MARIN

COMMUNITY WILDFIRE PROTECTION PLAN

DECEMBER 2020

FIRE Safe MARIN

MARIN COUNTY FIRE DEPT.

STi Sonoma Technology

Marin County Community Wildfire Protection Plan

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Plan Updates

Date	Section(s) Updated	Description of Update	Updated By
December 2020	All Sections	Overall update of socioeconomic, population, parcel data, and stakeholder feedback throughout the report	Sonoma Technology
December 2020	Section 2	Updated to reflect current stakeholder agencies and engagement	Sonoma Technology
December 2020	Section 3	New section added to highlight accomplishments since the 2016 CWPP	Sonoma Technology
December 2020	Section 4	Updated description and discussion of the WUI	Sonoma Technology
December 2020	Section 4.7	Added Section 2.7 discussing environmental considerations	Sonoma Technology
December 2020	Section 4.7	Added information on miles of unpaved road by fire agency jurisdiction	Sonoma Technology
December 2020	Section 5.1	Added discussion of extreme Diablo weather events	Sonoma Technology
December 2020	Section 5.2	Updated fuel model map and discussion of data	Sonoma Technology
December 2020	Sections 5.4 and 5.5	Updated fire history discussion, data, and ignition history discussion and data	Sonoma Technology
December 2020	Section 5.6	New section added to address climate variability	Sonoma Technology
December 2020	Section 6	Updated with new county-level fire hazard assessment	Sonoma Technology
December 2020	Section 7	New section with parcel-level fire hazard assessment to address structural ignitability	Sonoma Technology
December 2020	Section 8	Updated mitigation strategies to reflect new science and mitigation strategies across the county	Sonoma Technology
December 2020	Section 9	Updated recommendations and action items	Sonoma Technology
December 2020	Appendix A	Updated to reflect updates to the vegetation and fuel model data	Sonoma Technology
December 2020	Appendix B	Updated list of priority projects provided by fire agencies and land managers	Marin County Fire Dept.
December 2020	Appendix C	New section containing the report describing how the fuel model crosswalk was developed based on the lifeform vegetation classes	Sonoma Technology/ Dr. Chris Dicus

Signatures

The Marin County Community Wildfire Protection Plan (CWPP) was developed in accordance with the Healthy Forests Restoration Act. The plan was developed collaboratively among county stakeholders including federal, state, local, and private landowners and local fire departments throughout the county. The plan includes a prioritized list of hazardous fuel reduction strategies and addresses measures that community members can take to reduce structural ignitability. The undersigned have reviewed the Marin County CWPP and accept this document as the final draft representing 2020.

Reviewed by Jason Weber, Chief, Marin County Fire Department | **Date**

Reviewed by Christie Neill, Battalion Chief - Vegetation Management, Marin County Fire Department | **Date**

Reviewed by Mark Brown, Executive Officer Marin Wildfire Protection Agency | **Date**

Approved by Bill Tyler, President, Marin County Fire Chief's Association | **Date**

Approved by Jim Chayka, President, FIRESafe MARIN | **Date**

Adopted by Marin County Board of Supervisors

Katie Rice, President	**Date**

1. Executive Summary

The Marin County Community Wildfire Protection Plan (CWPP) provides a scientifically based assessment of wildfire hazard and threat to homes in the wildland urban interface (WUI) of Marin County, California. This version of the CWPP represents analysis and modeling work conducted in 2020, and provides an update to the 2016 CWPP. The CWPP was developed through a collaborative process involving Marin County fire agencies, county officials, county, state, and federal land management agencies, and community members. It meets the requirements set forth in the federal Healthy Forests Restoration Act for the development of CWPPs, which include:

- Stakeholder collaboration (Section 2)
- Identifying and prioritizing areas for fuel reduction activities (Section 6 and Appendix B)
- Addressing structural ignitability (Sections 7 and 8)

The purpose of the CWPP is to provide fire agencies, land managers, and other stakeholders in Marin County with guidance and strategies to reduce fire hazard and the risk of catastrophic wildfires in the WUI, while promoting the protection and enhancement of the county's economic assets and ecological resources. In Marin, approximately 65% of living units—valued at a combined $58.5 billion—are located within the WUI. Because of the mix and density of structures and natural fuels combined with limited access and egress routes, fire management is more complex in WUI environments.

Since 2017, California has seen some of the deadliest and most destructive wildfires in recorded history. The northern California fires of 2017 included five of the top twenty most destructive WUI fires in history, including the Tubbs fire in nearby Napa and Sonoma counties. Again, in 2018, the Mendocino Complex, Carr, and Camp fires devastated northern California, burning hundreds of thousands of acres and destroying thousands of structures. In 2020, a rare dry lightning weather event followed by strong easterly winds ignited and fueled hundreds of fires throughout northern California, burning a record 2.4 million acres by early October. As the number of acres burned and structure losses increases, more attention is being directed at pre-fire planning and public preparedness throughout California.

The North Bay fires of 2017 raised awareness of the potential vulnerabilities and fire hazard in Marin. In 2018, the Marin County Board of Supervisors published a report that discussed the lessons learned from the 2017 North Bay fires. In 2019, the Marin Civil Grand Jury published a report entitled *Wildfire Preparedness: A New Approach*, that described a more proactive and consistent approach to public education, wildfire preparedness, and vegetation management for Marin County. Following the Grand Jury report, in March 2020, tax Measure C was passed. The measure will raise approximately $20 million annually to fund wildland fire hazard mitigation efforts throughout the county. Following the passage of Measure C, the Marin Wildfire Prevention Authority (MWPA) was formed to serve as the governing body to manage the funds raised through Measure C.

Since the 2016 CWPP was published, fire agencies and land managers throughout Marin County have been working diligently to conduct public outreach and training focused on wildfire preparedness, home hardening, defensible space, and fire-smart landscaping so that structures and properties are more fire resilient. Accomplishments include:

- Increased public outreach;
- Increased number of property and defensible space inspections;
- Increased number of Firewise USA® communities, which promotes collaboration among neighborhoods and communities to increase fire resiliency;
- Supported the development of local-scale fire hazard assessments to address issues at the local-scale; and
- Developed priorities for the MWPA so that wildland fire mitigation efforts throughout the county are coordinated and consistent.

In 2018, the One Tam agency partners—the Marin Municipal Water District, Marin County Parks, the National Park Service, and the California Department of Parks and Recreation—initiated development of a Marin countywide fine-scale vegetation map and landscape database. As part of this CWPP update, the new vegetation data were used to develop an updated fuel model data set for the county.

These data sets are used as inputs for fire behavior models, which predict potential fire behavior and identify areas that may be potentially hazardous if a fire were to occur.

Using geographic information system (GIS) analyses, county-level and parcel-level fire hazard assessments were performed, with a specific focus on the WUI. The results of these analyses can be used to identify areas and communities that are at greatest risk of being negatively impacted by wildfires. The CWPP concludes with a discussion of mitigation strategies, and recommendations to (1) educate and prepare residents for wildland fires and (2) reduce fire hazard. Mitigation strategies and recommendations are focused on continued efforts to

- Conduct public and community outreach focused on wildfire preparedness and planning
- Reduce structural ignitability
- Better manage vegetation and defensible space
- Better prepare the public for evacuations and improve evacuation routes and alert systems

This CWPP update was funded by the Marin County Fire Department (MCFD) and a Federal Emergency Management Agency (FEMA) grant to support the Marin County Hazard Mitigation Plan.

2. Stakeholders and Collaboration

A key requirement when developing a CWPP is stakeholder and community involvement and collaboration. A CWPP provides a mechanism for obtaining community input and identifying high-risk areas, potential fire hazards, and a prioritized list of potential projects intended to mitigate areas of concern and fire hazard. During the development of the 2016 CWPP, a number of stakeholder and public meetings were conducted to provide the community a forum for identifying assets and communities at risk from wildfire. The 2020 CWPP update continues to integrate this community-focused approach through soliciting stakeholder input and review.

The information contained in this plan reflects the collaboration of county stakeholders and the public working together to develop a living document that will continue to be used over the next several years to implement the recommendations and action plan described in Section 9. In addition to feedback from elected officials and public citizens throughout Marin County's cities and towns, **Table 1** lists the stakeholders—fire agencies, land management agencies, utility operators, homeowner associations, FIRESafe MARIN, and other private and public entities—that participated in the CWPP development process.

Table 1. Participants in the CWPP development process.

Public, Private, and Volunteer Fire Agencies and Associations			
Marin County Fire Department	Ross Valley Fire Department	San Rafael Fire Department	Southern Marin Fire Protection District
Tiburon Fire Protection District	Central Marin Fire Authority	Marin Wildfire Prevention Authority	Marinwood Fire Department
Mill Valley Fire Department	Novato Fire Protection District	Bolinas Fire Protection District	Stinson Beach Fire Protection District
Inverness Public Utilities District	Nicasio Volunteer Fire Department	CAL FIRE	Skywalker Ranch Fire Brigade
Muir Beach Volunteer Fire Department	Kentfield Fire Protection District	Tomales Volunteer Fire Department	Marin County Fire Chiefs Association (Bill Tyler, Pres.)

Land Management Agencies			
National Park Service	Marin Municipal Water District	Marin County Parks and Open Space District	California State Parks

Private Groups and Foundations	
Pacific Gas and Electric	Firewise Community Sites
Marin Conservation League	FIRESafe MARIN
Fire and Environment Resilience Network	California Native Plant Society
Environmental Action Committee of West Marin	Marin Audubon Society

Homeowner Associations		
Homeowner Associations throughout Marin County	West Marin ranch and agricultural landowners	Large private landowners

2.1 Marin Wildfire Prevention Authority

In March 2020, with the passage of tax Measure C, the Marin Wildfire Prevention Authority (MWPA)[1] was formed. The MWPA consists of seventeen member agencies[2] and was formed to develop and implement a comprehensive wildfire prevention and emergency preparedness plan for most of Marin County. Key elements of the program include:

1. **Vegetation Management.** Through multiple strategies, efforts to reduce fuels using cost-effective practices for fuel reduction will be implemented on an ongoing basis.
2. **Improvements to Alerts, Warning Systems, and Evacuations.** Safety measures will be implemented that will improve early wildfire detection, alerts and warnings, as well as improve disaster evacuation routes for organized evacuation.
3. **Public Education.** The MWPA will provide expert information and assistance to improve public awareness and help the public be prepared for a wildfire event. Additionally, the MWPA will support FIRESafe MARIN community outreach efforts.
4. **Grants.** A local grant program will assist residents with access and functional needs, seniors, and the financially disadvantaged to reduce fire risk associated with their properties and the greater surrounding community. The MWPA will also seek grants and leverage local investments for wildfire prevention and disaster preparedness programs.
5. **Defensible Space Evaluations.** Funding will be allocated to expand and enhance defensible space home evaluations to ensure that homes meet fire and building codes, and to provide education to reduce the vulnerability of homes in Marin.
6. **Local Wildfire Prevention Mitigation.** The MWPA will provide local funding to MWPA member agencies for specific local wildfire mitigation needs specific to their service area.

