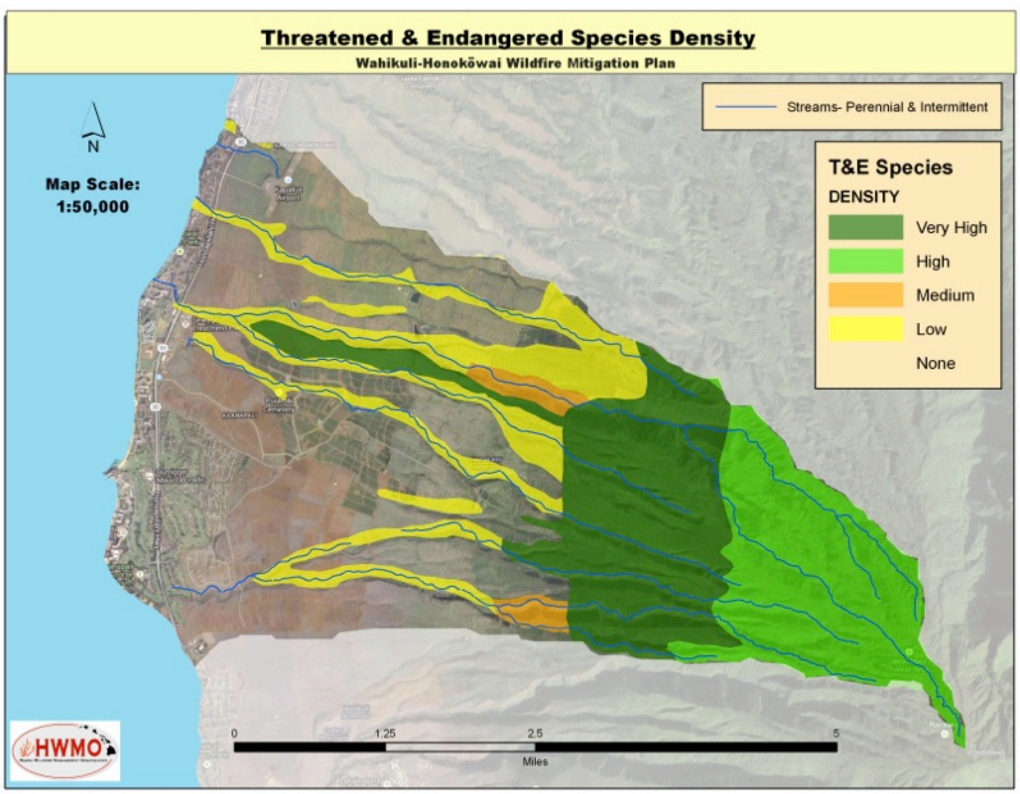
Vegetative fuels are combustible materials such as grass, leaves, ground litter, plants, shrubs, and trees that can feed a fire. Vegetative fuels management (often referred to simply as fuels management) is generally described as the effort to achieve wildfire hazard reduction via the strategic manipulation of vegetation. Vegetative fuels management includes strategic planning and site-specific and landscape-scale treatments designed to improve the protection of life and property, and to maintain or restore the sustainability of healthy ecosystems. This is accomplished by the application and integration of a variety of treatments that will minimize the probability and effects of large-scale, high-intensity fires. These treatments include, but are not limited to, mechanical, chemical, biological, and manual methods, and in many areas include prescribed fire and wildland fire use. Both naturally-occurring fuels and hazardous fuels accumulations resulting from resource management and land use activities are usually addressed.[2]

The following maps show the vegetation types within the Wahikuli-Honokōwai watersheds (Map 7) and Threatened and Endangered Species (Map 8). Specific vegetation maps for each large landowner can be found in the Appendix.



Landcover Type	Acres	% of Watershed
Alien Forest	2,245.96	18
Fallow Pineapple	1,599.85	13
Fallow Sugarcane	1,553.71	13
Fallow Seed Corn	1,251.43	10
Closed Ohia Forest	1,181.26	10
Ohia Forest	1,046.95	9
Open Ohia Forest	896.02	7
Developed, Low Intensity	841.01	7
Active Coffee	527.97	4
Alien Grassland	502.40	4
Developed, High Intensity	65.95	<1
Open Water	62.29	<1
Alien Shrubland	62.21	<1
Bog Vegetation	48.98	<1
Very Sparse to Unvegetated	34.96	<1
Native Wet Cliff Vegetation	30.25	<1
Uncharacterized Forest	14.01	<1
Uncharacterized Open-Sparse Veg.	11.80	<1
Uluhe Shrubland	3.56	<1
Native Shrubland / Sparse Ohia	2.19	<1
Uncharacterized Shrubland	1.78	<1
Native Dry Cliff Vegetation	0.89	<1
TOTAL	11,985.43	100

Map 7. Landcover and Ownership Boundaries Map, showing the specific vegetation community types and landowner boundaries. *A full-page version of this map is included in the Appendix and allows for better legibility.*



Map 8. Threatened and Endangered Species Densities, based on the State of Hawaii data layer.

Vegetative fuels management strategies and their associated considerations for Wahikuli-Honokōwai are provided below. They have been strategically selected to proactively decrease the potential of wildfire spread, increase the probability of successful and timely containment, and minimize adverse impacts. Of primary concern is the current abundance of fallow post-agricultural grass, as it presents the highest hazard for wildfire occurrence within the Wahikuli-Honokōwai WUI area. This hazard would be reduced if vegetation were managed for a reduced fuel load (such as through targeted grazing), if the land were converted to another use (such as active agriculture), if grasses were converted to drought tolerant native species, or if the development that is currently proposed becomes implemented. In its current state, it is critical that vegetative fuels be managed to reduce their ability to carry fire across the landscape.

Managing fuels with the goal of decreasing the ability of fire to travel across the landscape can reduce the size and intensity of fires, minimize the likelihood that a fire along the surface of the ground will become a crown/canopy fire (much more difficult to contain and much more quickly moving), and provide firefighters time, defensible space, and access to contain the fire.

There are numerous fuels management options and methods that can be used effectively in the Wahikuli-Honokōwai watershed, each with benefits and limitations. Table 2 below provides an overview of fuels management treatment types (manual/mechanical, biological, chemical) and their associated notes for Wahikuli-Honokōwai. It allows for comparison among the possible options for reducing fuels. As discussed above, reducing ignition risk can reduce the number of fires that occur, but unfortunately it is unlikely that all ignitions will be prevented. The recommended ignition reduction actions above should be coupled and expanded with the following fuels management treatments to reduce fire spread and better control fire behavior if ignition does occur.

The methods for reducing fuels are often selected according to capacity and opportunity of landowners and land managers. All fuels management treatments, however, should focus on addressing the comprehensive picture of wildfire vegetation risk. This includes tackling fuel issues:

1. In the urban area (private property, residences, subdivisions)
2. At the wildland-urban interface boundaries
3. In the wildland areas:
    - Grasslands and post-agricultural areas
    - Forests
4. To create tactical fuelbreaks to aid fire suppression

Each is discussed in greater detail below.

Numerous best practices are available that are specific to Maui County and to Hawaii. Consult these when implementing any treatment. Additional external resources are also being provided to the Ridge to Reef Initiative to complement this plan, such as a series of University of Hawaii Technical publications related to best practices for grazing, grazing leases, and more. The most comprehensive source of best practices is produced by the U.S. Department of

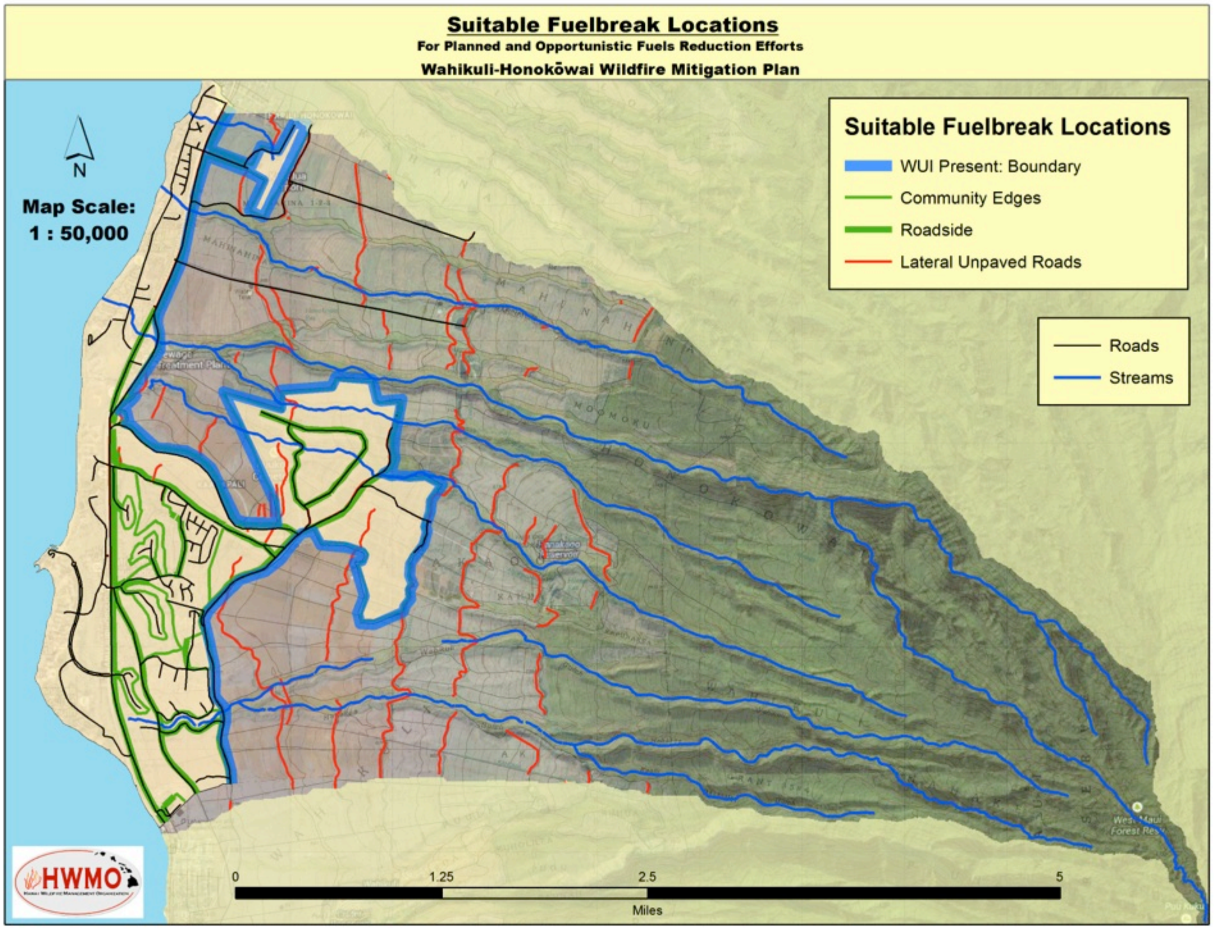
Agriculture's Natural Resource Conservation Service (NRCS). The NRCS Field Office Technical Guides have standards and specifications for fuel breaks, grazing, range management, riparian buffers, and more.[3] Those included in the appendix related to fuels management are as follows:

- Brush Management (Code 314)
- Forage and Biomass Planting (Code 512)
- Fuelbreaks (Code 383)
- Grazing Land Mechanical Treatment (Code 548)
- Herbaceous Weed Control (Code 315)
- Land Clearing (Code 460)
- Prescribed Grazing (Code 528)
- Range Planting (Code 550)
- Riparian Forest Buffer (Code 391)

The following table provides an overview and comparison of fuels reduction methods, treatment details, and considerations.

Fuels Management Types and Details	Manual & Mechanical	Biological	Chemical
Uses	Fire breaks, fuelbreaks, creating fuel mosaics, roadside fuels reduction, WUI fuelbreaks, tactical fuelbreaks	Pasture to landscape scale vegetation management, grass management	Reduce regrowth after manual/mechanical treatment methods
Treatment Details	Hand-pulling Weed whacking Mowing Limbing "ladder" fuels Bulldozing	Targeted grazing	Application of pre-emergent herbicides. (Other herbicides not recommended unless desiccated vegetation subsequently removed).
Location	Roadsides, community boundaries, opportunistically reduce vegetation wherever possible	Lower elevation sites; grasslands and grass-shrub complexes	Roadsides and community boundaries after other treatments
Benefits	Reduce fuels strategically according to geography, weather, high ignition risk areas	Low-cost and/or profit-making, organic matter rehabilitates soil	Fuels return more slowly than other treatments.
Challenges	Cost, regular maintenance required. Mechanical earthworks (dozing) very effective for fuel reduction and defensible space to improve firefighting, but may necessitate permits and other compliance procedures.	Best to graze fuels across multiple landowners and properties for proper and sustainable pasture rotations and agricultural profit. Need fencing and animal access to water.	Doesn't remove fuel load on its own— sprayed vegetation becomes standing dead fuel if not mowed or trimmed first. Post-herbicide plant community may change to more hazardous fuel type.
Weather Considerations	Use equipment at low risk times (early morning, cooler times of day, wet season) Prioritize areas with more sun exposure (and thereby drier) for reduction. Reduce vegetation just after peak growth.	Vegetation must be nutritious and palatable for animal consumption. Coordinate pasture rotations with fuel moisture and growth, so animals are grazing areas when they are green.	Consult herbicide application guidelines.
Topographical Considerations	Reduce vegetation around human access areas and roads. Create a fuel reduction buffer around riparian areas to avoid ignition and consequent "chimney effect." Place fuelbreaks perpendicular to slope and along windward edges of communities, roads, and protected areas.	Design pasture rotations to graze lands nearest high ignition zones (near human accessed areas) and to graze down areas that are the first to dry out while they are still green. Keep animals out of riparian areas- reduce fuels in these areas using alternative treatments.	Consult herbicide application guidelines.
Specific Recommendations for Wahikuli - Honokōwai (detailed below)	Targeted fuels reduction along community edges and roadways. Ladder fuels management on forest edge. Fuel mosaic during roadwork and other management activities. Riparian buffers.	Graze low elevation grasslands with strategic and sustainable pasture rotations. Build best practices into lease requirements. Create grazing coop to manage at landscape level rather than per property.	Minimize use of herbicides on standing fuel. Use pre-emergent only after other treatment types, and only after better understanding the potential post-herbicide vegetation conversion and any associated increased fire risk.

Table 2. Table of vegetative fuels treatments.



Map 9. Suitable Fuels Reduction Locations (Fuelbreaks)- Community boundaries, roads, and at the wildland-urban interface boundary.

Fuelbreaks, Firebreaks, and Other Wildfire Mitigation- Related Lexicon[4], [5]

Defensible Space: An area around homes or structures, which is either manmade or natural, where the vegetation is modified and maintained to slow the rate and intensity of an advancing wildland fire. It also provides room for firefighters to work and helps protect the wildland areas from becoming involved should a structure fire occur.

Fuelbreak: A natural or manmade change in fuel characteristics that affects fire behavior so that fires burning into them can be more readily controlled and managed. A fuelbreak can be created in conjunction with defensible space as part of a planned development or later to safeguard that development, during preparation of a homesite, or along the side of roads to reduce the risk of ignition from vehicles and pedestrians. Fuelbreaks also serve to break up large, vast areas of unmanaged vegetation. To be functional as a fuelbreak, it should be maintained periodically (annually in some ecosystems) to prevent significant fuels buildup.[6]

A fuelbreak serves three valuable functions. It:
Imposes an obstacle to prevent fire from spreading.
Creates a safe means for firefighters to access the fire.
Provides separation between large areas of forest, shrublands, or grasslands, or between vegetation and communities.