2.1.1 Ecologically Sound Practices Partnership

In partnership with the MWPA, the Ecologically Sound Practices (ESP) Partnership[3] is a collaboration between the fire authorities and climate and environmental organizations of Marin to mitigate the risk of wildfires while considering ecologically sound practices. The coalition is led by the ESP Steering Committee that defines best practices, provides expertise and recommendations for ecologically sound practices, and advises fire professionals on specific wildfire mitigation projects.

[1] http://www.marinwildfire.org.
[2] MWPA member agencies include: Bolinas Fire District, City of Larkspur, City of Mill Valley, City of San Rafael, County of Marin, Inverness Public Utility District, Kentfield Fire Protection District, Marinwood Community Services District, Muir Beach Community Services District, Novato Fire Protection District, Sleepy Hollow Fire Protection District, Southern Marin Fire Protection District, Stinson Beach Fire Protection District, Town of Corte Madera, Town of Fairfax, Town of Ross, and the Town of San Anselmo.
[3] https://www.marinwildfire.org/about-us.

The ESP Partnership allows a forum to:

- Provide expertise about ecologically sound best practices;
- Bring questions, concerns and solutions to the table;
- Coordinate communication with the fire professionals;
- Reduce redundancy of efforts; and
- Develop solutions across areas of expertise including vegetation management and habitat protection, carbon resource management, and defensible space for ecological benefit.

2.2 FIRESafe MARIN

FIRESafe MARIN (FSM), Marin County's Fire Safe Council, promotes public and private partnerships to enhance wildfire safety and build Firewise Communities.[4] FSM is a nonprofit organization with the dual mission of reducing wildland fire hazards and improving fire-safety awareness in Marin County. With the passage of tax Measure C in March 2020, the mission and focus of FSM was updated to reflect future wildfire prevention efforts and funding under the MWPA.

2.3 Fire Agencies

To engage local fire departments and agencies in the CWPP process, fire chiefs representing all fire departments in the county have provided information and updates that support the CWPP process and framework. As part of the 2020 CWPP update, fire chiefs were asked to provide an updated list of priority hazard mitigation projects for their jurisdictions. This updated information is included in Appendix B and will be used to support fuel reduction and mitigation projects throughout the county.

2.4 Land Management Agencies

To engage Marin's land management agencies, each agency was asked to review the 2016 CWPP and provide suggested edits and updates to the 2020 CWPP. They were also asked to provide an updated list of hazard mitigation projects within their jurisdictions; these lists are included in Appendix B.

The cities within Marin County, along with land management agencies, work to reduce fire hazards as directed by their management and planning documents. Planning is driven by the goals of protecting natural habitat and special status species while managing the growth of invasive species. Management strategies can be challenging and require interagency cooperation and collaboration in

[4] The National Fire Protection Association (NFPA) established the Firewise Communities Program to encourage local fire safety solutions by involving homeowners to take individual responsibility for preparing their homes for the risks of wildfires. The Firewise program uses their website (http://www.firewise.org/) to provide information and promote ways to keep homes from igniting.

fuel break and fuel reduction areas. Emphasis during fuel treatment planning needs to consider how to minimize the introduction, spread, and removal of invasive species. Agencies within Marin County include:

- **National Park Service.** Works under the guidance of a Fire Management Plan (FMP), which has gone through the federal environmental compliance process. The FMP's priority is to increase the reduction of hazardous fuels in high-priority areas (e.g., along road corridors, around structures, and in strategic areas to create fuel breaks) using prescribed fire and mechanical treatments.
- **Marin Municipal Water District.** Adopted the Biodiversity, Fire, and Fuels Integrated Plan (BFFIP) in October 2019 to minimize fire hazards and maximize ecological health of the district's watershed (Leonard Charles and Associates, 2012).
- **Marin County Parks and Open Space District.** Released its draft Vegetation and Biodiversity Management Plan (VBMP) in April 2015 to direct resource management efforts on the county's 34 preserves to maintain and increase biodiversity while reducing the risk of wildfire (May & Associates Inc., 2015). MCOSD manages nearly 16,000 acres, including an extensive network of approximately 249 miles of roads and trails. A significant portion of MCOSD's preserves are adjacent to private homes, structures, and evacuation routes; consequently, a great deal of effort is involved in working with neighbors and other local agencies to resolve disputes over responsibility for fuel reduction and defensible space.
- **California State Parks.** Reviews all proposed fuel breaks and vegetation modification zones on State Park land for environmental impacts. The impacts of greatest concern are the spread and proliferation of invasive species, impacts to listed and special status species, sediment issues associated with an increase in bare soil, and the cost of ongoing management in the fuel reduction zones. In lieu of installing fuel breaks, the State Parks work with MCFD and other fire agencies on vegetation modification zones to reduce fire hazards. Vegetation modification areas are completed to State Parks specifications to meet the goals of fuel reduction while minimizing environmental impacts. State Parks works with neighbors to issue permits for homeowners to do defensible space work on State Park land.

2.5 Community Stakeholders

During the development of the 2016 CWPP, several public meetings were conducted to capture the issues and concerns of private land and homeowners, neighborhood groups, civic organizations, professional organizations, and environmental groups. The concerns and ideas expressed during the public meetings were captured in meeting notes. Public concerns regarding fire hazards were consistent throughout the county, and generally include

- Increased public education and outreach
- Improvement of evacuation routes

- Improvement and enforcement of defensible space
- Cooperation with large land managers/owners
- Cooperation with absentee property owners
- Effective community-scale fuel reduction
- Increased use of technology for fire protection
- Protection of existing environmental resources

In response to these concerns, FIRESafe MARIN, in collaboration with the Marin County Fire Chiefs Association, Marin County Fire Prevention Officers Association, and wildfire and home hardening experts, created a comprehensive wildfire preparedness education program called *Living With Fire*. FIRESafe MARIN has been hosting *Living With Fire* workshops and webinars throughout the county since 2016. The *Living With Fire* program has also helped to promote neighborhood preparedness through the nationally recognized Firewise USA® program. Since 2016, the number of Firewise USA® communities in Marin has increased dramatically to over 70 sites.

3. Accomplishments

Following the North Bay fires of 2017 and fire season of 2018, the Marin County Civil Grand Jury (Grand Jury) conducted an assessment of Marin County's fire vulnerability and preparedness. Following the assessment, the Grand Jury issued a report in April 2019 entitled *Wildfire Preparedness: A New Approach* (Marin County Civil Grand Jury, 2019). The Grand Jury report concluded that Marin faces unprecedented danger to life and property from wildfire. The report recommended a new approach to reduce vulnerability and increase preparedness in four key areas:

- Vegetation management
- Educating the public
- Alerts and warning systems
- Evacuations

Following the Grand Jury report, tax Measure C was passed and the MWPA was formed.

Since the 2016 CWPP was adopted, fire and land management agencies throughout the county have implemented actions to accomplish five key goals set forth in the 2016 CWPP:

1. Continue to identify and evaluate wildland fire hazards and recognize life, property, and natural resource assets at risk, including watershed, wildlife habitat, and other values of functioning ecosystems.
2. Articulate and promote the concept of land use planning related to fire risk and individual landowner objectives and responsibilities.
3. Support and continue to participate in the collaborative development and implementation of wildland fire protection plans and other local, county, and regional plans that address fire protection and landowner objectives.
4. Increase awareness, knowledge, and actions implemented by individuals and communities to reduce human loss and property damage from wildland fires, such as defensible space and fuels reduction activities, and fire prevention through fire safe building standards.
5. Integrate fire and fuels management practices with landowner priorities and multiple jurisdictional efforts within local, state, and federal responsibility areas.

At a high level, accomplishments include (but are not limited to) the ongoing development of a robust archive of multi-agency GIS data; increased public outreach and education on wildfire preparedness including home hardening, defensible space, vegetation management, community and neighborhood protection; promotion and support for the Firewise communities program; support for chipper programs; increased property inspections; increased financial assistance and grant programs; increased community-level evacuation drills; increased fuel reduction along roadways and evacuation routes; and increased community-scale fire hazard assessments.

4. County Overview

Marin County is located in the North San Francisco Bay Area in California. The county is approximately 520 square miles (332,800 acres) with a population of approximately 259,000[5] and is largely rural. The county is bordered by Sonoma County to the north and east, the East San Francisco Bay Area to the southeast, and San Francisco County to the south, with the Pacific Ocean along its western border. Most of the county's population resides in the eastern, urban-developed region of the county along the Highway 101 corridor. The west region of the county—in and around Pt. Reyes—is a popular local tourist region covered by parklands and recreation areas, and the northwest is sparsely populated, agricultural rangeland.

Approximately 60,000 acres—18% of the county's land area—falls within the wildland urban interface (WUI) where residences (i.e., homes and structures) are adjacent to or intermixed with open space and wildland vegetation. **Figure 1** shows a map of Marin County and the WUI.[6]

The term "WUI" is not a designation of potential wildfire severity, but a defined description of an area where urban development meets undeveloped lands at risk of wildfires. The federal definition of WUI excludes areas where development falls below a certain threshold, so a single house far from other structures may not be considered to be in the WUI even though it is in the middle of a wild area. Conversely, areas with dense development may not be considered WUI because of the housing density, even though they may be close to wildlands.[7]

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[5] U.S. Census Bureau Marin County population estimate for 2019. Available at **https://www.census.gov/quickfacts/marincountycalifornia**.
[6] Note that the WUI map shown in Figure 1 does not accurately represent the current WUI boundaries for Tiburon. The WUI boundaries for Tiburon can be viewed at **https://www.tiburonfire.org/wp-content/uploads/2013/06/urban-interface-map.pdf**.
[7] FIRESafe MARIN (**https://www.firesafemarin.org/wui**).

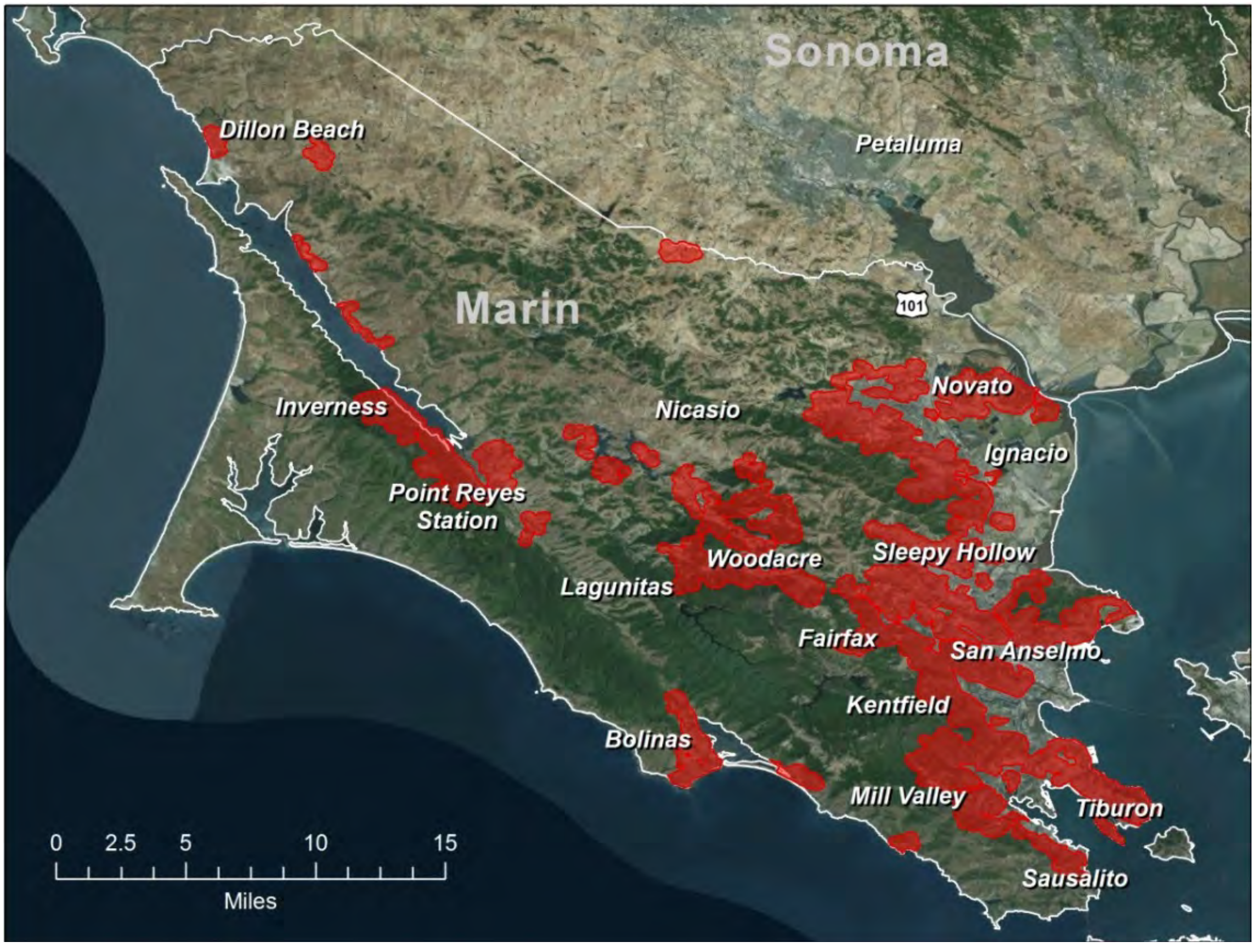

Figure 1. Map of Marin County and the wildland urban interface (WUI) boundaries (red). Note that the map does not accurately represent the current WUI boundaries for Tiburon, which can be viewed at **https://www.tiburonfire.org/wp-content/uploads/2013/06/urban-interface-map.pdf**.

4.1 Marin's Wildland Urban Interface

A recent assessment based on the latest tax assessor parcel data shows that there are approximately 69,400 living units valued at $58.5 billion within the WUI.[8] Because of the mix and density of structures and natural fuels combined with limited access and egress routes, fire management is more complex in WUI environments. In Marin County specifically, many of the access roads within the WUI are narrow and winding and are often on hillsides with overgrown vegetation, making it even more difficult and costly to reduce fire hazards, fight wildfires, and protect homes and lives in these areas.

[8] Marin County Tax Assessor's Roll 2018-2019 obtained from Marin County Fire Department.

Unincorporated rural areas within the county include the coastal communities of Muir Beach, Stinson Beach, and Bolinas; communities near Tomales Bay including Olema, Point Reyes Station, Inverness, Inverness Park, Marshall, Tomales, and Dillon Beach; and rural areas in the interior valleys including Nicasio, Lagunitas, Forest Knolls, San Geronimo, and Woodacre. These communities are primarily situated within or adjacent to the WUI, with moderate to dense concentrations of structures. Marin County has approximately 60,000 acres of WUI adjacent to 200,000 acres of watershed. Response times in these communities present significant challenges to firefighting as emergency fire access and evacuation egress is limited by narrow, winding roads lined with dense vegetation.

Fire can spread rapidly through ember dispersion, structures, and/or vegetation. Property owners have a responsibility to prepare their homes and property to reduce structural ignitability by complying with WUI building codes and ordinances, providing adequate defensible space, and hardening their homes from ember penetration.

The WUI map for Marin was first developed in the late 1990s and was based on the federal definition of WUI which is based on structure density and proximity to wildland vegetation density. Population shifts and structure density can change over time. In some cases, official WUI boundaries are defined based on structure density, proximity to wildland vegetation, and local conditions. The WUI map used throughout this CWPP represents the official WUI boundary map for Marin. The map is currently available on the Marin County geographic information system (GIS) web portal, MarinMap.[9]

Generally, the WUI boundaries shown in Figure 1 are based on areas with high structure density and proximity to high density of burnable fuels. The current map was developed several years ago before detailed GIS data for structures and building footprints were available. While most of the towns and cities in Marin County are "built-out," resulting in modest levels of new development, some residential development has occurred and/or is planned. Because the official WUI map is several years old, it may not capture development that has occurred within the past ten years.

Figure 2 shows Marin County's current WUI boundaries overlaid with a recent dataset showing building structure density per square mile. As shown in Figure 2, many of the county's structures are located in or near the existing WUI boundaries. There are a few areas where structure density is high in areas with dense natural vegetation but do not fall within the existing WUI boundaries. While updating the WUI map was not within the scope of this CWPP update, it is recommended that the existing WUI map be evaluated and updated based on the federal definition of WUI and input from local agencies.

[9] http://www.marinmap.org/Html5Viewer/Index.html?viewer=mmdataviewer&Run=WUILayerON&ServiceId=13&LayerName=Urban%20Wildland%20Interface&extent=5950502.26733493,2207544.30421775,5994476.00578578,2244189.08626013.

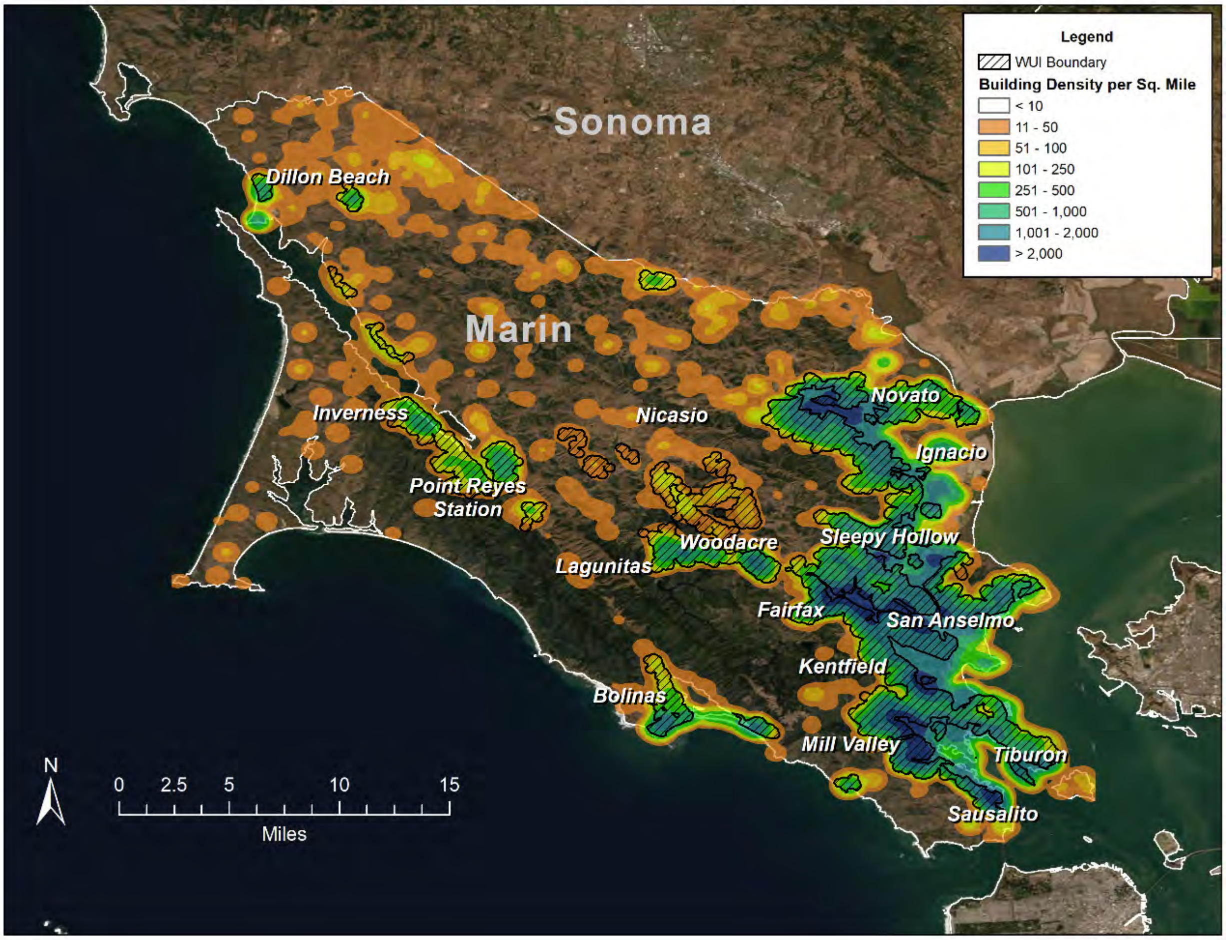

Figure 2. Structure density overlaid with Marin County's existing WUI boundaries.