The main goal of a fuelbreak is to change the continuity of the vegetation so that, as a wildfire enters the fuelbreak treatment area, the fire behavior changes, becoming less intense and slower to spread. To accomplish this, existing vegetation should be treated to reduce its density and distribution. The effectiveness of a fuelbreak is dependent upon its location, width, and frequency of follow-up treatments. In general, a wider fuelbreak with less residual vegetation will be more likely to slow a fire. A basic rule of thumb is that fuelbreak widths should be at least 3 times the height of the tallest adjacent vegetation.

Firebreak: A natural or constructed barrier used to stop or check fires that occur, or to provide a control line from which to work. A firebreak is more permanent than a fuelbreak, and completely removes fire fuels as opposed to temporary methods such as mowing or weed-whacking that require regular maintenance. Permanent fuel removal is often achieved though the use of non-flammable materials such as gravel, sand, bulldozed or paved roads, well maintained golf courses or watercourses that meet a specified width to stop fire (fuelbreak). This width is generally measured outward 1.5 times the height of the highest fuels directly adjacent to the break. Firebreaks are often buffered by adjacent fuelbreaks, wherein a road, bulldozed strip, or gravel access road is lined on its windward side with a strip of reduced vegetation 2-3 times the height of adjacent fuels.

Fire Behavior Terms
Surface Fuel: Vegetation on the ground, such as grasses and shrubs.
Canopy/Crown Fuel: Vegetation toward or at the tops of trees, especially dangerous due to increased wind-generated spread.
Ladder Fuels: Any vegetation that connects surface/ground vegetation to higher levels that allow fire to travel directly up into the canopy or crown of trees. The concept is that if you remove one "rung" of the ladder, fire cannot climb to reach the wind.

Inset 2. Definitions of Commonly Used Fire Words and Concepts.

VEGETATIVE FUELS MANAGEMENT RECOMMENDATIONS

1. ***Urban Areas- Private Property, Residences, and Subdivisions:***
   - Provide educational opportunities and incentives for residents and homeowners. Ultimately, private citizens are responsible for protecting the properties within subdivisions, but often need education and support to do so. At a minimum, residents should be informed and encouraged to follow Firewise and Fire-Adapted Community risk reduction recommendations, including the following:
     - Maintain wide and easy driveway access
     - Ensure house numbers and addresses are clearly visible
     - Utilize fire resistant plants in the landscape
     - Regularly maintain yards and landscaping, including pruning trees and shrubs to remove dead and dying plant material
     - Replace combustible building materials with fire-resistant roofing, siding, decking, fencing, and other materials
     - Enclose spaces under porches and decks
     - Properly dispose of or mulch green waste- do not throw into wildland areas, vacant lots, or into gulches

With the Western Maui Community Wildfire Protection Plan Funds in place, various grant funds are available to communities who organize to achieve these goals. Hawaii Wildfire Management Organization and DLNR-DOFAW are equipped to provide community fire preparedness education. Contact them for more details.

   - **Support the development of community action teams or movement toward becoming Firewise or Fire-Adapted communities.**

2. ***Wildland-Urban Interface Boundaries-*** The highest ignition risk areas are places where humans have personal or vehicular access. These include major roads, minor and unpaved public or work roads, areas undergoing equipment use, utility substations, lines, or access roads, and outside edges of subdivisions. Map 5 showing WUI areas of high ignition vulnerability and Map 9 demonstrating suitable fuelbreak locations are both relevant to treating vegetation at the WUI boundary. Fuel reduction treatments in these areas reduce fire suppression costs, improve safety for residents and firefighters, and improve the resilience of areas subjected to fire.[7] Map 9 above illustrates key areas for WUI fuels reduction, and includes the WUI interface itself, roads that are on outside edges of subdivisions, and major roads.
   - **Install and/or maintain fuelbreaks/firebreaks along community boundaries**, aiming toward the development of fuel-free zones along the urban interface (outer edges of subdivisions) that are a minimum width of 3-4 times the height of standing fuel. (*i.e.*, 3ft tall adjacent grasses require a 9-12ft break width). Breaks that are perpendicular to slope (lateral) can be wider for added benefit, especially if covered with gravel or otherwise hardened to provide fire truck access. Where possible, use fuelbreaks and firebreaks together to reduce maintenance and ensure firefighters have the defensible space they need. See Inset 2.

- **Maintain or initiate roadside fuels reduction efforts along frequently used roads** at a minimum width of 1.5 times the height of the adjacent fuels. The width can be less than the 3-4 times fuel height recommendation above because the road also functions as defensible space.

3. ***Wildland-*** Manage fuels in the 'wildland', which includes all lands on the undeveloped side of the urban interface and outside of public roads or utilities. The Wahikuli-Honokōwai wildland environment should be managed according to the following four zones of fuels:

   Wildland Type 1: Grasslands and Fallow Post-Agricultural Areas
   These large tracts of non-native grasslands are a priority for fuels reduction. Managing these fuels toward a reduced fuel load and to create a non-contiguous fuel mosaic across the landscape will interrupt the currently contiguous fuels that directly connect the urban interface to the upland native forest and nearby riparian areas. Currently, these unmanaged fuels provide a wick for fire to spread quickly from one area to the other. Disrupting the continuity of vegetation will be key to changing fire behavior toward a more easily-suppressed situation.

   A variety of methods can be used to reduce the fuel load in the grasslands (manual, mechanical, biological, chemical) depending on time of year, fuel load, private property owner permissions and preferences, funding, and opportunity. Provided below are specific strategies to maximize efficiency, efficacy, and sustainability of fuels treatments. However, the longer-term recommended measures may take some time to organize and/or fund. For this reason, management of the fuels in grassland and fallow post-agricultural areas should be addressed in two parts: 1) recommended treatment, and 2) stop-gap measures.

   - **Recommended Treatment- Utilize targeted grazing to reduce fuels.**
     Well-managed grazing can provide a sustainable solution to both fuels reduction and longer-term maintenance needs. When properly managed, targeted grazing can rehabilitate degraded soil through the addition of organic matter, and can be profitable for landowners and livestock producers. Utilizing grazing for fuels reduction has a number of best practices and must be carefully planned so that leases, pasture rotations, and stocking rates are well coordinated with seasonal changes in available forage, fire risk, and requirements for land stewardship. Additionally, the Wahikuli-Honokōwai watersheds would be served best by targeted grazing that is managed at the landscape scale according to fuel types, forage quality, and weather conditions, not according to property ownership boundaries. The NRCS Field Office Technical Guides related to grazing and forage and the UH Cooperative Extension Service both provide excellent information about best practices for grazing. These and other relevant publications are included with this plan in the Appendix and as external resources.

     To utilize targeted grazing as a fuels management and soil rehabilitation tool, develop a grazing management plan that includes:

- The development of a grazing cooperative among adjacent landowners so that lands can be managed across boundaries to allow for best grazing management practices to be followed.
- Pasture rotations based on precipitation/elevation gradients to maximize forage quality and availability, to reduce fuels in advance of desiccation due to drought or seasonality, and to prevent the impacts from unmanaged or over-grazing.
- Anticipated adjustments to pasture rotations when proposed developments begin construction.
- Non-grazed buffers around riparian areas and forest edges. These areas are critical areas in which to manage fuels, but are best protected through other treatment methods.

➢ **Stop-gap measures- Create a fuel mosaic by breaking up contiguous fuels.**

In the interim period while more specific and complex treatments having to do with targeted grazing are coordinated, the fuel load and fire hazard will remain high. A general rule to follow is: reduce fuels in the grass-dominated areas whenever possible to whatever extent is possible. Breaking up the fuel bed, even if not in its entirety, still offers an improvement in risk reduction when compared to no action.

To manage the wildfire hazard during this period, the following measures can be implemented:

- Create a mosaic of fuels across the landscape by reducing fuels in swaths and patches, as possible. This breaks up the fuel continuity and works to alter fire behavior in a way that will slow its ability to spread evenly and quickly across the landscape.
- Take advantage of opportunities to reduce fuels when other work is taking place (extra weed whacking along roadsides during roadwork, etc.).
- Take advantage of agricultural-era pre-cut or pre-used lateral roads to create breaks in contiguous fuels. Suitable fuels reduction in the fallow agricultural areas can be seen in Map 9 above.

Wildland Type 2: Riparian Corridors[8]

Fuel treatments in riparian areas pose distinct challenges. Often containing protected species and playing an important role in sediment capture, riparian corridors are a key area to protect from wildfire. They also can serve as a wick directing lowland fire quickly and intensely toward upland high-density fuel areas, such as protected forests. Due to the presence of invasive species, ladder fuels, and the tendency of fire to travel uphill, particularly in gulches and ravines, fuel treatments may be needed to maintain riparian biodiversity, restore valued ecological functions, and to prevent fire from traveling uphill to upland forested regions. This presents distinct resource management challenges and contraindications— some vegetation needs to be reduced and managed as a fire hazard, while other vegetation is threatened or endangered and must be protected. Concerns about reduced water quality due to erosion and sedimentation, decreased shade, and spread of invasive species leads to the following set of treatments, again divided into recommendations and stop-gap measures:

- **Recommended Action- Develop a riparian fuels management plan.**

Due to concerns about unknown or unpredictable effects to riparian habitat during fuels treatment and recovery phases, reduced water quality due to erosion and sedimentation, decreased shade, spread of invasive species, and the potential to affect numerous biological and physical resources and processes, it is particularly important to plan riparian fuels management projects with input from a range of resource professionals including fisheries biologists, wildlife biologists, hydrologists, and both fire ecologists and fire management staff. Coordinated planning should include clearly defining objectives and designing projects accordingly. Seasonality, fuel/soil moisture conditions, and existing vegetation must be carefully considered in planning riparian projects to meet objectives.

- **Stop-gap measure- Reduce fire risk to riparian areas by reducing fuels and managing ladder fuels around riparian corridors to form a buffer.**

This will mitigate the ability of an actively burning fire to carry along the riparian corridor edge and into the more densely vegetated riparian areas and their canopies. Unfortunately, this does not completely safeguard a riparian environment containing highly flammable fuel loads from embers that land in the middle of a riparian-stream area that contains dry flammable fuels.

While the current recommendation is to buffer riparian areas with careful and regularly maintained fuelbreaks, note that it is becoming increasingly common to actively manage riparian vegetation as part of a larger watershed-scale or larger approach to fuels management. This has likely resulted from recent information on large-scale fire behavior, fire return intervals, and greater appreciation of linkages between riparian areas and uplands. Although riparian functions and characteristics need distinct consideration, stream-riparian corridors are part of the larger landscape, and need to be integrated into landscape level planning. Many land managers across the Western US, for instance, are too concerned about high riparian fuel loads to leave them unmanaged while uplands or adjacent areas are treated, so they include these areas in fuels management plans to protect them from high severity fire and to exert some influence on fire behavior to mitigate upslope travel. For this reason, the following longer-term recommendation is advised:

Wildland Type 3: Forest Edges and Forest Access Roads

One of the highest social, cultural, and ecological values to protect from fire in the Wahikuli-Honokōwai watersheds are the upland forested areas. The most vulnerable areas of the forest are those that are accessed by humans (roads and trails) and the forest edges, where wildfire traveling uphill can ignite fuels along the forest edge and forest floor and travel into the canopy. The *forest edge zone* is defined as the line where grass and other herbaceous groundcover ends[9]. The following treatments for this zone are recommended:

Forest Access Road Recommendations:

- **Implement roadside fuels reduction practices for forest access roads** to prevent ignition.
- **Maintain vehicular and pedestrian access limitations and signage** during periods when fuels are dry and highly ignitable.
- **Prepare field crews, landowners, and land managers with training and basic equipment** to immediately suppress any fires they accidentally ignite. Ensure rapid communication and reporting of fires by field crews, etc.

Forest Edge Recommendations:

- **Clear all dead wood, dead limbs, and dead vegetation from the forest edge zone** (defined above) to a minimum distance of 3 times the height of the tallest adjacent trees. (i.e. If trees are 30 ft. tall, clear a 90 ft. buffer).
- **Manage ladder fuels in the forest edge zone.** Due to the prevalence of fire prone non-native vegetation at the forest edge, this area is vulnerable to allowing fire to travel from surface fuels into the canopy. Maintain a reduced height of surface fuels (grasses and herbaceous groundcover) in the edge zone and limb low hanging branches of trees to create separation (minimum 10 feet) between fuel types. Do not limb branches that have foliage above 10 feet (contributing to canopy cover that assists in shading out grass). Remove any non-native shrubs and trees less than 10 feet in height that are posing ladder fuel vulnerabilities along the forest edge, unless with continued growth they will contribute to a closed canopy. Otherwise, prune as specified.

4. ***Tactical Fuelbreaks-*** The development of tactical fuelbreaks is the final priority fuels management prescription for Wahikuli-Honokōwai covered in this plan. Tactical fuelbreaks are strategic low-fuel zones arranged throughout the landscape that provide tactical opportunities during fire suppression. They are an essential management tool for maximizing firefighter access, providing defensible space, and increasing opportunities for quicker containment (and therefore minimal spread and impact).