4.2 Fire Agencies, Capabilities, and Preparedness

Fire protection in California is the responsibility of either the federal, state, or local government. On federally owned land, or federal responsibility areas (FRA), fire protection is provided by the federal government, often in partnership with local grants and contracts. In state responsibility areas (SRA), which are defined according to land ownership, population density, and land use, CAL FIRE has a legal responsibility to provide fire protection. CAL FIRE is not responsible for densely populated areas, incorporated cities, agricultural lands, or federal lands. Local responsibility areas (LRA) include incorporated cities and cultivated agriculture lands. In LRAs, fire protection is provided by city fire departments, fire protection districts, or counties, or by CAL FIRE under contract to local government. SRA designations undergo a five-year review cycle, as well as annual updates to reflect incorporations/annexations, error fixes, and ownership changes (which do not require Board of Forestry approval). Figure 3 shows the FRA, SRA, and LRA in Marin County.[10]

[10] CAL FIRE, 2020 (https://egis.fire.ca.gov/portal/home/item.html?id=f35d2f86ab8c4bf4947f0a9b29134715).

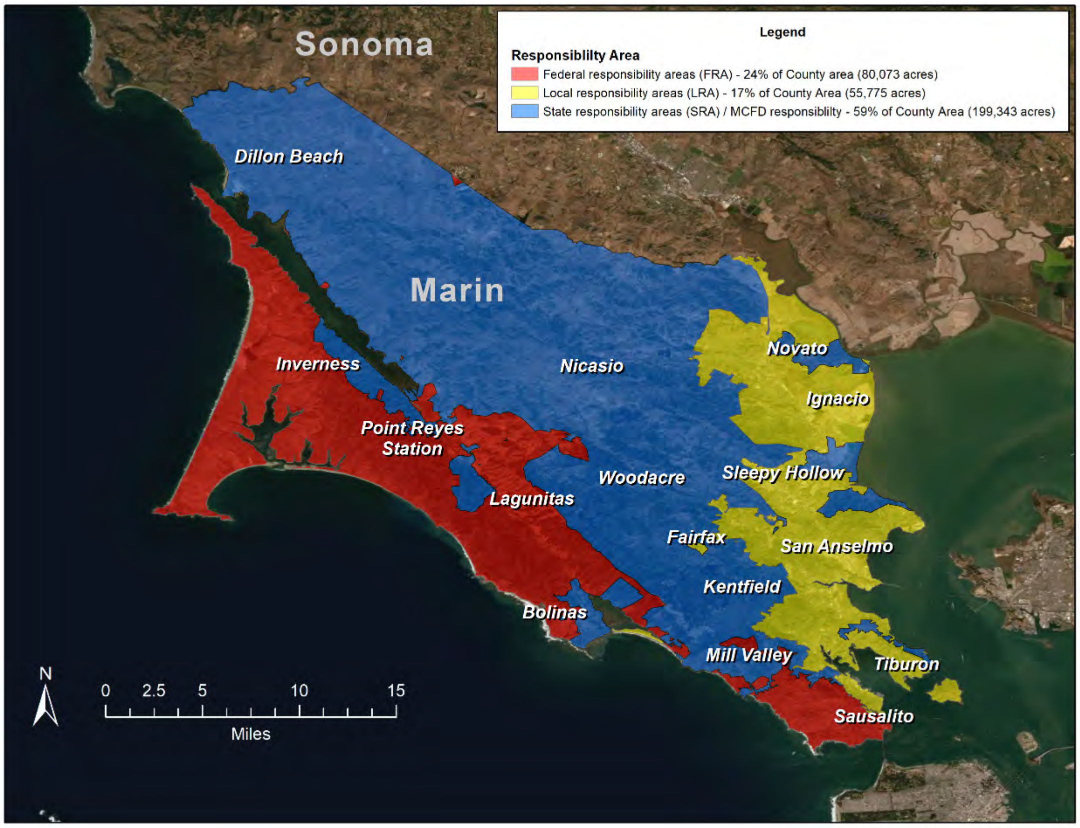

Figure 3. Map of the federal responsibility areas (red), state responsibility areas (blue), and local responsibility areas (yellow) in Marin County.

In Marin County, CAL FIRE contracts with MCFD to provide wildland fire protection and associated fire prevention activities for the SRA, which comprises more than half of the total land area in Marin. Marin is one of six counties in the state that contract with CAL FIRE to protect the SRA. The MCFD is responsible for the protection of approximately 200,000 acres of SRA within the county and is the primary agency that handles wildland fires. MCFD also provides similar protection services to approximately 100,000 acres of FRA in the Golden Gate National Recreation Area (GGNRA), Muir Woods National Monument, and Point Reyes National Seashore.

MCFD staffs an Emergency Command Center (ECC) that dispatches for MCFD and local volunteer fire departments, coordinates wildland incidents within the SRA or FRA, and acts as the California Governor's Office of Emergency Services (CalOES) coordination center for fire dispatching. In addition to MCFD, there are twelve fire service agencies and one volunteer department—Tomales Volunteer Fire Company (TVFC)—that provide fire services in Marin County. TVFC provides twelve firefighters to MCFD's Tomales response zone. One private fire brigade, Skywalker Fire, is situated on the Lucas Valley Ranch. Figure 4 shows a jurisdictional map for MCFD and the other twelve fire service agencies in Marin County, and Table 2 provides information on all of the fire service agencies in the county.

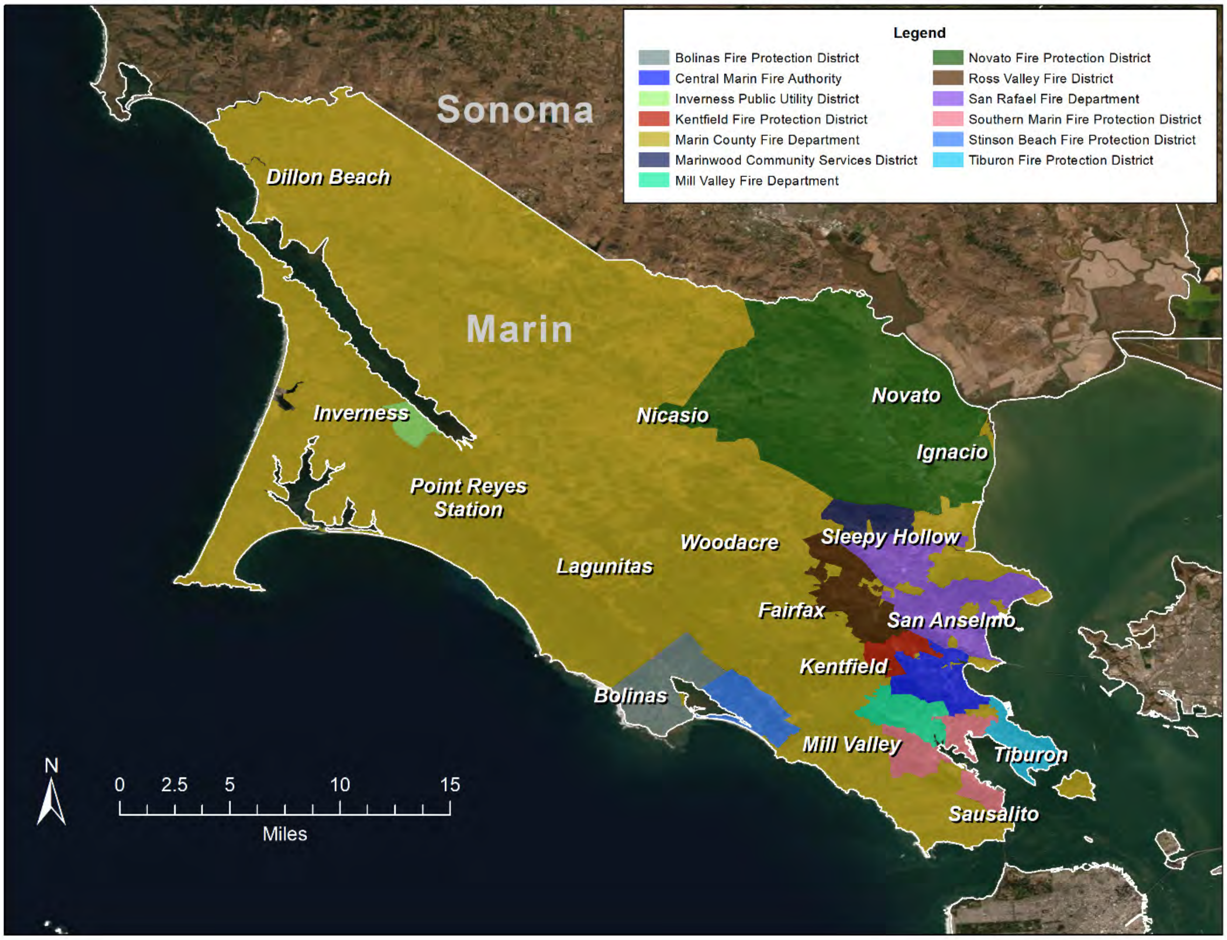

Figure 4. Map of Marin County fire service agency jurisdictions.

Table 2. Marin County fire service agencies.