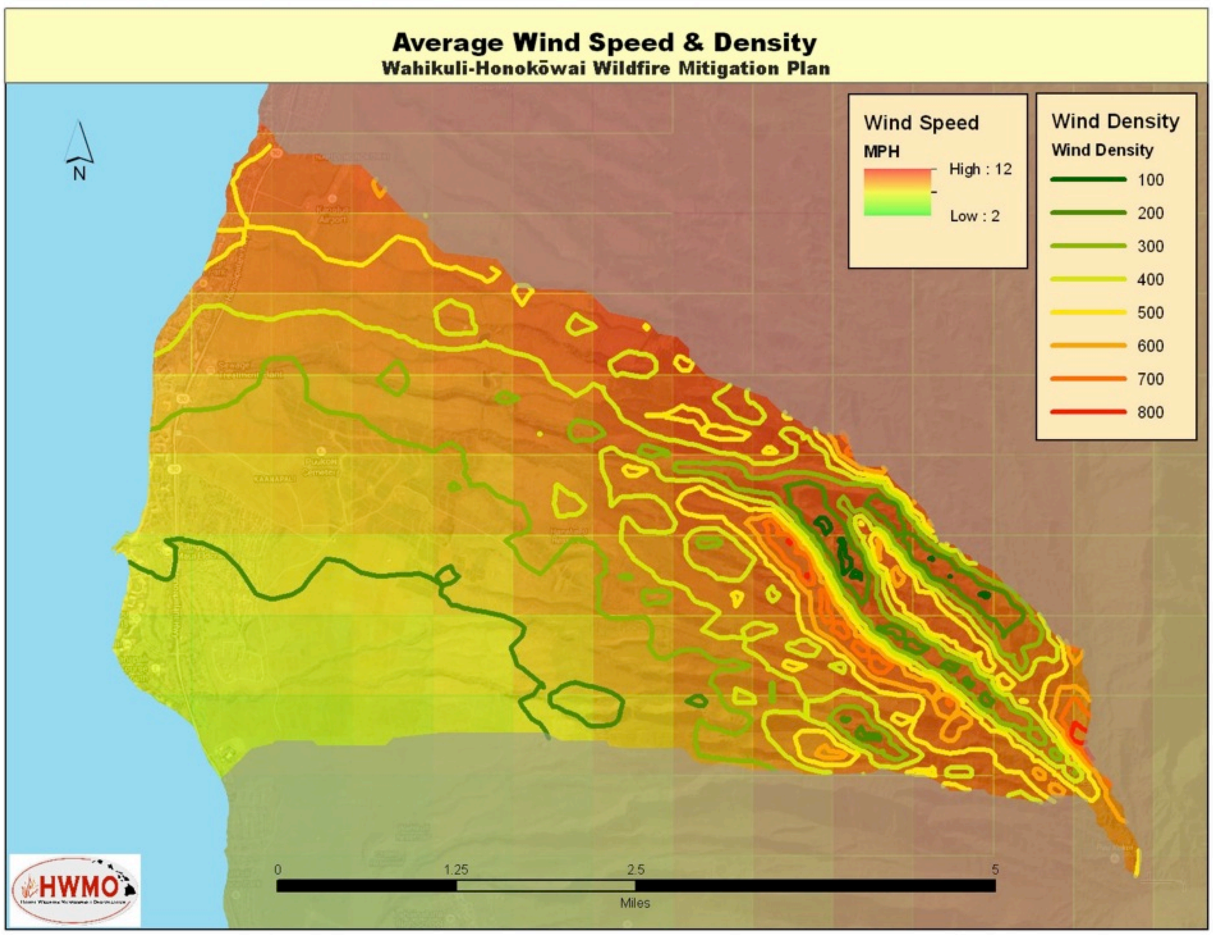
Tactical Fuelbreak Recommendations:

- **In consultation with local firefighting agencies, identify candidate tactical fuelbreak and firebreak areas** that could support fire suppression measures or provide fire crews with safe access**.** Plan all tactical fuelbreaks to ensure long-term, dry weather accessibility by fire suppression crews and water tanker trucks.
- **Integrate tactical fuelbreak development into all road planning** that takes place for natural resource management efforts and for proposed and new developments in Wahikuli-Honokōwai.
- **Integrate tactical fuelbreak development within the forest into existing and future natural resource and cultural resource management plans.**

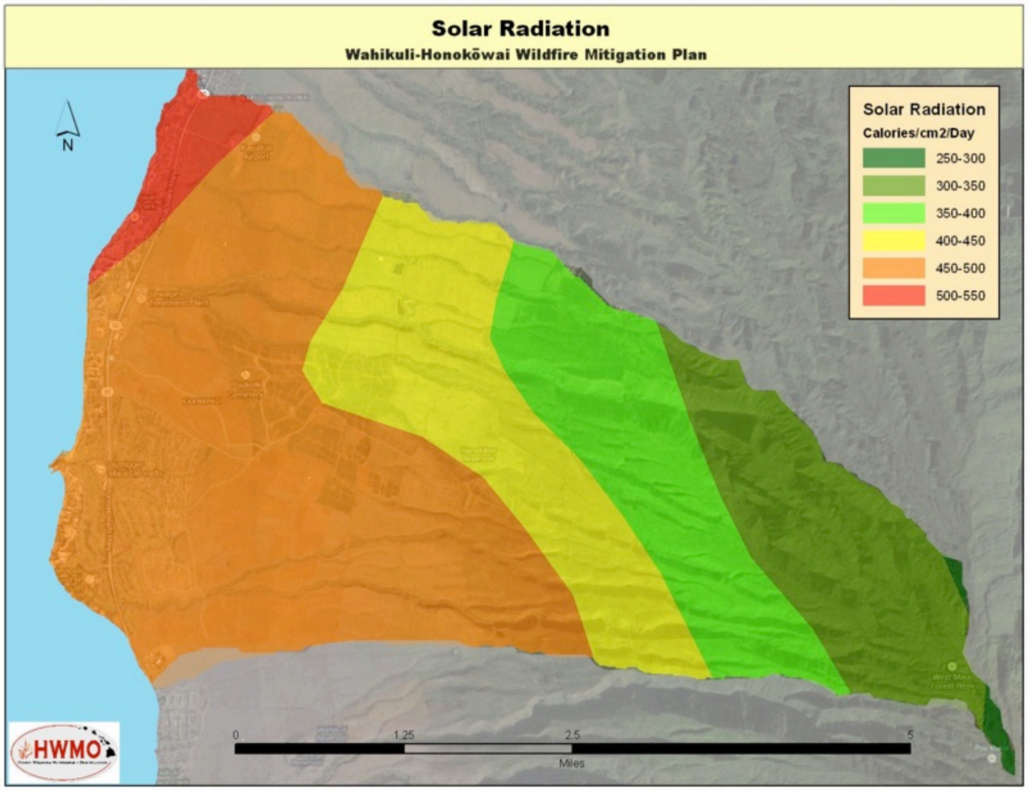
Map 9 displays areas for opportunistic fuels reduction along community edges, the wildland urban interface boundary, and lateral non-major roads (based on County of Maui 'other roads' data). These non-major roads, if still existent, could be suitable sites for opportunistic tactical fuelbreaks, depending on the expressed needs of fire managers.

Vegetation Management in Consideration of Weather and Topography

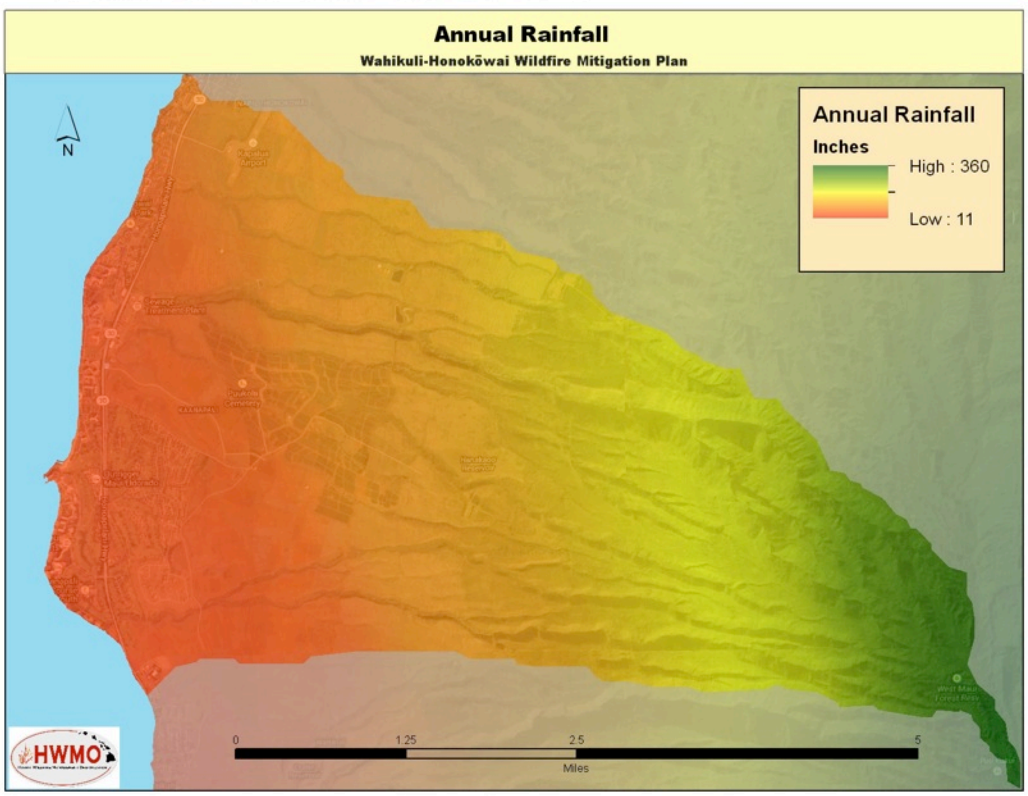
Maps 10-12 display average wind speed and density, solar radiation, and rainfall, which all contribute to fire potential and behavior. Minimal rain, high solar radiation and high wind speeds create a volatile environment if a fire is ignited. Wind speeds and densities tend to be highest at the northern boundary of the watershed. Eddies and pockets of reduced or higher winds occur around topographic features. These are demonstrated through the use of contour lines on Map 10.



Map 10. Average Wind Speed and Density.



Map 11. Solar Radiation.



Map 12. Annual Rainfall.

Weather and topography data can be used to prioritize mitigation treatments. Areas with strongest wind, least rainfall, highest solar radiation (most drying and heat), and steep slopes are of highest priority. Install fuelbreaks on the windward side of roads and communities first. Manage vegetation in the areas of least precipitation first. Weather and topography are also important considerations for post-fire stabilization, as well, when slope and rainfall are indicators of post-fire erosion potential.

The nearest long-term weather data set comes from a weather station in Lahaina.[10] The averages of data collected between January 1, 2000 and December 31, 2013 are as follows:

Max Temperature	81.66 °F	Max Humidity	79.58 %
Mean Temperature	75.90 °F	Mean Humidity	65.02 %
Min Temperature	70.13 °F	Min Humidity	53.85 %
Max Dew Point	66.88 °F	Max Wind Speed	30.02 MPH
MeanDew Point	64.35 °F	Mean Wind Speed	29.97 MPH
Min Dewpoint	61.34 °F	Max Gust Speed	14.95 MPH

Pre-Fire Mitigation:
Action Items Summary

Reduce ignition vulnerability:

- Address wildland-urban interface community sources of ignition.
- Control equipment-generated wildfire ignitions.
- Limit vehicular access during high fire risk conditions.

Manage vegetative fuels:

1. Private Property, Residences, and Subdivisions

- Provide educational opportunities and incentives for residents and homeowners.
- Support the development of community action teams or movement toward becoming a Firewise or Fire-Adapted Community.

2. Urban Interface

- Install and/or maintain fuelbreaks/firebreaks along community boundaries, aiming toward the development of fuel-free zones along the urban interface (outer edges of subdivisions) that are a minimum width of 3-4 times the height of standing fuel.
- Maintain or initiate roadside fuels reduction efforts along frequently used roads at a minimum width of 1.5 times the height of the adjacent fuels.

3. Wildland

Wildland Type 1: Grasslands and Fallow Post-Agricultural Areas

- Recommended Treatment- Utilize targeted grazing to reduce fuels.
- Stop-gap measures- Create a fuel mosaic by breaking up contiguous fuels.

Wildland Type 2: Riparian Corridors

- Stop-gap measure- Reduce fire risk to riparian areas by reducing fuels and managing ladder fuels around riparian corridors to form a buffer.
- Recommended Action- Develop a riparian fuels management plan.

Wildland Type 3: Forest Edges and Forest Access Roads

Forest Access Roads:

- Implement roadside fuels reduction practices for forest access roads to prevent ignition.
- Maintain vehicular and pedestrian access limitations and signage during periods when fuels are dry and highly ignitable.
- Prepare field crews, landowners, and land managers with training and basic equipment to immediately suppress any fires they accidentally ignite. Ensure rapid communication and reporting of fires by field crews, etc.

Forest Edges:

- Clear all dead wood, dead limbs, and dead vegetation from the forest edge zone to a distance equal to 3 times the height of the adjacent trees, from boundary.
- Manage ladder fuels in the forest edge zone.

4. Tactical Fuelbreaks

- In consultation with local firefighting agencies, identify candidate tactical fuelbreak and firebreak areas that could support fire suppression measures or provide fire crews with safe access.
- Integrate tactical fuelbreak development within the forest into existing and future natural resource and cultural resource management plans.
- Integrate tactical fuelbreak development into all road planning.

Preparing to Support Fire Suppression

Preparing Ahead of Time for During-Fire Operations
Effective fuels management within the Wahikuli-Honokōwai watersheds (above) will alter fire behavior across the landscape, protecting high value areas such as communities, forests, and riparian corridors through the creation of firebreaks, fuelbreaks, additional firefighting access, and a breaking up of contiguous fuels. These efforts represent an important first step to aiding firefighting efforts. Additional pre-fire support and preparation is also necessary to ensure firefighters have:

- Firefighting resources that are necessary to contain fires quickly and minimize the size of fires;
- A clear understanding of area-specific firefighting resources, priorities, and areas to avoid heavy equipment operations; and
- Necessary training to not only suppress fire but to also minimize impacts to the area through minimal impact suppression techniques (MIST) specific to Wahikuli-Honokōwai watersheds.

To prepare ahead of time for during-fire situations, it is essential that a fire management plan be developed for Wahikuli-Honokōwai. Additionally, an area-specific plan for use of minimal impact suppression techniques and post-fire correction of fire suppression damage will greatly aid in preventing post-fire erosion caused by the firefighting effort. Each of these recommendations is detailed below with background information and specific action items.

- **Develop a Fire Management Plan**

Wahikuli-Honokōwai needs a fire management plan. Developing a fire management plan is an important step toward bringing together land management and agency mandates, protection priorities, private landowner preferences, and landscape-level fuels management goals into one implementation plan. A fire management plan can be a tool for fire managers to use in directing wildland fire activities consistent with the goals and objectives identified in other planning documents[11]. It provides the context for understanding strategic decisions, selecting appropriate fire management responses and implementing the supportive tactical actions appropriate for specific lands and identified areas.

A fire management plan will likely be guided by other documents that describe general plans, goals, or mandates for fire preparedness and prevention, pre-fire mitigation, forest management, planned and proposed development, aviation management, pre-planned dispatch, and cooperative agreements. In addition to the Wahikuli-Honokōwai Watershed Management Plan, other important documents of reference will be the DLNR Division of Forestry and Wildlife Fire Management Five Year Plan and the Hawaii Statewide Assessment of Forest Conditions and Resource Strategy (SWARS, aka Hawaii Forest Action Plan) that complies with the National Forest Management Act (NFMA), the regulations for National Forest Land and Resource Management Planning, and the National Environmental Policy Act (NEPA). Plans related to the Clean Water Act such as the Coastal Non-Point Pollution Control Plan for Hawaii are also important to consult and follow.

The fire management plan should include all individuals and entities with jurisdiction in the area as collaborators. It should develop call lists for Incident Commanders to have on hand that includes landowners, agency contacts (public works, etc.), and cultural and natural resource experts. 'Call Lists' should also be developed for 'on call' experts and agency representatives who will need to be able to contact necessary police or incident commanders (for access or other specific needs) when called to service. The fire management plan will need to identify implementation authorities and agency/landowner jurisdictions, and include various procedures based on local and interagency needs. Examples include: a) Firefighter preparedness (including training, qualifications, readiness, detection and aviation); b) Records management- the fire management planning process is a good time to coordinate during- and post-fire mapping of fire boundaries for future analysis and mitigation planning; c) Pre-planning and data acquisition for incident decision support processes and tools (e.g. fire behavior modeling, water resources mapping, etc.); and d) Public interaction (e.g. information plans, Community Wildfire Protection Plans (CWPPs) or equivalent). Additional examples of procedures included in conventional fire management plans are as follows. However, many of these are already in place at the State-County level between Maui Fire Department and Hawaii State Division of Forestry and Wildlife:

- Cooperative or mutual aid fire management agreements.
- Cost apportionment agreements.
- Protection agreements.
- Cross-boundary fire agreements.
- Size-up, initial response and extended response procedures.

For Wahikuli-Honokōwai, it will be critical for the fire management plan to facilitate the development and/or update of any water use and access agreements between private landowners in the watershed and fire response agencies, particularly as reservoirs are decommissioned. The same is true for equipment use, as equipment that was once available for firefighting use from agricultural companies is no longer available.