Personnel	Fire Stations	Fire Apparatus	Additional Equipment/Services
Marin County Fire Department			
160 firefighters (full time, seasonal, volunteer), 14-person Tamalpais Fire Crew	Six	Seven Type 1 (two reserves), 12 Type 3 (5 reserves), two Type 6, two CCV, one transport/bulldozer, three water tenders, four ambulances/medic	Twelve Fire Detection Cameras, two Lookout Towers

Personnel	Fire Stations	Fire Apparatus	Additional Equipment/Services
Novato Fire Protection District			
76 (60 emergency response personnel, 15 administrative personnel, one fire mechanic)	Five stations, one administrative office building, one training tower	Seven Type 1 ALS (2 reserve), two Type 3 ALS, four ALS ambulances (two first out, one cross staffed and one reserve), one ALS aerial ladder truck, one water tender	Weather station, thermal imaging cameras
Kentfield Fire Protection District			
20 firefighters (full-time, seasonal, volunteer)	One	Three Type 1, one ladder truck, two utility units	N/A
Bolinas Fire Protection District			
21 firefighters (full-time, part-time, seasonal, volunteer)	One	Two Type 1, one Type 3, one MCI trailer	N/A
Stinson Beach Fire Protection District			
5 personnel (30 volunteers)	One	Two Type 1, one Type 3, one water tender, one BLS ambulance, two command vehicles	N/A
Inverness Volunteer Fire Department			
25 firefighters (full-time, part-time, volunteer)	One	Two Type 1 engines, one Type 6 engine, one small rescue, two utility/command vehicles	N/A
San Rafael Fire Department			
72 line personnel (full-time), 10 administrative/prevention personnel	Six	Nine Type 1 (two reserve), one Type 3, one Type 5, two ladder trucks, four medic ambulances, five utility units, four BC command vehicles	Eight thermal imaging cameras
Ross Valley Department			
32 personnel (full-time)	Four	Four Type 1 (one reserve), one Type 3, one OES Type 3	N/A

Personnel	Fire Stations	Fire Apparatus	Additional Equipment/Services
Tiburon Fire Protection District			
29 personnel (2 administrative, 27 full-time)	Two	Four Type 1, two Type 3, one rescue, one fireboat, two medic ambulances, two utility vehicles, two staff vehicles, three command vehicles	Three I/R cameras, emergency siren system
Central Marin Fire Authority			
39 personnel (full-time)	Four	Four Type 1 (one reserve), two ambulances (one reserve), two Type 3 (one reserve), one water tender – Type 1 tactical, four command vehicles (two trucks, two SUVs), four utility vehicles (three trucks, one SUV)	N/A
Mill Valley Fire Department			
31 personnel (1 administrative, 1 Chief, 2 fire prevention, 27 full-time firefighters)	Two	Three Type 1 (one reserve), one Type 3, one ALS ambulance, three Battalion Chief vehicles, four utility vehicles, 1 staff vehicle	N/A
Marinwood Fire Department			
29 firefighters (9 full-time, 20 volunteer)	One	One Type 1, one Type 3, utility truck	N/A
Southern Marin Fire Protection District			
61 (8 administrative, 8 fire prevention, 47 full-time firefighters)	Three	Four Type 1 (1 reserve), one Type 3, two ALS ambulances, one medium rescue, one ladder truck, one Battalion Chief vehicle (1 reserve), three staff vehicles, six prevention vehicles, three utilities	One water rescue apparatus, one fireboat, one IRB, two RWC, one dive tender unit

According to the latest available tax assessor's records and parcel data, there are 96,042 parcels and 107,487 living units in Marin County. Approximately 65% of living units (69,366 units) are located in the WUI. There are approximately 15,138 parcels and 13,058 living units located in the county's SRA. Table 3 lists the number of parcels and living units located in the SRA by fire jurisdiction.[11]

Table 3. Number of parcels and living units located in the SRA by fire jurisdiction based on 2018-2019 tax assessor records.

Fire Jurisdiction	Number of Parcels	Number of Living Units
Marin County Fire Department	7,066	6,032
Southern Marin Fire Department	2,590	2,529
Novato Fire Protection District	1,872	1,635
Bolinas Fire Protection District	1,207	728
Ross Valley Fire Department	897	853
Inverness Volunteer Fire Department	736	619
Marinwood Fire Department	295	245
Stinson Beach Fire Protection District	310	286
Tiburon Fire Protection District	165	131
Total	15,138	13,058

4.3 Agency Coordination

In addition to the CAL FIRE contract, Marin County has a well-organized local mutual aid system, based on the principles of resource sharing and cooperation with a goal of providing the public with the highest level of service that no one agency is equipped to provide. These agreements include resources from all fire agencies, law enforcement, volunteer fire departments, CalOES, the National Park Service (NPS), CAL FIRE, and local landowners. Table 4 lists the mutual aid agreements/plans and assistance-for-hire agreements. Mutual aid agreements are agreements among emergency responders to lend assistance across jurisdictional boundaries to supplement the resources of any fire agency during a period of actual or potential need.

[11] Parcel and living unit data are based on the 2018-2019 Marin County Tax Assessor's Roll.

Table 4. Mutual aid agreements/plans and assistance-for-hire agreements.

Mutual Aid Agreements and Plans
Countywide Mutual Threat Zone Plan
Marin Sonoma County Mutual Threat Zone Plan
Marin County Mutual Aid Agreement
County of Marin Urban Search and Rescue
County of Marin Office of Emergency Services
State of California Master Mutual Aid
North Bay Incident Management Team
Assistance-for-Hire Agreements
Marin Municipal Water District
Skywalker Ranch Fire Brigade
National Park Service in the areas of Point Reyes National Seashore, Golden Gate National Recreation Area, and Muir Woods National Monument

The ECC has been maintained by MCFD since the 1930s and serves as an independent dispatch center. The ECC receives, disseminates, and transmits information to field units and has the additional responsibility to act in a supervisory role during incidents before field units arrive. The ECC also acts as the central ordering point for all state resources that are committed to SRA incidents in the county, and for CalOES requests and coordination of local government fire resources entering or leaving the county operational area. The ECC processes approximately 3,800 calls annually, and is also responsible for handling all business calls received by the department.

The Communications Division of the Marin County Sheriff's Office operates the Marin County Public Safety Communications Center. The center provides service to the Sheriff's Office, five police departments, nine fire departments, six paramedic service areas, the Marin County Department of Public Works, and many other city and county government service departments. The center is the primary 9-1-1 public safety answering point for all unincorporated areas of the county, as well as Mill Valley, Belvedere, Sausalito and Tiburon.[12]

[12] https://www.marinsheriff.org/about-us/administrative-support/communications-division.

4.4 Population and Housing

According to 2019 census data, the population of Marin County is 258,826.[13] Table 5 shows the population distribution in Marin County by city, town, or community.

Table 5. Population distribution by city, town, or community.

City, Town, or Community	Population	% County Total
San Rafael	58,939	23%
Novato	55,523	21%
Mill Valley	14,343	6%
San Anselmo	12,567	5%
Larkspur	12,375	5%
Tamalpais-Homestead Valley	11,261	4%
Corte Madera	9,866	4%
Tiburon	9,151	4%
Fairfax	7,591	3%
Sausalito	7,139	3%
Kentfield	6,930	3%
Lucas Valley-Marinwood	6,841	3%
Strawberry	5,759	2%
Santa Venetia	4,790	2%
Marin City	3,173	1%
Point Reyes Station, Alto, Stinson Beach, San Geronimo, Muir Beach, Dillon Beach, Tomales, Nicasio	2,897	1%
Ross	2,309	1%
Sleepy Hollow	2,200	1%
Belvedere	2,098	1%
Black Point-Green Point	1,655	1%
Lagunitas-Forest Knolls	1,504	1%
Woodacre	1,303	1%
Inverness	1,127	0.4%
Bolinas	1,077	0.4%

[13] Source: U.S. Census Bureau, Population Division. American Community Survey, 2019 (https://data.census.gov/cedsci/table?q=Marin%20county%20population&tid=ACSDT1Y2019.B01003&hidePreview=false). Accessed November 2020.

City, Town, or Community	Population	% County Total
Total	**242,418**	**94%**

Note: the remaining 6% of the county's population lives in rural areas outside of the cities and towns listed in this table.

Most of the towns and cities in Marin County are "built-out," resulting in modest levels of new development. However, according to the PropDev 51 Annual Proposed Development Survey,[14] some future residential development is expected in the areas of Novato, San Rafael, and unincorporated parts of the county.

4.4.1 Tourism and Population Flux

An important consideration from a fire planning and emergency response perspective is the tourist population and temporal shifts in the transient population during the summer fire season, particularly in the western coastal areas. On warm days during the summer, the transient tourist population more than doubles as people come to the county's parks, beaches, and recreation areas. There is often heavy traffic on roadways to and from west Marin County and along Highway 1. Consideration of the tourist population flux is important for planning strategic fuels treatment projects, reducing potential ignition sources, and allocating emergency response personnel.

4.5 Land Ownership

Landowners and vegetation managers in Marin County are some of the key stakeholders in the CWPP development process. Land ownership in Marin County is quite diverse and includes federal, state, local (county), and private property owners; Table 6 shows the distribution of land ownership in the county. Approximately 85% of the land area in Marin is protected from development through open space purchases, federal parkland, watershed lands and strict agricultural zoning.[15]

[14] PropDev 51 Annual Proposed Development Survey, October 2016. Available at (https://www.marincounty.org/-/media/files/departments/cd/planning/currentplanning/publications/landuseplan/propdev/pd51_report.pdf).
[15] https://www.visitmarin.org/things-to-do/outdoor-activities/the-bay-and-protected-open-space/.

Table 6. Distribution of land ownership in Marin County.

Landowner	Percent Ownership
Private	56%
National Park Service	24%
Marin Municipal Water District	6%
County Open Space District	5%
State Parks	4%
Other Parks[a]	5%
Total	**100%**

[a] Includes land controlled by municipalities and school districts, US Army Corps of Engineers, California Department of Agriculture, California Fish & Game, North Marin Water District, and private organizations.

4.6 Natural Resources

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) included thirteen protected Marin wildland areas of the Golden Gate Biosphere Reserve in 1988, recognizing the global significance of its habitats and biodiversity (United Nations Educational, Scientific and Cultural Organization, 2002). The California Floristic Province, including Marin, is recognized by Conservation International as one of the twenty-six biological hotspots in the world. Marin County is the only area with this designation in the United States, and represents one of the greatest opportunities for restoration of declining habitats in the world.

Fuel reduction projects are able to either enhance or detract from the biological diversity and natural resources of Marin. For example, removing invasive exotic plants as potential fuel can restore native plant community structure and ecological function. On the other hand, over-grazing or removal of soil protective plants can lead to more invasive exotics and damage ecological functions. There are many opportunities to align habitat restoration and fuel reduction in many locations in the county where open space abuts neighborhoods. Many fuel reduction strategies and projects require monitoring and maintenance on the part of the landowner or fire agency.

4.6.1 Biodiversity

Marin County has a wide variety of plants, including several rare or locally endemic species. The twelve most distinctive plant communities are redwood forest, tanbark oak-madrono woodland, oak-buckeye woodland, Douglas fir forest, bishop pine forest, chaparral, coastal brush, grassland, streambank and lakeshore, freshwater marsh, saltwater marsh and dunes (Howell et al., 2007).

Additionally, the California Native Plant Society and the California Department of Fish and Wildlife characterize Marin County as one of the most biodiverse parts of the state. These agencies have identified more than one hundred distinct plant alliances in Marin.