The fire management plan will need to link to resource management, development, and municipal plans. It is extremely helpful if the plan can also identify any equipment assets and needs, and make a plan for securing what will be needed (by whom, where it will be stored, who can use it, etc.). The plan should identify and map:

1. Fire management 'units' (areas of land with like fire management strategies and characteristics and/or ownership and jurisdictional boundaries)
2. Sensitive cultural and natural resource areas
3. Areas for bulldozers and suppression efforts to avoid (native plant populations, cultural and archaeological sites, etc.)
4. Access
    - Gates, locks, and keys
    - Water sources and fire hydrant locations
    - Contact phone numbers

- Roads: conditions and widths
- Bridge loads
- Vehicle turn outs
- Safety zones
- Fire breaks

5. Operational information, such as:
    - Permanent repeater locations
    - Radio frequencies
    - Radio 'dead spots'
    - Communication plan
    - Evacuation plan
    - Water dip sites
    - Helispots
    - Remote automated weather stations (RAWS)
    - Potential fire camp locations

A comprehensive fire management plan includes specific goals, implementation schedules, and responsible parties for additional fire protection goals, such as: a) improving fire prevention outreach and community engagement, b) reducing hazardous fuels and creating both firebreaks and fuelbreaks, c) bolstering suppression resources such as equipment and access to water, and d) preparing ahead of time for immediate post-fire stabilization of soil and longer term post-fire response, rehabilitation, and restoration (see Section 4).

Finally, the fire management planning process should be followed by initial and repeat visits (as needed) to watersheds with landowners, land managers, Maui Fire Department and DLNR-DOFAW personnel to go over the mapped resources, areas/resources to protect, potential incident command and safe zone sites, MIST practices essential for specific areas, and other protocols, firefighting assets, and challenges identified in the fire management plan.

All relevant parties should be familiar and comfortable with the contacts and protocols established in the fire management plan well in advance of a fire. The plan should be revisited and updated each year if possible, every two years at minimum.

➢ **Work Toward Minimal Impact Suppression**

Fire suppression activities can create more damage than the fire itself and are usually a primary contributor to post-fire erosion issues. Potential firefighting and equipment impacts include soil disturbance, vegetation removal, and stream sedimentation.[12] In addition, fire retardant chemicals can be harmful to aquatic species and natural areas.

Minimal Impact Suppression Tactics (MIST) are designed to manage a wildfire with the least amount of impacts to natural and cultural resources. MIST provides guidelines that can be used in staff training and preparation exercises. To reduce the firefighting impact to the watershed, it is crucial to adequately and regularly prepare land management staff, fire fighting personnel and Incident Command leaders with general MIST guidelines and expectations as well as provide them with a MIST guide specific to Wahikuli-Honokōwai. The Hawaii State Division of Forestry and Wildlife Best Management Practices for Maintaining Water Quality[13] provides useful information, and numerous other publications from the national level exist to aid in utilizing MIST techniques.

It will be important to work with fire suppression agencies and dozer operators before fire season to review and discuss MIST strategies as they relate to Wahikuli-Honokōwai. The fire management plan (above) will have mapped and outlined areas to protect during the firefighting effort. These include threatened and endangered species, archeological or historical sites, riparian corridors, and any other sensitive features.

DURING-FIRE MINIMAL IMPACT AND POST-FIRE CORRECTIVE ACTION RECOMMENDATIONS:

- **Conduct site visit(s) with likely or potential Incident Commanders, firefighters, and bulldozer operators.** Coordinate initial and yearly onsite area-specific MIST trainings to discuss parameters for least-damaging fire suppression strategies and to prepare firefighters and bulldozer (dozer) operators with general MIST and Wahikuli-Honokōwai-specific information. These can be coupled with the broader fire management plan site visits or held separately. Discuss and plan what MIST decisions could be made in various firefighting circumstances, particularly near areas identified as sensitive. Site visits should occur before fire season each year, and initiated/coupled with the development of the fire management plan. If yearly refreshers are not possible, firefighters and bulldozer operators should be provided reminder checklists of do's and don'ts, at minimum.

- **Prepare to immediately implement corrective actions to damaging bulldozer work implemented during firefighting effort**. Bulldozer operations are by far the most damaging activity of firefighting, in terms of creating post-fire erosion potential. Ideally, before the dozer is released, dozer operators would restore the area to prevent erosion. Preferably, this would happen while the fire is still burning so the work will be paid for as part of the clean up since it is directly caused by the suppression effort. Unfortunately, the State and County do not currently include this in their fire suppression budgets. Doing so has strong precedent in the majority of states and federal lands. It is recommended that landowners and land management partners work toward revised bulldozer requirements or agreements toward corrective dozer actions for the final stages of fire containment and mop-up as part of suppression contract requirements. In the meantime, it is highly advisable to work toward having funds available and agreements in place to ensure bulldozer lines are reworked to reduce long-term impact and erosion potential before the first rain event. This can be contracted out if fire suppression agencies do not agree to assist in the effort to mitigate or correct fire suppression impacts and their associated hazards.

The full MIST actions list is extensive and a compilation is included in the External Resources Section. The inset below provides a brief summary.

Minimal Impact Suppression Guidelines- Some Basics[14, 15, 16]

Concept of MIST

The concept of MIST is to use the minimum amount of force necessary to effectively achieve the fire management protection objectives consistent with land and resource management objectives. The focus is how to suppress a wildfire yet minimize the long-term effects of the suppression action on the land. MIST may also require greater rehabilitation efforts than previously practiced.

MIST Tactics

Escape Routes and Safety Zones

- In any situation the best escape routes and safety zones are those that already exist (identify natural openings, existing roads and trails).
- Be particularly cautious with snags (standing dead trees) that have been allowed to keep burning, partially burned live and dead trees, and unburned fuels between you and the fire.

General Considerations

- Consider the potential for introduction of noxious weeds and mitigate by removing weed seed from vehicles, personal gear, hoses, cargo nets, etc. Equipment should be washed down prior to leaving the incident in order to prevent the spread of noxious weeds.
- Consider impacts to riparian areas when setting up water handling operations.
- Ensure adequate spill contaminant at fuel transfer sites and pump locations. Stage spill containment kits at the incident.

MIST Rehabilitation, Restoration & Evaluation

Rehabilitation is a critical need. This need arises primarily because of the impacts associated with fire suppression and the logistics that support it. The process of constructing control lines, transport of personnel and materials, providing food and shelter for personnel, and other suppression activities has a significant impact on sensitive resources regardless of the mitigating measures used. Therefore, rehabilitation must be undertaken in a timely, professional manner. During implementation, the resource advisor should be available for expert advice and support of personnel doing this work as well as quality control. See Appendix 3 for details and water bar spacing guidelines.

Inset 3. Basic Overview of MIST Guidelines

At the time of writing, the State of Hawaii is reviewing and considering new post-fire Bare Area Emergency Response (BAER) processes, which may improve the availability of funds for the corrective dozer actions and post-fire assessment, planning, and response. Additional information is not available at the time of writing and may impact future MIST and post-fire action steps.

Preparing to Support Fire Suppression:
Action Items Summary

- **Develop a Fire Management Plan**

- **Work Toward Minimal Impact Suppression**

  - Conduct site visit(s) with likely or potential Incident Commanders, firefighters, and bulldozer operators.

  - Prepare to immediately implement corrective actions to damaging bulldozer work implemented during firefighting effort (prepare funds and contractor list/agreements).

Preparing Ahead of Time for a Strong Post-Fire Response

Post-fire planning requires a great deal of organization well in advance of a wildfire event. This plan outlines preparations that can be made to have the foundations in place for a strong post-fire response. The action steps listed below will help prepare the Wahikuli-Honokōwai watershed partners ahead of time to deal with a post-fire situation. Having a trained team in place and a process for bringing it together, a decision-making strategy, and some general supplies and funds available will enable partners to act fast to prevent or slow erosion and safeguard riparian and coral reef ecosystems from sediment influx.

BAER, BAR, ESR, Post-Fire Team… What's the difference?

The U.S. Forest Service has its own burned area recovery program and funding process known as Burned Area Emergency Response (BAER). BAER focuses on emergency stabilization during and immediately after a wildfire event. A Burned Area Rehabilitation (BAR) process follows the days- to weeks-long BAER process for up to three years. The Wahikuli-Honokōwai Watershed Management Plan recommended a BAER plan, indicating the need for emergency soil stabilization and post-fire response preparedness. However, BAER and BAR are only funded for federal lands. Emergency Stabilization and Rehabilitation (ESR) is another similar federal program. It is a protocol developed by the U.S. Department of Interior (DOI) to restore areas damaged by wildfire. It is part of a long-term (3 years or more) process for recovery of burned areas. Currently, this inter-agency protocol is used only by the Bureau of Land Management (BLM), National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), and Bureau of Indian Affairs (BIA). ESR is designed to reduce erosion, restore burned areas to their pre-fire state, and reduce fuels available to future fires. ESR is implemented to ensure full compliance with environmental protection laws (e.g. NEPA). The DOI and USFS are working to streamline their fire damage response protocols and funding mechanisms, but currently the agencies operate under separate systems. Hawaii has only a few areas with access to BAER, BAR, and ESR resources and, at the state level, has no such formalized team. It does not yet have a funding mechanism to support one, especially for complex land ownership and jurisdictions. For this reason it is vital to form an informal team of experts and work through how and if their time would be covered to participate in a post-fire response assessment for Wahikuli-Honokōwai. Certain entities, such as University of Hawaii Cooperative Extension Service, are available at no cost to land managers and may be a good starting point for requesting expertise and involvement to address post-fire erosion reduction.

Inset 4. Description of Federal-Level Post-Fire Response Efforts and Acronyms.

It is important to note the different stages of post-fire measures, as the goals, prescriptions, and time scales for each of these stages vary. The bulk of the post-fire response discussion and action items in this plan are focused on emergency stabilization. This is both because it is the most critical period for erosion prevention after a fire, and because rehabilitation and restoration plans will vary according to landowner preference and future land uses of each parcel. The post-fire response stages are defined below:

> ***Emergency Stabilization*** – Stabilization consists of planned actions that occur immediately after a fire, ideally before the first rain event. All measures usually take place within one year (maximum) of a wildfire event to stabilize soils and prevent further damage to natural and cultural resources. Stabilization actions may be physical improvements made to minimize threats to life and property and degradation of natural resources. The post-fire team will conduct a post-fire assessment, which is a rapid

assessment of the burned area and its potential impacts, to determine if emergency stabilization treatments are needed.

Rehabilitation – Rehabilitation efforts occur within three years after the wildfire, and after the burned areas have been stabilized. The purpose of rehabilitation is to repair lands that would not otherwise recover to an acceptable management condition. Rehabilitation techniques include planting and earthwork to mitigate longer-term erosion and other post-burn damages.

Restoration – Restoration occurs on the longest time scale. Restoration extends and expands the rehabilitation efforts to fully return an area to a healthy and thriving ecosystem. This includes restoring watershed function and long-term protection of natural and cultural resources.

The needs and order of events immediately after a fire to work toward emergency stabilization are as follows:

At 80% containment:

1. Identify dozer lines and assess for post-fire erosion potential.
2. Implement corrective actions if possible during mop-up, otherwise implement corrective actions immediately after containment.

Immediately after containment:

1. Complete any last dozer line corrections.
2. Conduct post-fire assessment.
3. Develop emergency stabilization plan.
4. Implement stabilization measures.

In order to achieve each of these activities, various preparation steps are required. Each is explained below.

POST-FIRE PREPAREDNESS RECOMMENDATIONS:

- **Develop a Clear Understanding of Future Land Use Plans and Preferences**

Having a clear understanding of current, near-term future, and long-term future land use plans for all parcels within the watershed will be vital to having a strong and effective post-fire response. Most post-fire actions will need to take future land uses into consideration when devising treatment strategies, as some situations will have multiple options for emergency stabilization. The selected emergency stabilization strategies for an area that is planned for development in the near-term could be the same *or* very different than for an area planned for conservation. For example, there may be trade-offs between planting slower-growing native plants and fast-growing non-natives. It will depend greatly on the cost-benefit analysis of erosion control in the short-term and longer-term objectives for the area. Either way, the area is prioritized for treatment, but the strategy can vary to take best advantage of the situation for landscape protection and other goals. For this reason, one of the recommended action items is to develop a list or map of current, near-term, and future land use goals for each parcel within the watersheds. This list and/or map will be used by the post-fire team.

- **Secure Post-Fire Response Materials**

While it is impossible to predict the types and numbers of materials to secure ahead of time to be prepared for a strong post-fire response, Section 4 provides details of potential treatment options and likely post-fire erosion issues. Having enough supplies on hand to initially address a 100-acre fire will allow urgent emergency treatments to be installed in the highest priority areas immediately after a wildfire event while additional supplies are secured. Approximate cost ranges for purchasing materials for this purpose are included in the Appendix.

- **Develop a Post-Fire Response Team**

It is also critical to have a Post-Fire Response Team in place before fire season starts so that post-fire action can start without delay. The following team member expertise is recommended both before the fire is completely contained (Team A) and in the immediate post-fire period (Post-Fire Team). Depending on funding arrangements for correcting dozer impacts, Team A may be called in at 80% containment to assess any firefighting impacts that need corrective action before suppression equipment is released. This involves anticipating post-fire impacts left by the firefighting effort and communicating recommended dozer corrective actions to the Incident Command and/or mop-up crew. The protocols for this should be laid out in the fire management plan or by previous discussion and planning with fire suppression agencies, as most agencies in Hawaii do not traditionally consider this part of the final containment and mop-up tasks. However, this is standard practice at the federal level and in many jurisdictions across the United States. There is precedent set for this elsewhere, and options and protocols for this type of erosion mitigation should be explored for Wahikuli-Honokōwai.

At the time of writing, the State of Hawaii is evaluating if and how it might develop a state Bare Area Emergency Response (BAER) Team for state lands. In the interim, and especially because it contains more than state-owned land, it is strongly recommended that Wahikuli-Honokōwai develop its own watershed-specific team of expertise that can assist toward a strong post-fire response to safeguard the landscape and values at risk, as well as post-fire actions to fix dozer damage. The following table outlines the type and timeline for the various expertise needed.

Table 3 below provides a list of types of expertise recommended for the Post-Fire Team, including Team A, as well as when their expertise would likely be needed.

- **Prepare the Post-Fire Team with knowledge of Wahikuli-Honokōwai**

Once individuals are selected, prepare team members by touring the watersheds. Discuss and review:

- Priority areas to protect and areas with highest erosion potential.
- Goals for each property, current land uses, and the anticipated future land uses. These provide the baseline for post-fire decision-making and actions.
- Fire Management Plan and areas that are to be avoided by dozer operations.

When needed onsite to evaluate burned area	Referred to as... throughout this document	Expertise needed
80 % Containment and immediately after containment	Team A	• Team Leader • Area-Specific Environmental Specialists, such as watershed partnership coordinator or watershed coordinator • Hydrologist and/or Erosion Control Specialist • Road or Civil Engineer
Immediately after containment	Post-Fire Team (Includes Team A)	• Team A above, plus the following: • Soil Scientist • Stream or Aquatic Biologist/Ecologist • Forester • Botanist • Rangeland Specialist • Cultural Resource Specialist • GIS Specialist • Geologist • Document Specialist (for permits, titles, legal requirements, legislation) • Public Information Officer and Community Liaison • Interagency Coordinator • Larger fires may need an expert to perform a cost-benefit analysis

Table 3. Expertise Needed on Post-Fire Teams and When They Should Plan to Arrive (Team A depends on funding arrangements for dozer corrections).

➢ Develop Post-Fire Go-Time Plan

In addition to preparing the Post-Fire Team, it will be necessary to develop a plan and set of protocols for team member assistance in the event of a fire. This plan will need to include:

- Communications/contact plan for calling team into action.
- Funding mechanisms for travel and time (if necessary).
- Travel plan (lodging, transportation, etc.).
- General 'order of events' for touring site, assessment, planning, and taking action.
- Expectations of team members, memoranda of understanding for assistance (if necessary).
- Protocols and/or agreements with landowners and fire agencies for team to gain access to burned areas at 80% containment and after.
- Media plan or protocols for releasing post-fire treatment information to public.

➢ Prepare for Post-Fire Assessment and Planning

Once called to action and assembled to address a wildfire event, the Post-Fire Team will need to conduct a post-fire assessment. The objectives of this assessment are to:

- Identify potential impacts of firefighting and provide input for corrective action (Team

A only, if dozer corrections are funded by agency completing mop-up; otherwise the full Post-Fire Team may be involved in this after the fire is contained).

- Assess and map the burned area, burn severity, and areas of high risk for erosion.
- Identify significant post-fire threats to human life and safety, property (roads, trails, structures, infrastructure facilities), and critical natural and cultural resources. This includes downslope areas that will be affected during post-fire rain events.
- Enable the planning and implementation of immediate actions to manage unacceptable risks.

The post-fire assessment process is a rapid assessment process, not a detailed survey. The early stages of the post-fire assessment should take place while the fire is still being contained (at 80% fire containment). The next stages of the assessment and subsequent planning processes should be completed within seven days of 100% fire containment. [17] Communications, reporting, and funding protocols should be developed ahead of time so that the post-fire team has a clear idea of who will receive the report and recommendations, who will be able to implement the recommendations, and what their funding and staffing assets and challenges may be. All of these are important considerations after the assessment team completes the assessment and creates an implementation plan. Online training is available for the Post-Fire Team from the U.S. Forest Service Moscow Forestry Sciences Laboratory.[18] The post-fire assessment phase is generally comprised of two phases— 1) assessment and 2) planning. Priority steps within each phase are provided below.

1) Post-Fire Assessment Phase I- Assessment

The assessment process includes the following:

At 80% containment:

- Identify and communicate the fire suppression impacts that can be reduced or corrected during the mop-up phase using bulldozers and other onsite equipment.

After containment:

- Measure and map soil burn severity- Has the fire changed soil properties related to its capacity to absorb precipitation, affecting the potential for erosion? Soil should be assessed for changes in surface soil structure, consumed fine roots, hydrophobicity, and more. Delineate unburned, low, moderate, and high burn severity areas to aid in prioritizing treatment areas.
- Identify 'values at risk' (which include human life, property, structures, roads, utilities infrastructure, communities, riparian areas, and cultural and natural resources).
- Estimate the probability of a damaging consequence to the 'values at risk' and determine risk level. Determine if there is an emergency or if natural regrowth will occur rapidly enough to prevent erosion and protect 'values at risk' during the next rain events.

2) Post-Fire Assessment Phase II- Planning

Following an assessment that has determined emergency action is needed, the Post-Fire Team will conduct a planning process to select treatments. Prescribed treatments will be selected according to the following standards and should:

- Substantially reduce the risks

- Be proven effective
- Be implemented before first damaging storm or rain event
- Be cost effective
- Identify and address hazards associated with the treatments
- Fit within the capacity of funding and management entities
- Be coordinated with other agency, landowner, and land manager post-fire planning efforts and land-use plans
- Follow federal, state, and county regulations and best management practices

➢ **Develop a plan for funding and implementation of post-fire treatments**

If treatments are feasible, the funding or management entity should begin necessary measures to secure supplies, ensure labor or contract service providers will be available, coordinate implementation details, etc. With the understanding of funding and implementation capacity of the landowners and land management entities developed ahead of time, the team will have the information at hand to quickly undertake this step. Treatments will be assigned for areas based on effectiveness and achievability. Preparing for a strong post-fire response must include preparing for the expenditure of funds for erosion control materials, labor, and contracted services.

Preparing Ahead of Time for a Strong Post-Fire Response: Action Items Summary

- ➢ **Develop a list and/or map of long-term land use and desired future uses for each parcel.**
- ➢ **Secure post-fire stabilization materials.**
- ➢ **Develop a Post-Fire Response Team** (Team A may come early to assess dozer damage at 80% containment, and the full Post-Fire Team [including Team A] will complete the post-fire assessment and planning process immediately after containment).
- ➢ **Identify and develop a plan for funding and implementation of any post-fire treatments.**
- ➢ **Prepare the Post-Fire Team with knowledge of Wahikuli-Honokōwai.**
- ➢ **Develop the Post-Fire Team Go-Time Plan for calling Post-Fire Team into action.**
- ➢ **Prepare the Team with a plan and training for conducting the post-fire assessment and planning process.**

Section 3- During Fire:
Enacting the Post-Fire Team Go-Time Plan

Section 3- During Fire

Enacting the Go-Time Plan

The Post-Fire Team Leader will call Team A into action to assess firefighting impacts that need corrective action before suppression equipment is released or immediately afterward if these actions will be privately contracted immediately after the fire. This includes: 1) anticipating post-fire impacts left by firefighting efforts and 2) communicating recommended dozer corrective actions to Incident Command/ Mop-up Crew according to the protocols developed during the fire management planning process and the Post-Fire Team development process. If this is not feasible due to fire suppression agency limitations on funding and mop-up activities, Team A can arrive with the rest of the Post-Fire Team immediately after containment instead and assess dozer damage and corrective action needs at that time. Funds should be in place ahead of time for contracted services to implement corrective actions deemed necessary to offset damages created by fire suppression activities that may lead to post-fire erosion.

DURING-FIRE RECOMMENDATIONS:*

- **Call Post-Fire Team into action**. Depending on funding arrangements for dozer corrective actions, Team A may come at 80% containment of fire. The rest of the Post- Fire Team will begin to arrange travel, etc. for arrival immediately post-fire.

- **Coordinate necessary permissions and logistics and tour fire-affected area with team.** This should be relatively simple because agreements between landowners and fire agencies should already be in place, as per the Fire Management Plan.

During Fire:
Action Steps Summary*

- **Call Post-Fire Team into action (Team A to arrive at 80% containment and full Post-Fire Team to arrive immediately after containment).**

- **Coordinate necessary permissions and logistics and tour fire-affected area with team.**

* These recommendations and actions steps are relevant and possible if and only if the Post-Fire Team was established pre-fire as recommended in Section 2.

Section 4- Immediately After Fire
Emergency Stabilization

Section 4- Immediately After Fire

Post-Fire Emergency Stabilization
Immediately following a fire, the Post-Fire Team will assess the specific damage and erosion risks resulting from that fire and create a plan to address the specific issues in each locale (see page 43). There will be a different erosion stabilization plan for each fire that takes place in the watersheds. These plans are site-specific and tailored to the needs and conditions of each burned area. Common potential erosion "hot spots" that need treatment can occur on steep hill slopes and roads. It is also important to implement measures to protect stream channels, nearshore areas, and the ocean from sedimentation resulting from post-fire erosion. Post-fire erosion and sediment control is more critical after a wildfire event in a watershed than at almost any other time. It can become a worst-case scenario if you have a high-intensity rain event over highly erodible, severely burned land.

There are numerous techniques that are considered effective in stabilizing soils immediately after fire. However, the techniques used in each specific circumstance and their efficacy will depend on factors such as size of fire, location of fire, severity of fire, topography, anticipated rain intensity and how soon rain will occur. Proximity to riparian areas, cultural resources, and urban developments are also important considerations, often referred to as "values at risk" in post-fire resource documents and guides. Certain techniques are most applicable or effective on hillslopes, roads, near riparian areas, and to best protect nearshore resources. Some depend on availability of water for irrigation, access for transporting and installing materials, and other considerations or challenges that may be unique to each burned area. HWMO has created numerous maps of the area for the Post-Fire Team to use as baseline information, all of which are included in the Appendix.

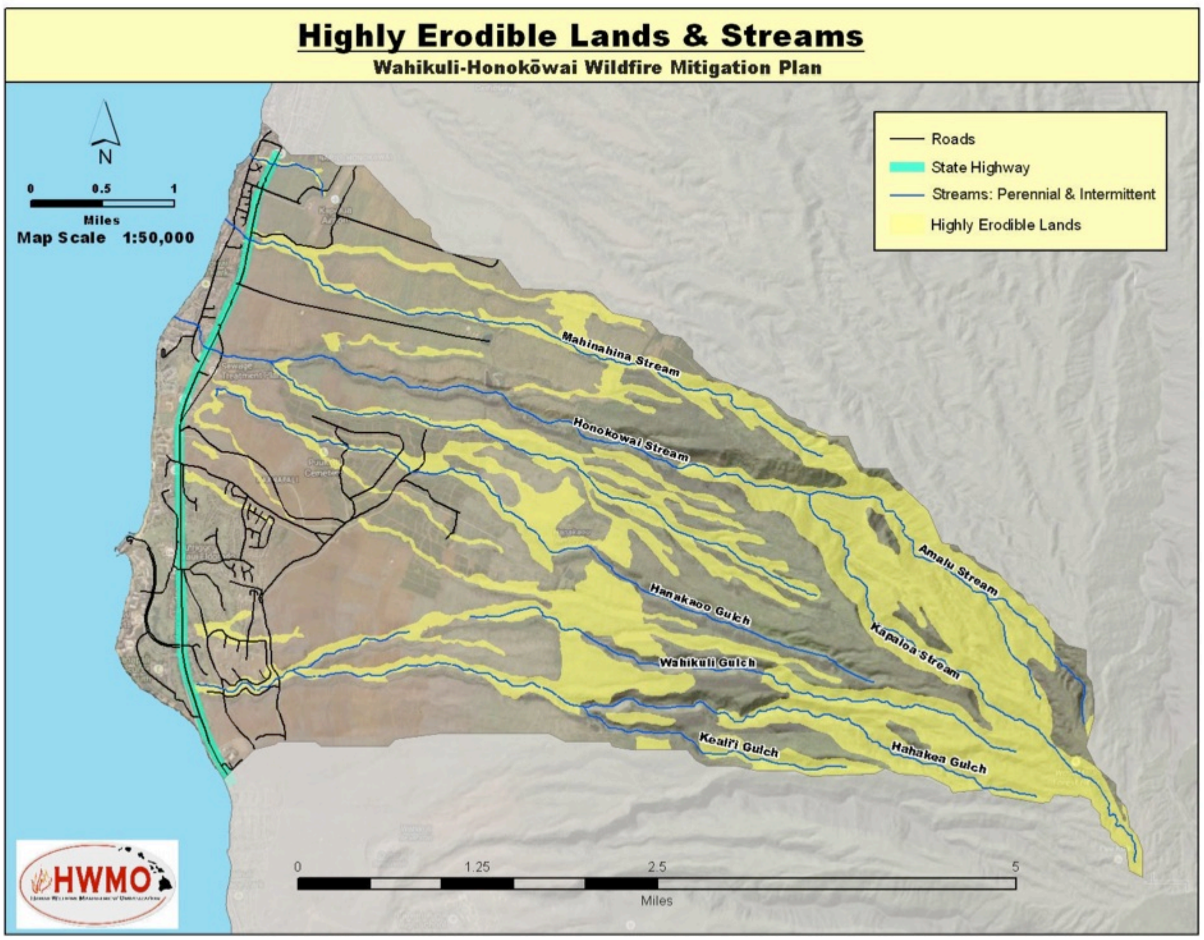
Excellent sources of specific information, strategies, considerations, and precautions about specific treatments are available from the following sources and should be consulted during the post-fire assessment, planning, and implementation processes:

- Bare Area Emergency Response (BAER) treatments catalog [19] and other BAER tools.[20]
- Natural Resource Conservation Service (NRCS) Field Office Technical Guides (FOTG) Standards and Specifications related to erosion and sediment control, among them:
    - Channel bank vegetation (322)
    - Deep tillage (324)
    - Conservation cover (327)
    - Conservation crop rotation (328)
    - Residue and tillage management (329)
    - Contour farming (330); cover crop (340)
    - Critical area planting (342)
    - Diversion (362)
    - Field border (386);
    - Filter strip (393)
    - Grade stabilization structure (410)
    - Grassed waterway (412)
    - Mulching (484)

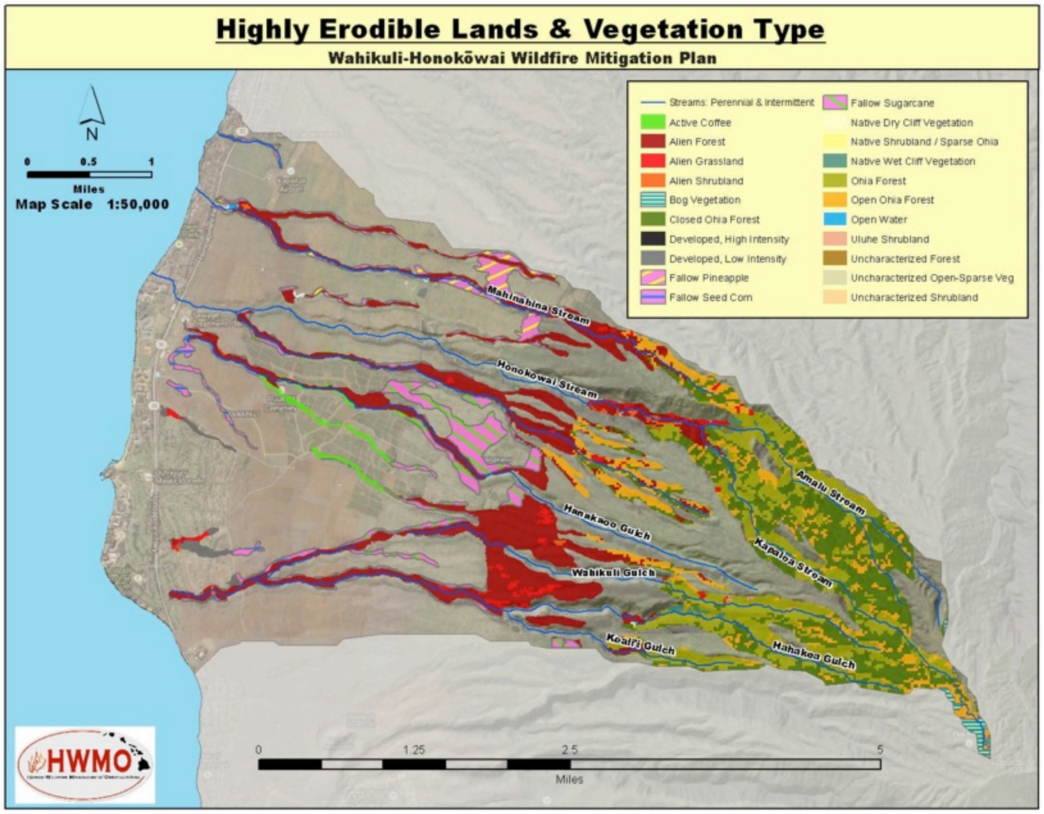
- Sediment basin (350)
    - Stream bank and shoreline protection (580)
    - Strip-cropping (585)
    - Terrace (600)
    - Water and sediment control basin (638)

  Each of the above are included in the Appendix.
- Hawaii DLNR-DOFAW Best Management Practices Guide for Maintaining Water Quality in Hawaii.[21]
- Hawaii's Management Measures for the Coastal Nonpoint Pollution Control Program.[22]