Rare, threatened, or endangered species (both plants and animals) are present in Marin County. Extensive information about vegetation and their habitats is documented in the Marin County Parks and Open Space District's (MCOSD) Vegetation and Biodiversity Management Plan and by the Marin Watershed Program.[16] The county has critical habitats for the following list of special-status or locally rare species:

- **Wildlife (birds).** Cooper's hawk, sharp shinned hawk, white-tailed kite, grasshopper sparrow, northern spotted owl, olive-sided flycatcher, brant, northern harrier, San Francisco common yellowthroat, California black rail, snowy egret, osprey, Ridgeway's rail, Samuel's song sparrow, California horned lark, yellow warbler, burrowing owl, Sacramento splittail, California black rail, golden eagle, Virginia rail, San Pablo song sparrow
- **Wildlife (fish, frogs).** Coho salmon, central California coast steelhead, Chinook salmon, California red-legged frog (a threatened species)
- **Wildlife (other).** Pallid bat, American badger, salt marsh harvest mouse, land snail
- **Broadleaf herbaceous annuals and perennials.** Indigo bush, coast ground cone, Tiburon buckwheat, Mt. Tamalpais jewelflower, Brewer's redmaids, Hooker's tobacco brush, silver lupine (host plant of mission blue butterfly), coast rhododendron, marsh milk vetch, Humboldt Bay owl's clover, Point Reyes bird's beak, bent-flowered fiddleneck, Mt. Tamalpais manzanita, Mt. Tamalpais lessingia, common manzanita, Brewer's claytonia, Van Houtte's columbine, serpentine reedgrass, St. Helena morning glory, Calistoga navarettia, rough leaf aster, needle-leaved yellow linanthus, coast piperia, California lace fern, bristly linanthus, Wallace spike-moss, marsh zigadenus, Oakland star tulip, Mt. Tamalpais thistle, Marin dwarf flax, Marin County navarettia, Santa Cruz microseris, coast rock crest, California bottlebrush grass, California fremontia, Durango root, bristly leptosiphon, wind poppy, San Francisco gum plant, San Francisco leafy fleabane, black sage, tufted eschscholzia, wooly headed lessingia, fragrant fritillary, Baker's navarettia, streamside daisy, featherleaf navarettia, Lobb's buttercup, Tiburon indian paintbrush, Tiburon jewelflower, California grass of Parnassus, Tiburon mariposa lily, Santa Cruz clover, pitted onion, long-rayed brodiaea, serpentine coyote mint

Challenges to Marin County's biodiversity include controlling and eliminating invasive species because they displace native plants and can change ecosystem functions. Small shrubs are particularly hard to control because they may be widely distributed spatially. In addition to displacing native species, some invasive shrubs can form a dense understory beneath forest canopies, and could alter fire behavior and severity. Invasive trees, shrubs, plants, and grasses in Marin County include

[16] Marin Watershed Program (**https://www.marinwatersheds.org/creeks-watersheds/plants-wildlife-fish**).

- **Trees.** Acacia, blue gum eucalyptus, Monterey cypress, Monterey pine
- **Shrubs.** Cotoneaster, French broom, Himalayan blackberry, Pride of Madeira, Scotch broom, Spanish broom
- **Plants.** Bullthistle, purple starthistle, wooly distaff thistle, yellow starthistle, fennel, highway iceplant (also known as Hottentot fig), perennial pepperweed (also known as tall whitetop), puncture vine, stinkwort, thoroughwort (also known as eupatorium)
- **Perennial Grasses.** Cordgrass, erect veldtgrass, Fescue, Harding grass, jubata grass/pampas grass, velvet grass
- **Annual Grasses.** Barbed goatgrass, Italian wildrye, medusahead, rattlesnake grass, wild oats

4.6.2 Watersheds and Water Districts


Photo by Don DeBold[17]

There are approximately 22,000 acres of protected watershed land on Mt. Tamalpais and in the west Marin hills, including seven reservoirs which provide 75% of the water for central and southern Marin. The Marin Municipal Water District (MMWD) was founded in 1912 and manages the watershed land in central and southern Marin, including the seven reservoirs. The MMWD watershed has approximately 92 miles of roads, 59 miles of trails, and a network of wildfire protection fuel breaks. Access and use of the lands by the public is limited to protect the natural landscape. During extreme fire weather conditions, such as red flag warnings[18] and other emergencies, vehicle access is limited on MMWD land.[19]

The North Marin Water District (NMWD), founded in 1948, is an independent special district in the northern portion of the county and operates under the authority of Division 12 of the California Water Code. NMWD provides water service to the greater Novato area and to areas of West Marin (Point Reyes Station, Olema, Bear Valley, Inverness Park and Paradise Ranch Estates). NMWD purchases approximately 80% of its Novato water supply from the Sonoma County Water Agency,

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[17] "Lake Lagunitas reservoir" (https://www.flickr.com/photos/ddebold/3681496492/) by Don DeBold. (https://www.flickr.com/photos/ddebold/) is licensed under CC BY 2.0 (http://creativecommons.org/licenses/by/2.0/legalcode). No changes were made to this image.

[18] A red flag warning is a weather forecast warning issued by the National Weather Service to inform the public, firefighters, and land management agencies that conditions are ideal for wildland fire combustion, and rapid spread. Red flag warnings are typically issued for Marin County when winds are high, temperatures are high, and relative humidity is low.

[19] https://www.marinwater.org/mission-and-history.

with the remaining 20% derived from the District's Stafford Lake Reservoir (located in Marin County just west of Novato) and recycled water (Bentley and Landeros, 2015).

4.7 Environmental Considerations

Fire agencies and natural resource organizations recognize the importance of vegetation management, often referred to as fuel treatments or fuel reduction, as a tool for reducing fire hazards and restoring ecosystems. Likewise, native vegetation provides essential habitat for many species of wildlife. Native vegetation can be affected both by fuels management and wildfire. Fuel reduction projects can adversely affect native plant communities, wildlife habitats, and water quality. Therefore, environmentally and ecologically sound practices should be incorporated into fuel reduction projects to eliminate or mitigate adverse impacts. Strategies for protecting the natural environment while also reducing the fire hazard and risk to adjacent communities can be mutually beneficial. Prior to any vegetation management project that may result in direct or indirect physical changes to the environment, the potential impacts to the environment should be considered. Environmental considerations include (but are not limited to)

- Cutting or removal of trees, brush, and/or limbs.
- Use of mechanized equipment that may cause damage to sensitive plants or habitats.
- Creating dust, smoke, or noise.
- Exposing mineral soil.
- Disturbing species or reducing habitats, including plants, birds, bees, fish, mammals, reptiles, amphibians, and/or special status species.
- Changing the aesthetics or ecological integrity of the natural environment.

All agencies developing vegetation management projects should consider resource protection, monitoring, mitigation, and adaptive management measures and compliance in project planning. Additional time and budget are generally required to ensure that sensitive natural and cultural resources are protected.

4.7.1 Environmental Compliance

This CWPP is an advisory guiding document prepared in collaboration with stakeholder agencies pursuant to the HFRA. The CWPP development team was comprised of stakeholders (or their representatives) and the contents of this CWPP are opinions of these stakeholders. Because this CWPP is a guiding document, it does not legally commit any public agency to a specific course of action or project and thus, is not subject to the California Environmental Quality Act (CEQA) or to the National Environmental Policy Act (NEPA).

However, if funding is received from local, state, or federal agencies to implement a specific project, and prior to work performed, the lead agency must consider whether the proposed activity is a project under CEQA or NEPA. If the lead agency makes a determination that the proposed activity is a project subject to CEQA or NEPA, the lead agency must perform environmental review prior to obtaining permits or other entitlements by any public agencies to which CEQA or NEPA apply.

In addition to CEQA and NEPA, other environmental rules and management plans should also be considered. For example, agency-specific vegetation management plans, state or federal endangered species acts, the Migratory Bird Treaty Act, air district burn permit requirements, U.S. Army Corps of Engineers (USACE) 404 permits, and Stream Bed Alteration Agreements 1600. Resource surveys for rare and listed species and for archaeological and historic sites should be considered during planning. Treatment areas, schedule, and methods should be adjusted to avoid and protect resources and should be reflected in the CEQA compliance process. A comprehensive list of Best Management Practices (BMPs) for resource protection, including those listed in the California Vegetation Treatment Program (CalVTP),[20] is being developed by the Marin Wildfire Prevention Authority (MWPA) in coordination with the Ecologically Sound Practices (ESP) Partnership and One Tam agencies.

The recently passed California Assembly Bill No. 3074 (AB3074)—*Fire prevention: wildfire risk: defensible space: ember-resistant zones*—requires that CAL FIRE develop guidelines that provide "regionally appropriate vegetation management suggestions that preserve and restore native species that are fire resistant or drought tolerant, or both, minimize erosion, minimize water consumption, and permit trees near homes for shade, aesthetics, and habitat." The implementation of AB3074 has not yet been determined; however, once developed, the guidelines from CAL FIRE should also be considered.

4.7.2 Post-Fire Recovery Planning

As a protection plan and guiding document, it is not within the scope of a CWPP to address issues related to post-fire recovery. However, post-fire recovery is an important aspect of wildland fire management. Significant damage can occur after a major fire including loss of homes, businesses, infrastructure, natural resources, damage to watersheds, and soil erosion, to name a few. Pre-determining strategies for post-fire recovery is difficult because there is no single planning approach that fits all scenarios and post-fire recovery actions largely depend on land ownership, land ownership policies, and funding sources. Marin Recovers[21] is an organization made up of county offices and cities that focuses on post-disaster recovery and information dissemination for business owners and the public.

On federal lands, fire suppression repair plans are developed to repair areas that may have been affected by fire suppression efforts and to help restore the natural environment. On state lands, burned area recovery plans are developed to help restore land and assets to their pre-fire state. At

[20] CalVTP (**https://bof.fire.ca.gov/projects-and-programs/calvtp/**).

[21] https://marinrecovers.com.

the community level, hazard mitigation and post-disaster plans can be developed to help communities recover from disasters.

4.8 Roadways and Streets

Many homes in Marin County stand on hillsides and ridges, with narrow and winding roads providing the only access routes through neighborhoods and communities. In addition, cul-de-sacs generally serve new housing developments and most of the smaller canyons, valleys, and hillsides. Some planned unit developments are accessed by privately maintained roads, which create access issues (i.e., narrow paved widths and limited on-street parking). According to California Fire Code specifications, roadways that are considered hazardous in terms of fire access and protection are those with

- Less than 20 feet of unobstructed paved surface and 13.6 vertical feet,
- Dead-ends longer than 800 feet, and
- Cul-de-sac diameter less than 68 feet.

Driveways that are less than 16 feet wide or that do not have adequate turnaround space are also considered hazardous. A large number of roadways and driveways in many of Marin County's communities fall into one or more of the above categories.

An article in the Marin Independent Journal (August 23, 2019) discussed how several communities in Marin could face major traffic during a disaster. The article was based on research by StreetLight Data Inc.[22] that was inspired, in part, by the gridlock faced by residents of Paradise, California, during the Camp Fire in 2018. Researchers looked at communities of 40,000 residents or less across the country, showing how traffic would flow during an emergency and pointing out potential bottlenecks. Of the 30,000 communities analyzed, about 800 had scores that were three or more times the national average, including 107 in California, indicating that residents in California have fewer options than average when evacuating during an emergency. Twenty-two of the towns and cities are in the Bay Area, and of these, seven are in Marin County.

[22] https://learn.streetlightdata.com/hubfs/Other/Evacuation%20 Route%20CSV/StreetLight%20Data%20Limited%20Evacuation%20Routes%20List.pdf?utm_medium=email&_hsmi=95739312&_hsenc=p2ANqtz-8Nw2hC8aqgfaeQlZV85SM17tZr-oqnRastiZu-f95AKEA67zgi2aY3iYD6T9dcuWrfkYPUFKtVZ6WIYB4ZT7NJBkQDkQ&utm_content=95739312&utm_source=hs_automation.

Vegetation maintenance adjacent to roadways is an issue throughout Marin County. Primary highways such as Highways 1, 101, and 37 are maintained at the state level by the California Department of Transportation (Caltrans). Other primary and secondary roads are maintained at the county, city, or town level. Primary and secondary roads in State Park or NPS lands are maintained by the land ownership agency. There are many private roads in unincorporated parts of Marin County. The California Civil Code requires that these roads be maintained by private property owners and responsibility be shared equitably by the landowners benefiting from these roads.

4.8.1 Fire Road and Fuel Break Networks

Historically, fuel reduction efforts have focused on maintaining Marin's main fire road and fuel break networks extending from the shore of the San Francisco Bay in Sausalito to Lagunitas. This network of fire roads and fuel breaks generally follows ridgetop emergency access roads and incorporates natural (existing grassland) or human-made features (e.g., golf courses). In addition, lateral fuel breaks extend from the primary fuel break to the east, and specific fuel breaks and projects (i.e., prescribed burns, fuel removal projects) are implemented to protect specific communities. Fire roads and fuel breaks are in various states of repair, with some fire roads showing signs of regular maintenance, and other locations unpassable by vehicles due to vegetation overgrowth, washouts, or other unsafe surface conditions.

Maintaining fire roads and fuel breaks that provide firefighting equipment and personnel access to undeveloped areas is important. These roads were mapped to help identify potential wildfire response and emergency access issues, and to consider implications for evacuation during an emergency incident. Fire roads primarily include those roadways and trails on adjacent open space lands, including unpaved roads and trails, as well as some paved roads that connect and pass through open space areas **Figure 5** shows a map of unpaved roads within each fire agency jurisdiction. **Table 7** lists the mileage of unpaved roads by fire service agency.

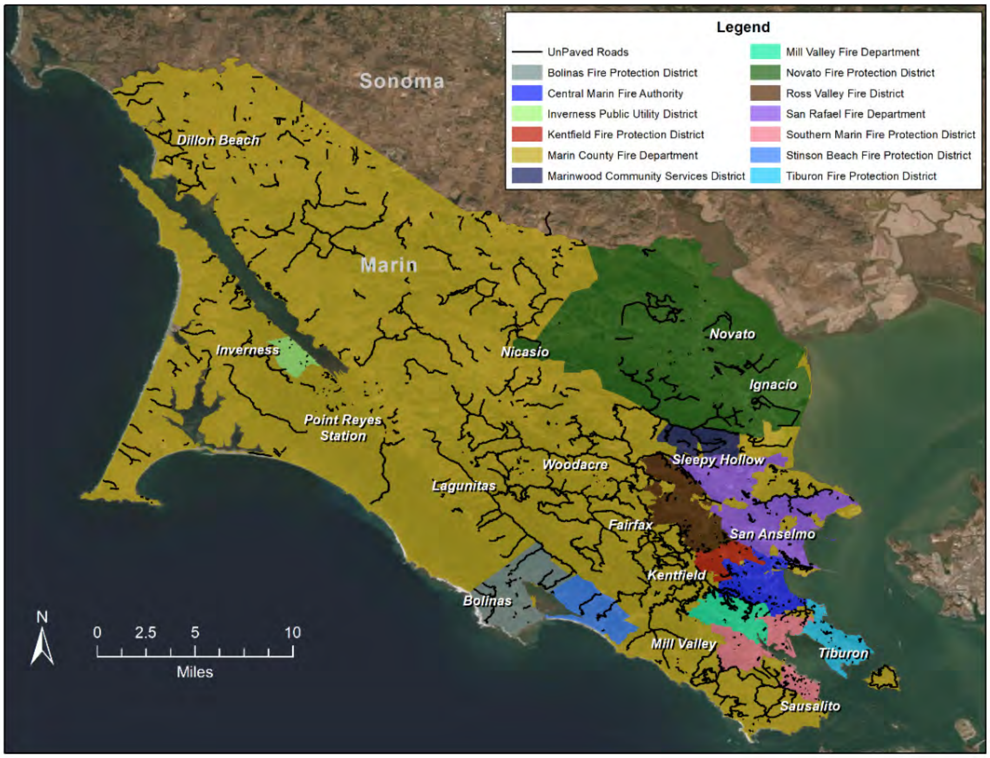

Figure 5. Map of unpaved roads overlaid with fire service agency boundaries.

Table 7. Approximate miles of unpaved roads by fire service agency.

Fire Jurisdiction	Miles of Unpaved Roads
Marin County Fire Department	426.9
Novato Fire Protection District	52.5
San Rafael Fire Department	21.2
Bolinas Fire Protection District	12.0
Central Marin Fire Authority	11.6
Mill Valley Fire Department	11.2
Ross Valley Fire Department	9.9
Southern Marin Fire Department	9.7
Marinwood Fire Department	9.2
Stinson Beach Fire Protection District	4.3
Tiburon Fire Protection District	3.3
Kentfield Fire Protection District	2.1
Inverness Volunteer Fire Department	0.7
Total	574.6

As part of this CWPP update, fire and land management agencies were asked to provide information about fuel reduction projects and/or hazard mitigation efforts within their jurisdictions. Appendix B provides a list of hazard mitigation efforts provided by the stakeholder agencies listed in alphabetical order by agency name (not in order of priority). Many of the projects listed in Appendix B have the objective of improving or maintaining fire roads, fuel breaks, and evacuation routes.

5. Fire Environment

The mix of weather, diverse vegetation and fuel characteristics, complex topography, and land use and development patterns in Marin County are important contributors to the fire environment. The MCFD Woodacre ECC currently manages data from five Remote Automated Weather Stations (RAWS). During the fire season, data from the RAWS are used to predict fire danger utilizing the National Fire Danger Rating System (NFDRS). The RAWS are located in Woodacre, Middle Peak, Barnabe, Big Rock, and Novato.

5.1 Weather

Marin County is bounded by the cool waters of the Pacific Ocean to the west, the San Francisco and Richardson Bays to the southeast, the San Pablo Bay to the east, and Sonoma County agricultural lands to the north. The combination of these large bodies of water, location in the mid-latitudes, and the persistent high pressure over the eastern Pacific Ocean results in several micro-climates. Weather in the county consists of warm, dry summers and cool, wet winters. The climate in early fall and late spring is generally similar to the summer climate, and late fall is similar to winter. Spring is generally cool, but not as wet as the winter. While these general weather conditions are fairly representative of typical Marin County weather, complex topography, annual variability of weather patterns, and less frequent and transient weather patterns are important to fire conditions.

Typical Summer Weather Conditions

In the late spring through the fall, the combination of frequent and strong high-pressure systems (known as the Pacific High) over California, combined with the cool waters of the ocean/bays, results in persistent fog and low clouds along the coast (including over southern Marin County near the San Francisco Bay). The fog often penetrates into the inland valleys of northern and central Marin County, especially during overnight hours. At the coastline, mist from fog can keep the land surfaces modestly moist, while inland land surfaces above the fog or inversion are often very dry.

The Pacific High that persists from late spring through early fall over the eastern Pacific, combined with a thermal low pressure over the Central Valley of California, results in an almost continuous sea breeze. These winds usher in cool and moist air and can be strong (15 to 25 mph), especially over the ridge tops and through valleys running northwest to southeast, including San Geronimo/Ross, Hicks, and Lucas Valleys. These westerly winds are usually highest in the afternoon, decrease in the evening, and are light overnight before increasing again in the late morning/early afternoon.

Extreme Summer Weather Conditions

Occasionally in the mid- to late-summer and more often in the fall and early winter, the Pacific High moves inland and centers over Oregon and Idaho, while low pressure moves from the Central Valley of California to southern California and Arizona. The resulting north-to-south pressure gradient can be strong enough to retard the typical sea breeze and can result in winds blowing from the land to the ocean. These easterly winds occur as systems of high pressure form in the Great Basin and flow over the Sierra Nevada Mountains (from the east) toward the Pacific Ocean (to the west). As winds flow over the Sierra Nevada, the winds compress, become warmer, and lower the relative humidity while drying out vegetation. As the winds move through canyons, they pick up speed and create strong gusts (**Figure 6**). These Northern California Diablo winds are most common in the late summer through early winter. It is under these wind regimes that California typically experiences its largest and most destructive fires.