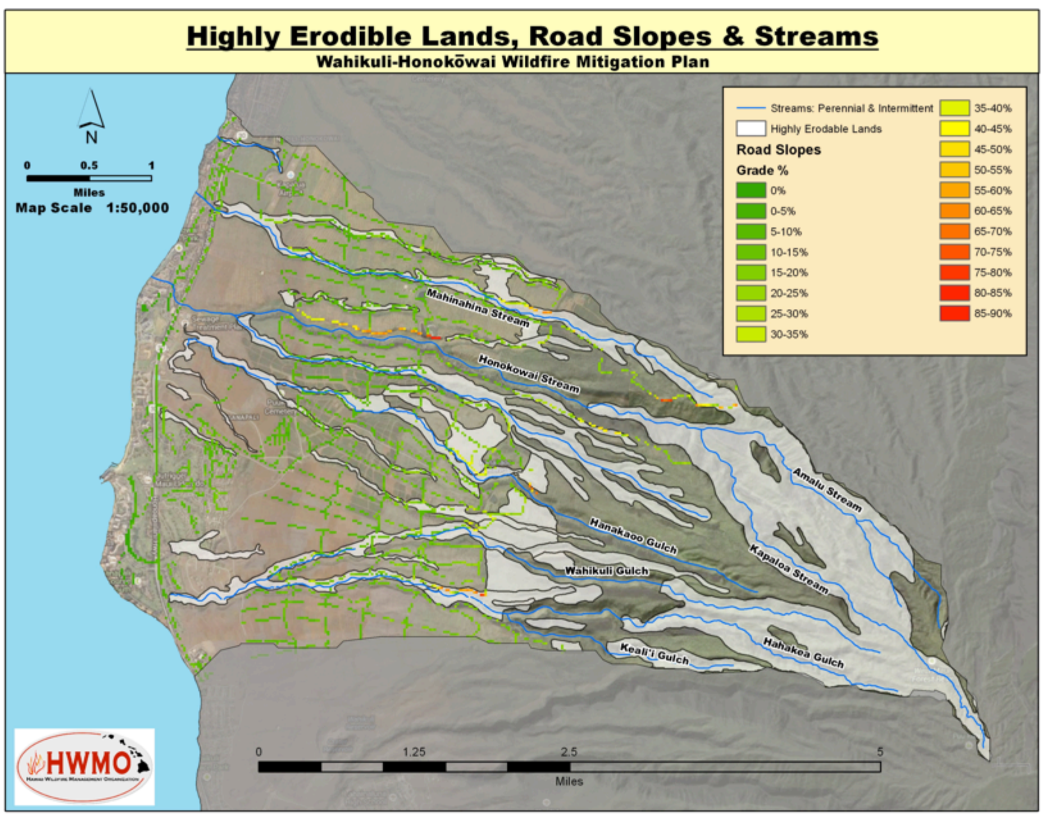
It can be useful to understand ahead of time what the concerns may be in each type of area and what some of the options are for mitigating post-fire erosion in Wahikuli-Honokōwai. The following maps (Maps 13-15) provide an overview of highly erodible lands within the watersheds.



Map 13. Highly Erodible Lands and Stream Channels.



Map 14. Highly Erodible Lands and Vegetation Types.



Map 15. Highly Erodible Lands, Road Slopes, and Streams.

Key Emergency Stabilization Zones and Strategies
Hillslopes
It is well documented that the potential for hillslope erosion increases after a wildfire event. The extent of the increase depends on burn severity, topography, soil type, soil moisture, and groundcover (live and dead vegetation). Rainfall, runoff, wind, and gravity are the main drivers of post-fire hillslope erosion. The gradient, length, and shape of the slope contribute to the erosion response. The erosion response is also extremely dependent on rainfall characteristics such as intensity and amount.

Pre-fire vegetation acts as a buffer between the atmosphere and soil— above-ground plant material absorbs the impacts of raindrops and below-ground material contributes to the mechanical strength and stability of the soil.[23] Wildfires can affect hydrologic conditions by exposing soils to raindrop impact and by increasing the hydrophobicity of soils (decreasing infiltration).[24] Additionally, soils exposed to high temperatures during a fire can increase the soil erodibility.

When a high severity fire results in substantial changes to the hydrologic conditions, runoff and peak flows dramatically increase, leading to flooding, channel incision, debris flows, and downslope sedimentation.[25] Ultimately, this leads to nearshore sedimentation, affecting coral reef habitats, fisheries, and economies associated with nearshore resource use.

Hillslope Treatment Considerations: [26]
The following factors will affect treatment needs and efficacy:

- ***Rainfall-*** Potential rainfall amounts, intensities, and seasonal patterns directly impact post-fire hillslope treatment effectiveness.
- ***Wind (Dry Ravel)-*** Destabilized hillslopes are created when wildfires consume plant roots and ground cover that hold soil on hillslopes and can result in large increases in wind-driven erosion (dry ravel) in the first year following a fire. The wind-transported material is often deposited in channels where it becomes a sediment source for water-driven transport in subsequent wet season rains, contributing to riparian and downstream sedimentation issues. Treatments that protect soil from wind are important in high-wind areas (see Map 10).
- ***Topography-*** The erosion rate generally increases as slope and hillslope length increase. The drainage pattern can concentrate or dissipate erosive energy. Longer flow paths and convergent hillslopes (swales) allow overland flow to concentrate and increase erosive power causing the majority of hillslope erosion.
- ***Fire/Burn severity-*** Fire/burn severity is measured by the degree of soil heating and vegetation mortality. Higher burn severity is associated with larger and more rapid watershed responses (such as erosion and flooding) to rainfall.
- ***Soil burn severity-*** The fire effects of soil heating and the consumption of organic material on the soil surface and near-surface lead to changes in soil properties that generally reduce soil infiltration rates and increase soil erodibility. The Post-Fire Team will map soil burn severity and use it to prioritize areas for treatment.
- ***Amount of bare soil-*** The amount of bare soil is an important factor used to map burn severity and has been positively related to post-fire erosion rates. There is evidence

that post-fire erosion is reduced when various types of mulch are used to provide protective post-fire ground cover to reduce raindrop impact.

- ***Hydrophobicity or soil water repellency-*** Since soil water repellency can be assessed more easily than infiltration rates, post-fire soil water repellency is often used to estimate the potential reduction in infiltration rates.
- ***Soil erodibility-*** Generally, soils with greater infiltration rates, higher levels of organic matter, and improved soil structure are less erodible.
- ***Time since fire***- Natural recovery of vegetation reduces erosion over time. However, recovery rates vary by climate and vegetation type.

Hillslope Treatments

There is no single best approach to post-fire hillslope stabilization. The Post-Fire Team will have to match any treatment recommendation to the specific environmental and climatic factors, burn conditions, and probable hydrologic responses of the burned area. If natural regrowth will occur and stabilize the soil quickly, emergency stabilization treatments may not be needed. The Post-fire Team will determine the best course of action; particularly as the future land use and goals for the area are taken into consideration. However, in areas where burned hillslopes with high erosion potential are adjacent to stream channels, drainages, or riparian areas, these areas should be treated first to prevent sediment transport downstream to nearshore areas.

The key to reducing post-fire erosion is to maintain, supplement, or otherwise increase groundcover in order to cover bare soil and to capture sediment before it is transported into stream channels or along untreated roads. Common post-fire hillslope erosion control treatments include: mulching, erosion barriers, and seeding and planting (usually in combination with mulch or erosion barriers).

In many cases, mulch is the most effective treatment for covering soil and reducing erosion immediately after a wildfire event. For the purposes of erosion control, it is important to leave existing vegetation if the plants do not threaten personal safety or property (hazardous trees in danger of falling should be identified first).[27] For Wahikuli-Honokōwai, there are several local mulch options, including bagasse, wood chips, cut guinea grass, and more. See Appendix D for local vendors. Mulch is defined as materials spread over the surface of the soil to reduce raindrop impact, water flow over the land, and erosive action. It is an excellent immediate treatment for the stabilization of hillslopes because it reduces erosion potential effectively and immediately. It is often combined with seeding (see below) because it aids in retaining soil moisture. There are two types of mulch— wet mulch (usually hydromulch that is mixed with water and applied across the surface of the affected area) and dry mulch (often straw, but bagasse, guinea grass, and wood chips are viable local options). Using materials from nearby sources will aid in reducing the high transport costs and travel times associated with off-island or mainland materials (see Appendix D for local insight on bailed guinea grass as a mulch source). It will also reduce the likelihood of new weed species seeds and accidental introductions of exotic species not currently on the landscape. Hydromulch is more resistant to wind and sticks better to the soil surface, and can be combined with seeds of desired species. It is best used on shorter slope distances, as it is does not uphold well against large flows and degrades quickly.

Erosion barriers, which are structures designed to slow runoff and capture eroded sediment, are also viable options for hillslope erosion control. When properly designed and installed, these barrier treatments can assist with increasing infiltration, slowing erosive energy, and reducing sedimentation that would otherwise travel downslope into stream channels and into the ocean. Erosion barrier treatments include wattles (long mesh tubes most often filled with straw), filter socks (similar to wattles except made from different materials), hand or machine-dug contour trenches, and straw bales. Wattles and filter socks can be laid out in staggered rows across the affected areas, are flexible, easily transported by truck or helicopter, and easily rolled out across the landscape. However, the materials can be expensive and often have to be shipped from elsewhere, creating a concern about exotic weed seeds. If wattles or filter socks are selected, choose a vendor that supplies weed free materials. Erosion barriers are not permanent solutions, but rather emergency stabilization treatments that reduce erosion for the first few rain events after the fire while other longer-term rehabilitation or restoration treatments can be planned and implemented, or until vegetation returns, roots begin holding soil, and vegetation or leaf litter protects soil from raindrop impacts

Combining seeding or planting with mulching or erosion barriers is very common on post-burn lands. Seeding and planting are additional treatment options, especially as current and future land uses are taken into account. Seeding and planting are important if vegetation is not anticipated to return quickly, if the returning plant community is not desirable, or to ensure plant regrowth occurs before erosion barriers expire. Seeding and/or planting can provide an opportunity to direct the plant community toward something more desirable or aligned with long-term plans for the area.

There are numerous seeding and planting techniques, depending on the selected species. Both natives and non-natives can be used. For fastest protection, seeding with grass is most effective and can be used to create nutritious and palatable forage for grazing if that is a desired post-fire land use. However, if this is an area identified in long-term plans for native plant restoration, then seeding/planting the area with a fast growing native species may be more appropriate.

Unfortunately, the use of native plant seeds for erosion control in Hawaii is a challenge. There are two major factors that influence the use and applicability of native seeds—the lack of large quantities of native seeds and of technology to successfully apply and establish native seeds over large parcels of land.[28] HWMO has contacted land managers across Hawaii who have conducted seeding, planting, and restoration efforts on degraded, denuded, and post-fire landscapes and has developed a list of lessons learned about seeding and planting native plants that may be appropriate in Wahikuli-Honokōwai (see Appendix). HWMO also recommends consulting relevant resource documents such as those listed above and those in the Appendix for standards, specifications, and guidelines relevant to Maui County. There is often relevant and useful information in these documents for post-fire seeding and planting, but it is classified as soil conservation cover (see pg 27, Vol II of Wahikuli-Honokōwai

Watershed Plan), row cropping, or by other identifiers as opposed to post-burn or post-fire seeding and planting. The strategies for traditional seeding and erosion control planting methods are applicable to many post-fire situations. However, emergency stabilization requires the use of techniques that will most-rapidly restore groundcover, and only those with proven speedy and reliable growth should be selected.

Finding a source of seeds and plants can also be challenging. The following are options for dealing with this issue:

- Purchase or collect seeds (following all relevant regulations) ahead of time and ensure/find proper storage.
- Develop a relationship with the plant growers and/or seed providers so they will have seeds and plants on hand in case you need them.
- Purchase or collect seeds (following relevant regulations) or plants ahead of time and maintain a nursery in preparation for post-fire planting.

Keep in mind that the primary purpose of emergency stabilization of hillslopes after a wildfire event is to prevent or reduce erosion. Fire strips land of vegetation, making it more susceptible to erosion via high winds or rain events; therefore, it is critical to implement measures to stabilize soil as soon as possible. Longer-term rehabilitation and restoration can focus more extensively on directing the plant community toward long-term goals. The costs and benefits of slower growing native species versus rapid stabilization of soils need to be carefully considered when choosing a treatment. A loss of soil immediately after a wildfire can stymie longer-term restoration efforts. Therefore, post-fire stabilization, rehabilitation, and restoration are most often accomplished through a sequence of prescriptions rather than all at once.

Key emergency stabilization techniques for hillslopes in Wahikuli-Honokōwai and their approximate costs are included in the table below. Please see the reference documents listed above (BAER Treatment Catalogs, NRCS Standards and Specs, and other state guidance documents for best management practices and specific guidelines for each treatment). The treatments included here are those identified as most relevant and appropriate for Wahikuli-Honokōwai. Additional treatment options can be found in the BAER treatments catalog.

Hillslope Treatments Treatments to slow water flow, increase infiltration, and trap sediments				
Erosion Treatment	**Description**	**Estimated Cost/Acre**	**Considerations**	**Notes**
Mulching	Mulch protects bare soil from erosion. Use local mulch when possible to reduce costs, avoid exotic seeds, and decrease transport time. Protects from raindrop impacts and erosive energy.	Hand Mulching: $500-$1,200 Heli-Mulching: $250-$950	Apply 2-3 in. deep (1-2 tons per acre). Straw mulch not recommended due to potential for weed seeds to spread. Bagasse, guinea grass, and wood chips are viable local options for mulch.	Mulching is immediately effective to protect bare soil. Unclear how quickly bagasse breaks down and loses protective effect.
Erosion barrier treatments: - Wattles - Filter socks - Fiber rolls	Long tubes of plastic netting filled with straw or other material—traps sediment, increases infiltration, reduces slope length & erosion.	$1,100-$4,000	Can bend to contour of slope. Easily installed and moved into location. Best used on slopes under 40%. Shipping can be expensive. Potential weed source, purchase weed-free.	Purchase from supplier. Not a long-term solution, but effective for controlling erosion from first few significant rain events.
Seeding	Less effective for emergency stabilization. Reseeding with non-native grass or native seed/shrub mix for long-term stabilization and vegetation conversion.	$20-$170	Combine with mulching or other conservation cover effort. Consider hand-held cyclone seeders to expedite seeding.	Recommend testing sites first with fast growing native & non-native species (see species list in Appendix).
Planting	Less effective for emergency stabilization. Plants and roots slow water flow, help water infiltrate & capture sediment.	Plant in specific areas – around riparian areas on low end of contours $1.80/Pili grass plant	Most plants need to be watered for first 6 months to establish. Combine with seeds and mulch.	Consider installing temporary drip irrigation system or manually water with gravity from water tank on truck.

Table 4. Erosion Control Treatments for Hillslopes

Roads

Like other post-fire "hot spots" for erosion, roads are a priority for post-fire erosion control treatment. There are numerous treatment options. The Post-Fire Team should include technical experts such as a hydrologist and road engineer to predict increased levels of water flow and to determine the priority areas and specific treatments to implement. There are numerous modeling programs available to assist with predicting potential surface flow, and experts in the field likely have trusted models they use to determine the level of flooding and sedimentation risks posed by a burned area and roads within that area. Road treatments can include culvert installation, modification, upgrading, or removal; debris racks or storm patrols on culverts; ditch cleaning or armoring; outsloping road installation; road decommissioning; and rolling dips and water bars.

Rolling dips, water bars, and wing dips/ditches are the most frequently recommended road treatments by BAER specialists. These are used to drain water effectively from the road surface and reduce the concentration of flow. They also can provide a relief valve when a culvert is plugged. Definitions for each are provide below:

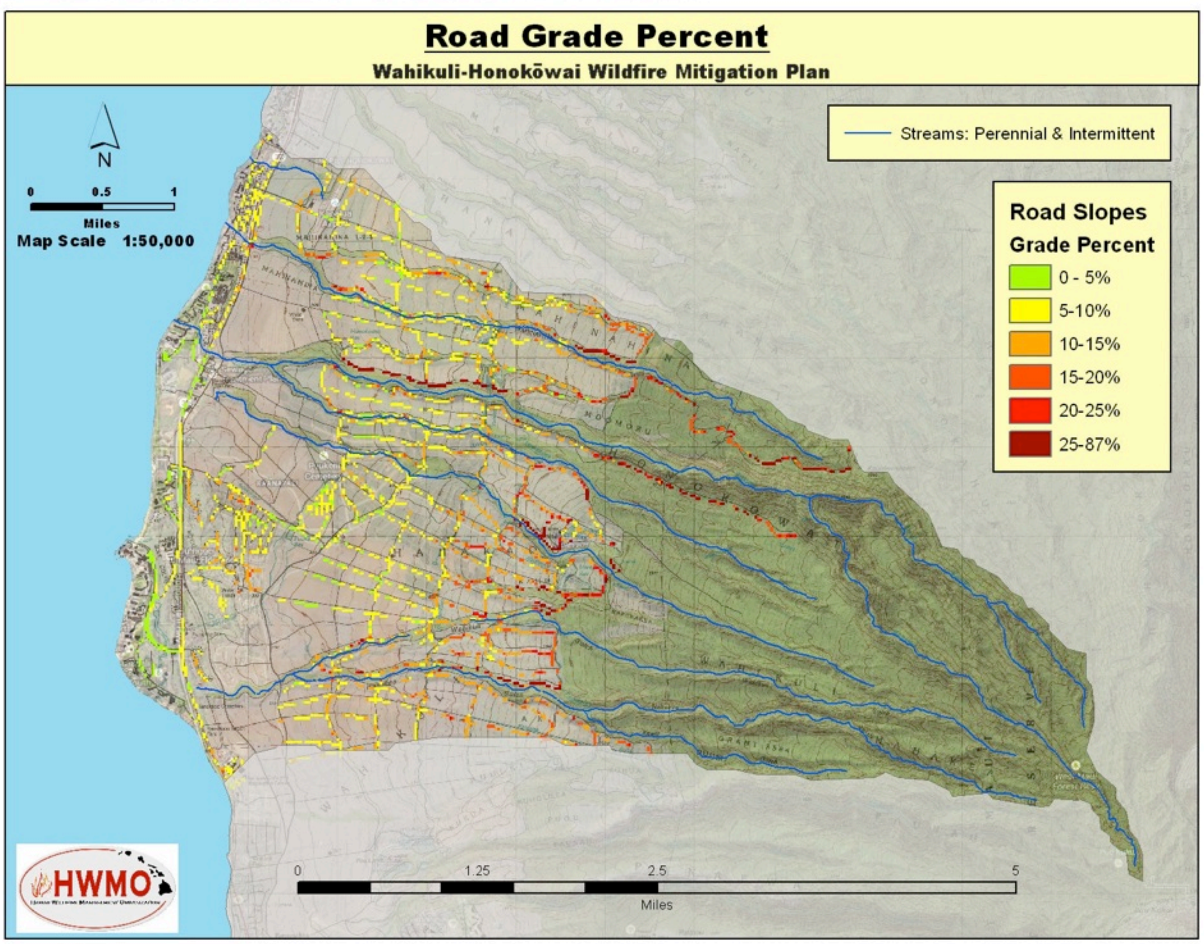
- **Water Bar** – A constructed berm of dirt used to collect and divert runoff water from a firebreak, dirt road, or other disturbed area to facilitate drainage and minimize erosion.
- **Wing Dip/ Wing Ditch / Hillside Ditch** – A diversion ditch constructed to collect and disperse runoff water away from a firebreak or road into stabilized areas. The created channel has a supporting ridge on the lower side, is constructed across the slope at defined gradient and horizontal or vertical interval, and safely controls the flow of water by diverting runoff from upland sloping areas to a stable outlet.
- **Rolling Dip** – A shallow depression built diagonally across a light duty road or trail to divert surface water runoff from the road or trail. Often, rolling dips are armored and used instead of a culvert upgrade because of their relatively low cost. However, they may erode away with strong currents caused by periods of high waterflow.[18]

On the steepest grades, only water bars should be considered. Water bars must be constructed of materials that are compatible with the use and maintenance of the road surface. Water bar discharge areas must be well vegetated or have other erosion resistant materials.[29] See NRCS Field Office Technical Guide on Access Roads for more information (in Appendix).

In addition to major roads, firebreaks and temporary roads should be assessed after a fire and water control structures (water bars, wing ditches, rolling dips) installed when necessary to minimize soil erosion. These structures should not discharge within 50 feet of a streambed or channel. Without providing drainage, roads and firebreaks can collect runoff water from the surrounding landscape and create a gully that funnels sediment long distances, potentially discharging them into streams or other water bodies. Stream crossings and tie-ins should be rehabilitated whenever practical. Firebreaks and roads must sometimes cross through or connect to a stream or other water body. It is important to remove any dirt that is pushed into the stream that will obstruct the natural flow of the channel, and to reshape and stabilize the banks to ensure that no sediment can wash off the road or firebreak into the stream.[30]

The following map (Map 12) displays road slopes of major and minor roads throughout the watersheds. They have been classified by slope to assist in prioritization of road areas to treat in a post-fire situation. Road treatments will consider both the road slope and affected distance. The table that follows (Table 4) provides an overview of road treatments that are appropriate for Wahikuli-Honokōwai.

Prescribing road treatments follows the same post-fire assessment and planning process as other treatments, to include identifying values and resources at risk and determining priority areas, the likelihood and severity of impacts from fire-caused changes, and the window of implementation and available funds. It is vital for the Post-Fire Team to determine the number of treatments that can be implemented before the next likely high-intensity rain event. Key emergency post-fire techniques for roads in Wahikuli-Honokōwai and their approximate costs are included in the table below. Please see the reference documents listed above (BAER Treatment Catalogs, NRCS Standards and Specs, and other state guidance documents) for best management practices and specific guidelines for each treatment. The treatments included here are those identified as most relevant and appropriate for Wahikuli-Honokōwai. Additional treatment options can be found in the BAER treatments catalog and NRCS Field Office Technical Guide.



Map 16. Road Slope Grade Percentages.

Road Treatments Treatments to slow water flow, increase infiltration, and trap sediments				
Erosion Treatment	**Description**	**Estimated Cost/Acre**	**Considerations**	**Details**
Water Bars **-Soil Berms** **-Bedded Logs** **-Slash or Log (temporary <5% slope)**	Soil berms or bedded logs to channel water off roads and trails and prevent gullies – divert water to vegetated areas	$300 - $500 per bar	Most frequently used. Keep water on road for as short as possible. Angled downslope to a vegetated area. Spacing depends on soils and grade. Good for roads with >10% slope.	Roads are a major concern as a continual source of sediment. Recommend lots of water bars. Use a track excavator or backhoe.
Rolling Dips	Drain water from road by creating a raised berm (hill) followed by a road dip that drains into a low dip outlet and adjoining vegetation	$950- $1,200 per dip	Armor the dips if lots of road use. Use if < 12% grade. Ideal for low daily traffic levels and speeds (<30mph).	Dips are sloped to the outside of the road edge usually at 30-45 degree angle to road
Hillside Ditches and Wing Ditches	Constructed to collect and disperse runoff water away from the firebreak or road into stabilized areas.	Varies, depends on costs of labor and equipment needs	Design the ditch to be compatible with the erosion resistance characteristics of soils of the site.	Wing Ditches disperse concentrated ditch flows by reducing the length of flow into more manageable and less erosive dispersal areas.

Table 5. Erosion Control Treatments for Roads

Streams, Drainages, Riparian Areas

Streams and riparian areas are important zones to address after a wildfire for reducing sediment transport to downslope areas. Unmanaged streams, drainages, and riparian areas capture and convey sediment downslope to nearshore and ocean environments. If it rains and soil in a burned area is not yet stabilized by other treatments along hillslopes and roads, sediment can flow into these sensitive natural areas. Therefore, treatments to prevent sediment flow into streams, drainages, and riparian areas are paramount.[31]

Stream Channel Stabilization

If a fire gets into a stream channel, the vegetation in the channel and on the stream banks tends to burn. In this situation, it is very important to implement post-fire measures to stabilize the stream banks, both to protect from hillslope sediment flows into the stream and to protect from high water flow-caused bank erosion in the stream channel itself. Outside of

Hawaii, post-fire in-channel stabilization treatments include in-channel tree felling, grade stabilizers, stream bank armoring, channel deflectors, and debris basins. Of these, only grade stabilizers are included as a recommendation here.

Grade stabilization structures are used to stabilize the grade and control erosion in channels. The purpose is to prevent channel incisions and control the grade of a stream bank that may become destabilized from increased post-fire storm runoff and velocities. They are the only channel treatment recommended as part of this plan due to the lack of research on the efficacy of the other treatments for post-fire situations in Hawaii. However, under the guidance and expertise of the Post-Fire Team and other experts, other treatments may be viable options. The simplest grade stabilizer can be constructed from various materials including rocks, logs, and wood. A hydrologist should be consulted for the most effective design and implementation strategy for each particular site. Considerations include available material, access to site, labor needs/availability, and permissible/affordable mechanized equipment use (backhoe or excavator).

Sediment Transported To Stream Channels From Nearby Hillslopes

Check dams are an important, albeit temporary, solution to capturing post-fire sediment that enters stream channels and drainages from adjacent lands. They can be constructed with rocks, straw bales, and other materials sourced locally or brought in for this purpose. Check dams are temporary devices placed across channels or ditches to reduce scour and erosion by reducing flow velocity and promoting sedimentation. In Hawaii, they are appropriate for small open channels conveying runoff from 10 acres or less, steep channels with runoff velocities exceeding 2 ft/sec, and in temporary ditches, which do not require installation of erosion resistant linings due to expected short-term use. Check dams are often more effective when implemented in gentle gradients, high in the watershed, and placed in a series.

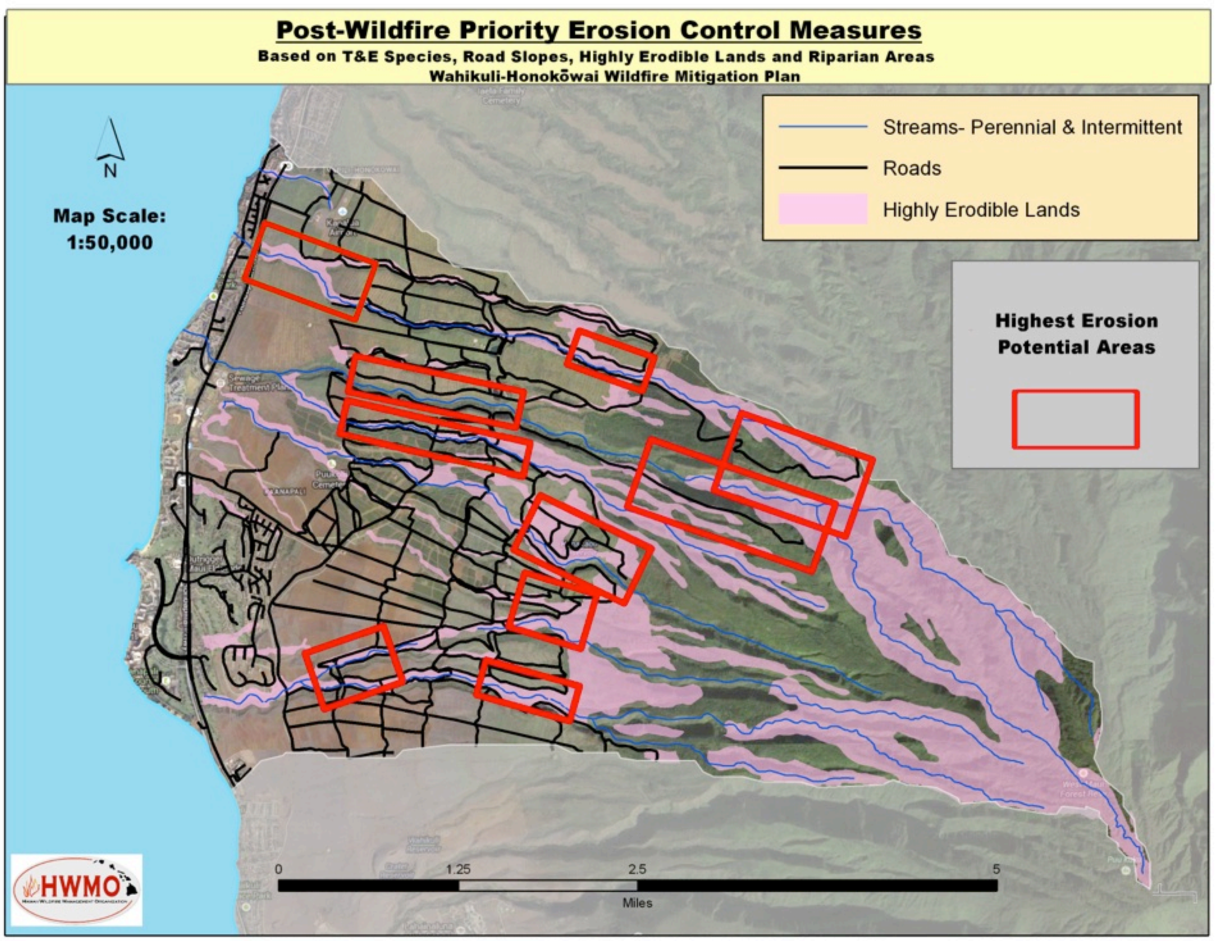
In the immediate term, check dams can be effective in retaining sediment entering stream channels that would otherwise continue on downstream. This may be useful while other treatments to retain soil and prevent erosion take effect on the broader landscape. However, check dams are not a long-term solution (they don't address source of erosion) and can create numerous problems. Problems with checkdams include filling to capacity from small storms and complete structure failure from large storms.[32] Check dams are stop-gap measures and should be removed once vegetation grows back or sediment loss is otherwise prevented and/or controlled.[33] However, the Hawaii Department of Transportation Best Management Practices for check dams[34] cautions that subsequent storms or removal of the check dam may re-suspend trapped sediment.

Longer-Term Post-Fire Sediment Capture

Vegetative filter strips that can serve a longer term streamside sediment capture function may be initialized during an emergency stabilization effort by applying the hillslope mulching and planting techniques (Hillslopes section, above) with plant selections geared toward creating a longer term vegetated buffer along stream channels. A vegetative filter strip functions by removing sediment and other pollutants from runoff by filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilization, thereby reducing the amount of pollution entering surface waters. Vegetative filter strips are appropriate for use in areas adjacent to surface water systems that may receive polluted runoff containing sediment, suspended solids, and/or nutrient runoff. They are designed for use under conditions in which runoff passes over the vegetation in a uniform sheet flow. Such a flow is critical to the success of the filter strip. If runoff is allowed to concentrate or channel, the vegetated filter strip is easily inundated and will not perform as it was designed to function.[21]

Full restoration of complex riparian functions impaired by wildfire is difficult and expensive to address, depending on site conditions, the complexity of the system to be restored, the availability of native plants, and other factors. It will likely be a multi-staged process, but must begin with emergency measures to mitigate impacts from the first rain events. The NRCS standards relevant to this work are included in the Appendix. Specific practices for longer-term restoration must be tailored to the specific ecosystem type and site conditions.[35]

The Post-Fire Team can use Map 16 above and Map 17 below to assist in prioritizing stream channel, drainage, and riparian treatments. Based on an analysis of landscape slope, vegetation, road slopes, and proximities to streams, the following areas on Map 17 have a high likelihood of post-fire erosion, and will likely become high priorities for erosion control if burned. The minimum stabilization or treatment for stream channels often focuses on a 30-90 foot buffer from the top of the stream bank.



Map 17. Post-Fire Erosion Control Priority Areas.

Table 6 demonstrates estimated costs per acre for treatments in riparian areas and channels.

Riparian & Channel Treatments[36, 37, 38, 39, 40] Channel treatments trap sediment, and slow water down				
Erosion Treatment	**Description**	**Estimated Cost/Acre**	**Considerations**	**Details**
Check Dams	Straw bales, rocks or logs act as dams collecting sediments and slowing water flow. When used with vegetation treatments can reduce erosion by 80% and sediments by 95%.	$150-$600 each	Place below the ground line at least 6 in. If slopes are stable, top of watershed is best where low flow rates (<11 cfs) or drainage area is <20 acres.	Recommend to be used with filter fabric on the upside of each dam & a spillway apron. Labor intensive. Straw is not recommended because of potential weed seeds. Logs may be hard to find. Rocks may be most accessible material.
Grade Stabilizers	Stabilize streambanks and maintain stream channels from increased flow.	$250-$4,000/structure	Use in <6% channel gradient with low to moderate seasonal channels, persistent hydrophobic soils;.	Place logs, rocks, wood, etc. at grade.
Vegetative Filter Strips	Hillslope planting and seeding can be focused on hillslopes adjacent to priority riparian areas and directed toward longer term vegetative filter strip goals for sediment management. See hillslope treaments for costs and NRCS standards (included in Appendix) for best practices.			

Table 6. Riparian and Channel Treatments for Post-Fire Emergency Sediment Management

Post-Fire Emergency Stabilization: Action Steps Summary

- **Assemble full Post-Fire Team for comprehensive assessment of burned area for immediate stabilization planning and implementation.** The Post-Fire Team's action steps should be determined during pre-fire team assembly and development of Go-Time Plan.
- **Conduct Post-Fire Assessment for emergency stabilization needs.**
- **Develop an Emergency Erosion Stabilization Plan** if Post-Fire Team determines burned area is at risk of contributing significant erosion.
- **Install specific management practices recommended by the Team, based on areas of concern.** Implement emergency erosion stabilization plan that is based on emergency needs, but considerate of the desired future land use. Seeds, etc. may be selected based on longer-term goals when doing so does not interfere with stabilization objectives.

Section 5- After Fire
Longer-Term Post-Fire Response

Longer Term Post-Fire Response

The specifics of developing a long-term rehabilitation or even longer-term restoration plan are beyond the scope of this plan, particularly because each area or parcel will have varied objectives based on landowner preference or mandate. We mention it here because many of the pre-fire mitigation activities and post-fire emergency stabilization preparedness recommendations contained within this plan could be useful first steps toward rehabilitation and restoration. For example, the development of a list or map of desired or future land uses for each parcel to aid in emergency stabilization treatment planning can be further detailed during the development process toward rehabilitation or restoration goals.

Pre-planning or preparing for potential rehabilitation may be simpler than planning for restoration. Rehabilitation planning will involve identifying the lowest acceptable level of watershed or ecosystem-related function for each parcel. Restoration preparedness and planning is more complex, in that landowners identify their desired immediate and long-term land uses for each area and develop potential trajectories for change based on what the soil, climate, and land management capacity can support.

NRCS Ecological Sites and State-and-Transition Models will be valuable tools for developing rehabilitation and restoration preparedness plans.[41] These NRCS resources provide specific information on classes of land defined by recurring soil, landform, geological, and climate characteristics. Ecological sites recur on similar soil components, and differ in plant production, species composition, soil properties, ecosystem services provided, responses to management, and processes of degradation and restoration. Ecological site descriptions identify the biophysical properties of ecological sites, vegetation and surface soil properties of reference conditions that represent historical ranges of proper functioning condition or potential natural vegetation, and a description of ecosystem services provided by the sites.

There are numerous NRCS Ecological Sites within the Wahikuli-Honokōwai area, each with its own models of what plant communities exist and what alternative plant communities are possible for the site. State and transition models (STMs) describe changes in plant communities and associated dynamic soil properties that can occur on an ecological site. The causes of change, the constraints to reversibility of the change, and the management interventions needed to prevent or initiate change, are also described. Crossing into alternative states indicates that energy-intensive restoration actions will be needed to recover previous plant communities and ecological services, including undergoing a wildfire event.

Precise restoration plans will, like emergency stabilization plans, be dependent on the burned area boundaries at the time of the fire event and the ecological possibilities for that site, in addition to landowner objectives for the area. This discussion here is provided to encourage the completion of a few proactive steps that will allow the post-fire response to follow emergency stabilization activities through to the next stages of rehabilitation and restoration more smoothly. As part of the preparation process, compile ahead of time the Ecological Site descriptions and State-and-Transition models for each area within Wahikuli-Honokōwai that might undergo post-fire treatment. This will enable planners, landowners, and land managers to know what is and is not possible in each area and to understand how those alternative states can occur or be redirected.

Suggested additions to the list and map recommended for pre-fire planning are as follows:

For rehabilitation:

- Acceptable on unacceptable levels of ecosystem or landscape function. Include water infiltration, erodibility, percent of bare soil/ percent cover of vegetation, and other baseline factors for specific land uses.

Rehabilitation is assumed to be first step toward restoration, so rehabilitation and restoration planning should occur in sequence.

For restoration:

- Acceptable and unacceptable plant communities and species (based on landowner preference and on what is possible). Again, to better understand what can grow in the area, consult NRCS State and Transition Models for Maui.
- How and to what extent would likely or ideal restoration activities occur (along riparian corridors, across hillslopes, permanent buffers, etc.)?

LONGER-TERM POST-FIRE RESPONSE RECOMMENDATIONS:

- ➢ Compile NRCS Ecological Site descriptions and State-and-Transition models for each ecological site within Wahikuli-Honokōwai to have on hand for planning.

- ➢ Identify and develop long-term rehabilitation and/or restoration goals for each parcel or land area, to include acceptable and unacceptable levels of ecosystem function, water infiltration, erosion control, and plant communities.

Section 5
Longer-Term Post-Fire Response Action Items Summary

- ➢ **Compile and review NRCS Ecological Site Descriptions and State-and-Transition Models for each ecotype in the Wahikuli-Honokōwai watersheds.**

- ➢ **Develop longer-term rehabilitation and/or restoration goals for each parcel.** This could be completed at the same time as developing a clear understanding of future land uses (see section 2, page 39).

References

[1] **West Maui Development Projects.** Maui County Department of Planning: Long Range Planning Division; 2014. (Draft format, not released to public as of 8/27/14)

[2] **Forest and Rangelands. Glossary of Terms**. http://www.forestsandrangelands.gov/resources/glossary/f.shtml

[3] **Natural Resource Conservation Service Field Office Technical Guides for Maui County, HI.** Section IV. http://efotg.sc.egov.usda.gov/treemenuFS.aspx

[4] **Planning and Implementation for Burned Area Rehabilitation and Restoration**. Hawaii Wildfire Management Organization. Tarnas. 2010.

[5] **Wildland Fire Leadership Council, Glossary of Terms**. http://www.forestsandrangelands.gov/resources/glossary/r.shtml

[6] **Best Management Practices for Creating and Maintaining Wildfire Fuelbreaks in New Jersey's Wildland Urban Interface**. New Jersey Forest Fire Service. 2011. http://www.state.nj.us/dep/parksandforests/fire/docs/wildfire_best_management_practices.pdf

[7] **Harvesting and Thinning Guidance for Treatments in the Wildland Urban Interface of TSA29**. Day, J,K. 1998 Extension Summary. http://afrf.forestry.ubc.ca/files/2012/04/FuelMgtGuidance_WUI_IDF_WLTSA.pdf

[8] **A Guide to Fuels Management in the Interior West**. Dwire, Meyer, Ryan, Riegel, Burton, T. Joint Fire Science Program Final Report 09-2-01-20. https://www.firescience.gov/projects/09-2-01-20/project/09-2-01-20_09-2-01-20_Deliverable_01.pdf

[9] **Fuel Treatments in Juniper and Oak-Juniper Woodlands throughout the Range of the Golden Cheeked Warbler**. US Fish and Wildlife Service. http://www.fws.gov/southwest/es/Documents/R2ES/AUES_GCWA_FINAL_BMP.pdf

[10] **Customized weather history data from 2000 to 2013 for Lahaina, HI**. Compiled from data made available on Weatherunderground.com

[11] **Fire Management Plan, Clearwater and Nez Perce Forests**, 2008.

[12] **The Effects of Fire on Watersheds: A Summary**. Nicholas Dennis. USDA Forest Service Gen. Tech. Rep. PSW-109. 1989.

[13] **Best Management Practices for Maintaining Water Quality.** Hawaii State Division of Forestry and Wildlife. http://dlnr.hawaii.gov/forestry/files/2013/02/Hawaii-BMP.pdf

[14] **Resource Advisor's Guide for Wildland Fire**. National Wildfire Coordinating Group. U.S. Department of Agriculture. January 2004

[15] **USDA Forest Service Northern Region Minimum Impact Suppression Tactics Guidelines-Fireline Handbook**. From MiFO Fire Mgmt Plan. August 2004

[16] **USDA Forest Service: Fire and Aviation Management web page.** http://www.fs.fed.us/fire/safety/10_18/10_18.html

[17] **US Forest Service Burned Area Emergency Response Program**. Brent Roath. Pre and Post Wildfire Conference. http://ucanr.org/sites/Prepostwildfire/files/2674.pdf

[18] On-line BAER Training offered during winter months by Pete Robichaud of USFS Moscow Forestry Sciences Laboratory (http://forest.moscowfsl.wsu.edu/)

[19] **Burned Area Emergency Response (BAER) Treatments Catalogue**. USDA - Forest Service. National Technology & Development Program: Watershed, Soil, Air Management. 0625 1801—SDTDC. 2006. http://www.fs.fed.us/eng/pubs/pdf/BAERCAT/lo_res/06251801L.pdf

[20] **Burned Area Emergency Response Tools**. US Forest Service. Moscow FSL. http://forest.moscowfsl.wsu.edu/BAERTOOLS

[21] **Hawaii DOFAW Best Management Practices for Maintaining Water Quality in Hawaii** http://dlnr.hawaii.gov/forestry/files/2013/02/Hawaii-BMP.pdf

[22] **Hawaii's Management Measures for the Nonpoint Pollution Control Program** http://files.hawaii.gov/dbedt/op/czm/initiative/nonpoint/management_measure_update_2010.pdf

[23] **Water Erosion**. Class presentation NREM 461. Bruland, G. University of Hawaii Natural Resources and Environmental Management. http://www.ctahr.hawaii.edu/brulandg/teaching/46106%20Water%20Erosion.pdf

[24] **Post-fire treatment effectiveness for hillslope stabilization.** Robichaud, Peter R.; Ashmun, Louise E.; Sims, Bruce D. 2010. Gen. Tech. Rep. RMRS-GTR-240. Fort Collins, CO: U.S. Department of Agriculture: Forest Service. https://www.firescience.gov/projects/08-2-1-10/project/08-2-1-10_rmrs_gtr240.pdf

[25] **Forest fire effects on geomorphic processes**. Moody and Martin, 2009. In: Cerda and Robichaud, eds. Fire effects on soils and restoration strategies. Enfield, NH: Science Publishers: 41-79.

[26] **A synthesis of post-fire road treatments for BAER teams: methods, treatment effectiveness, and decision making tools for rehabilitation**. Foltz, Robichaud, and Rhee. 2009. General Technical Report. RMRS-GTR-228: Dept of Agriculture, Forest Service.

[27] Phone conversation with **Jim Elliot, Civil Engineer**. USDA Forest Service Moscow Forestry Sciences Laboratory. 2014

[28] **Finding Ways to Increase the Large Scale Utilization of Native Hawaiian Plants for Erosion Control. Natural Resource Conservation Service Hawaii.** Based on work by Joseph DeFrank, UH Dept. of Tropical Plant and Soil Science.
http://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/hipmcot8077.pdf

[29] **Conservation Practice Standard Access Road,** Natural Resources Conservation Service Pacific Islands Area Code 560.
http://efotg.sc.egov.usda.gov/references/public/HI/560_PI_Standard_1-2012.pdf

[30] **Wildfire Recovery: Protecting Your Property From Soil Erosion.** Bastrop Fire- Short Term BMPs for Water Quality Technical Guidance. Natural Resource Conservation Service.

[31] **Wetlands, Riparian Areas, and Vegetated Treatment Systems- Hawaii Coastal Zone Management Plan**. CNPCP Management Plan Part III - Management Measures for Wetlands CHAPTER 7.
http://files.hawaii.gov/dbedt/op/czm/initiative/nonpoint/cnpcp_mgmt_plan_sections/III_7-Wetlands.pdf

[32] **After Wildfire- Post-Fire Treatment Guide**. New Mexico State University, US Forest Service, US Army Corps of Engineers, Natural Resources Conservation Services, New Mexico State Forestry, and High Water Mark LLC. http://afterwildfirenm.org/post-fire-treatments/post-fire-treatments-pdf

[33] **Check Dams SC-9 Best Management Practices.** Hawaii Department of Transportation.
http://stormwaterhawaii.com/pdfs/BMP/Check_Dams.pdf

[34] State of Hawaii DOT Highways Division Construction BMP Field Manual.
http://stormwaterhawaii.com/pdfs/BMP/Check_Dams.pdf

[35] **Wetlands, Riparian Areas, and Vegetated Treatment Systems- Hawaii Coastal Zone Management Plan**. CNPCP Management Plan Part III - Management Measures for Wetlands CHAPTER 7.
http://files.hawaii.gov/dbedt/op/czm/initiative/nonpoint/cnpcp_mgmt_plan_sections/III_7-Wetlands.pdf

[36] **Cost Effective and Sustainable Road Slope Stabilization and Erosion Control: A Synthesis of Highway Practices.** National Cooperative Highway Research Program (NCHRP) 430. 2012.

[37] **Road Surface Drainage Typicals.** Napa County Resource Conservation District http://www.naparcd.org/documents/RoadSurfaceDrainageTypicals.pdf

[38] **Rural Roads: A Construction and Maintenance Guide for California Landowners**. UC-Division of Agriculture and Natural Resources. anrcatalog.ucdavis.edu/pdf/8262.pdf 2007.

[39] **Cross Drain Update**. United States Department of Agriculture Forest Service Technology & Development Program. 9877 1804—SDTDC . 1998.

[40] **BAER Burned Area Reports Database**. USDA Forest Service. http://forest.moscowfsl.wsu.edu/cgi-bin/BAERTOOLS/baer-db/index.pl

[41] **Ecological Sites and State-and-Transition Model Development.** http://nitcnrcsbase-www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043495.pdf