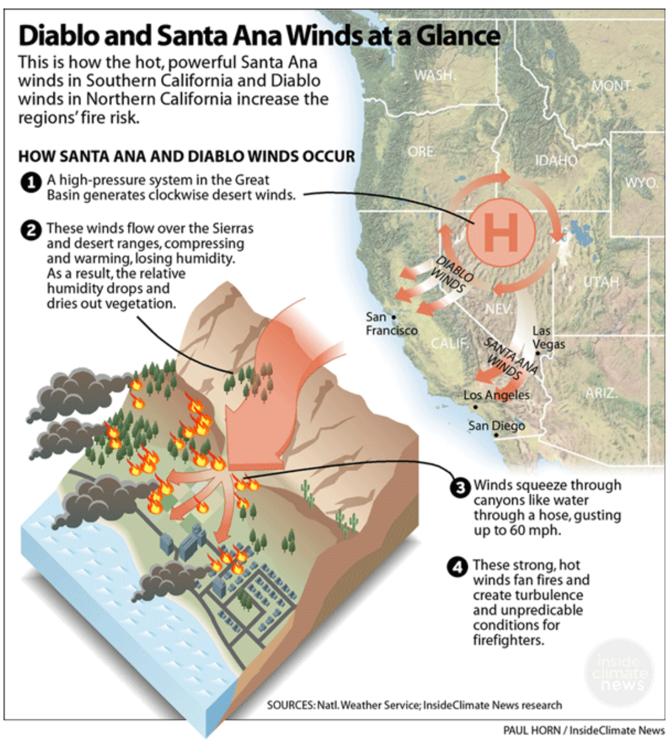

Figure 6. Illustration and explanation of the Diablo and Santa Ana winds. Source: National Weather Service, InsideClimate News research.

Under these "Diablo" wind conditions, observed during the northern California fires of 2017, 2018, and 2020, temperatures in Marin County can reach 100°F or higher in the inland areas and 80°F or higher at the coast, and relative humidity can be very low. In addition, wind speeds can be high (20 to 40 mph) and gusty, and are often much higher over the mountains and ridge tops of Marin (such as Mt. Tamalpais, Loma Alta, and Mt. Burdell) than over low-lying areas. Historically, the largest and most destructive fires in Marin, including the Vision Fire, the Angel Island Fire, and the Woodward Fire, have occurred during these offshore (also known as Foehn) wind events.

A few times per year in the summer and fall, monsoonal flow from Mexico brings moist and unstable air over central and northern California, which can result in thunderstorms with or without precipitation. With the otherwise dry summer conditions, the lightning can ignite fires. These monsoonal flow patterns are usually only one- to two-day events.

In August 2020, Northern California experienced a rare dry lightning weather event that ignited hundreds of wildfires. The lightning was caused by widespread, severe summer thunderstorms that formed from an unusual combination of very hot, dry air at the surface and advection of moisture from the remains of Tropical Storm Fausto that traveled northward into the Bay Area. Many of the lightning-ignited fires formed complex fires, the largest of which were the August Complex, the SCU Lightning Complex, the LNU Lightning Complex, and the Creek fire. As of November 8, 2020, approximately 4.2 million acres had burned in California as a result of these and other fires.[23]

Winter Weather Conditions

Beginning in late November and lasting through the end of March, the Pacific High typically moves south and weakens, allowing storms that originate in the Gulf of Alaska to move over California. These storms bring precipitation and, at times, strong winds out of the south. Each storm usually results in one-fourth inch to several inches of rain over a day or so. Near Mt. Tamalpais, rainfall amounts are enhanced by orographic lifting, resulting in higher rain amounts in the Kentfield and Fairfax areas than in the rest of the county. Typically, after the first rain in November, the cool weather and occasional storms keep the ground wet through late spring. However, in some years, significant rain does not occur until later in the year (e.g., early to late December) and there can be several weeks without any storms and rain. During storms, temperatures are usually mild.

When there are no storms over California, a land-breeze typically forms (i.e., winds blowing from the Central Valley to the Pacific Ocean). These winds can reach 30 mph, and travel through the southeast to northwest lying valleys, over low-lying ridges such as the Marin Headlands, and through the Golden Gate. These winds are usually highest in the mid-morning hours and decrease in the afternoon as the Central Valley warms during the day. The winds are associated with cold and modestly moist air.

[23] CAL FIRE 2020 Fire Statistics (**https://www.fire.ca.gov/stats-events**).

Spring Transitional Conditions

In late February/early March through late April, the Pacific High strengthens and moves north, and storms impacting the county become less frequent. During this time of year there is often a low pressure area over the desert in southwest California. The combination of the Pacific High to the north and low pressure to the southwest results in strong winds blowing from the northwest to the southeast. Like the sea breeze, these winds bring in cool, moist air and are usually strongest in the afternoon hours. Because of winter and spring rains, the land is wet and there is little danger of wildland fire despite the high winds and only occasional precipitation. There is often little coastal fog this time of year.

5.2 Vegetation and Fuels Characteristics

Vegetation, which in the context of wildland fire is also referred to as fuel, plays a major role in fire behavior and potential fire hazard. A fuel's composition (including moisture level, chemical make-up, and density) determines its degree of flammability. Of these, fuel moisture is the most important consideration. Generally, live trees contain a great deal of moisture, while dead logs contain very little. The moisture content and distribution of fuels determine how quickly a fire can spread and how intense or hot it may become. High moisture content slows the burning process since heat from the fire must first eliminate moisture.

In addition to moisture, a fuel's chemical makeup determines how readily it will burn. Some plants, shrubs, and trees such as chemise and eucalyptus (both present in Marin County) contain oils or resins that promote combustion, causing them to burn more easily, quickly, and intensely. Finally, the density of a fuel influences its flammability; when fuels are close together but not too dense, they will ignite each other, causing the fuel to spread readily. However, if fuels are so close that air cannot circulate easily, the fuel will not burn freely.[24]

Marin County has extensive topographic diversity that supports a variety of vegetation types. Environmental factors, such as temperature, precipitation, soil type, aspect, slope, and land use history, all help determine the existing vegetation at any given location. In the central and eastern parts of the county, north-facing slopes are usually densely wooded from lower elevations to ridge peaks with a mixture of mostly hardwood tree species such as coast live oak, California bay, Pacific

[24] http://www.nps.gov/fire/wildland-fire/learning-center/fire-in-depth/fire-behavior.cfm.

madrone, and other oak species. Marshlands are also present throughout the county in parts of Novato, San Rafael, Bolinas, Dillon Beach, Stinson Beach, and Pt. Reyes; once ignited, marsh fires can be difficult to contain and extinguish.

Grasslands with a mixture of native and nonnative annual and perennial plant species occur most often in the northern and western parts of the county due to a combination of soil type, lower rainfall, and a long history of ranching. The southern and western slopes tend to have a higher percentage of grasslands, which in turn have the potential to experience higher rates of fire spread. Grassland fires are dangerous even without extreme fire weather scenarios because of the rapid rate of fire spread; in some cases, fires spread so quickly that large areas can burn before response resources are able to arrive.

In the west portion of the county closer to the coast, where precipitation is higher and marine influence is greater, most areas are densely forested with conifer species (i.e., Bishop pine, Douglas fir, and coast redwood) and associated hardwood species. Chaparral vegetation also occurs in parts of the county, especially on steeper south- and west-facing slopes. This mix of densely forested areas mixed with chaparral results in higher fuel loads and potentially higher fire intensity. Expansion of the residential community into areas of heavier vegetation has resulted in homes existing in close proximity to dense natural foliage; these homes are often completely surrounded by highly combustible or tall vegetation, increasing the potential that wildland fires could impact them.

5.2.1 2018 Updated Vegetation and Fuel Model Map

MCFD is coordinating with Marin public land management agencies, via the One Tam collaborative, to ensure the updated fuel model map in the CWPP has the most recent, up-to-date data available. This coordination will continue as agencies work together to protect communities from wildfire while also protecting the unique natural resources in Marin.

In 2018 the One Tam agency partners—Marin Municipal Water District, Marin County Parks, the National Park Service, and the California Department of Parks and Recreation—initiated development of a Marin countywide fine-scale vegetation map and landscape database. The fine-scale vegetation map, expected to be completed in 2021, is a robust geospatial dataset developed using the California Department of Fish and Wildlife Vegetation Classification and Mapping Program methodology, which combines on-the-ground fieldwork with advanced remote-sensing technology. The project's landscape database features a number of high-resolution topographic and landcover datasets, including 4-band 6-inch aerial imagery, QL1 LiDAR-derived digital elevation models and topographic contours, hydrological system mapping using United States Geological Survey (USGS) National Hydrography Dataset (NHD) standards, and impervious/permeable surface mapping. Several datasets, including LiDAR derived ladder fuels raster, canopy height model, canopy closure model, and vegetation lifeform map were provided to MCFD and used to support the updated fuel model map as part of this CWPP revision.

The fine-scale vegetation map and landscape database products are also being integrated into One Tam's Regional Forest Health Strategy for Public Lands. The Strategy, estimated to be completed in early 2022, will produce additional forest-related geospatial datasets and include monitoring and fuels treatment best management practices. Products from the fine-scale vegetation map and forest health strategy will assist Marin's public safety and land management agencies in planning, compliance, and implementation of forest health and fuels reduction projects, as well as provide foundational data to support the conservation of important vegetation communities and wildlife habitats across the county. As part of this 2020 CWPP update, an updated fuel model map layer was created using the data recently collected as part of the One Tam collaborative. The vegetation and LiDAR data collected as part of the Vegetation Map and Landscape Database project represent 2018 ground vegetation and structure. Fire behavior models require fuel model data as input. Fuel models provide set of quantitative vegetation characteristics that can be visually identified in the field and are used to predict fire behavior.

Vegetation distribution in Marin County is characterized by approximately 22 different types of vegetation, which have been classified into 18 fire behavior fuel models. Table 8 lists the fuel model types for Marin County, while Figure 7 shows a fuel model map; the data shown were developed to support this CWPP update and represent the most current and highest-resolution vegetation coverage data available for the county. The methods used to develop the fuel model dataset are documented in Appendix A.

Table 8. Fuel model types for Marin County.

Scott & Burgan Fuel Model Description (and Number)	Acres	Percent of County Total
Short, sparse, dry climate grass (101)	126,859	38%
Very high load broadleaf litter (189)	41,959	12%
Very high load, dry climate timber-shrub (165)	39,413	12%
Moderate load broadleaf litter (186)	28,391	8%
High load, dry climate shrub (145)	22,377	7%
Low load broadleaf litter (182)	14,313	4%
Open water (98)	12,461	4%
Very high load, dry climate shrub (147)	10,246	3%
Moderate load, dry climate grass (104)	7,724	2%
Urban/undeveloped (91)	6,929	2%

Scott & Burgan Fuel Model Description (and Number)	Acres	Percent of County Total
High load, dry climate grass (107)	5,873	2%
Low load, dry climate shrub (141)	5,046	2%
Low load, dry climate grass (102)	4,854	1%
Moderate load dry climate shrub (142)	2,511	1%
Bare ground (99)	2,185	1%
Low load compact conifer litter (181)	2,055	1%
Low load, dry climate grass-shrub	1,685	1%
Other	1,264	<1%
Total	**336,143**	**100%**

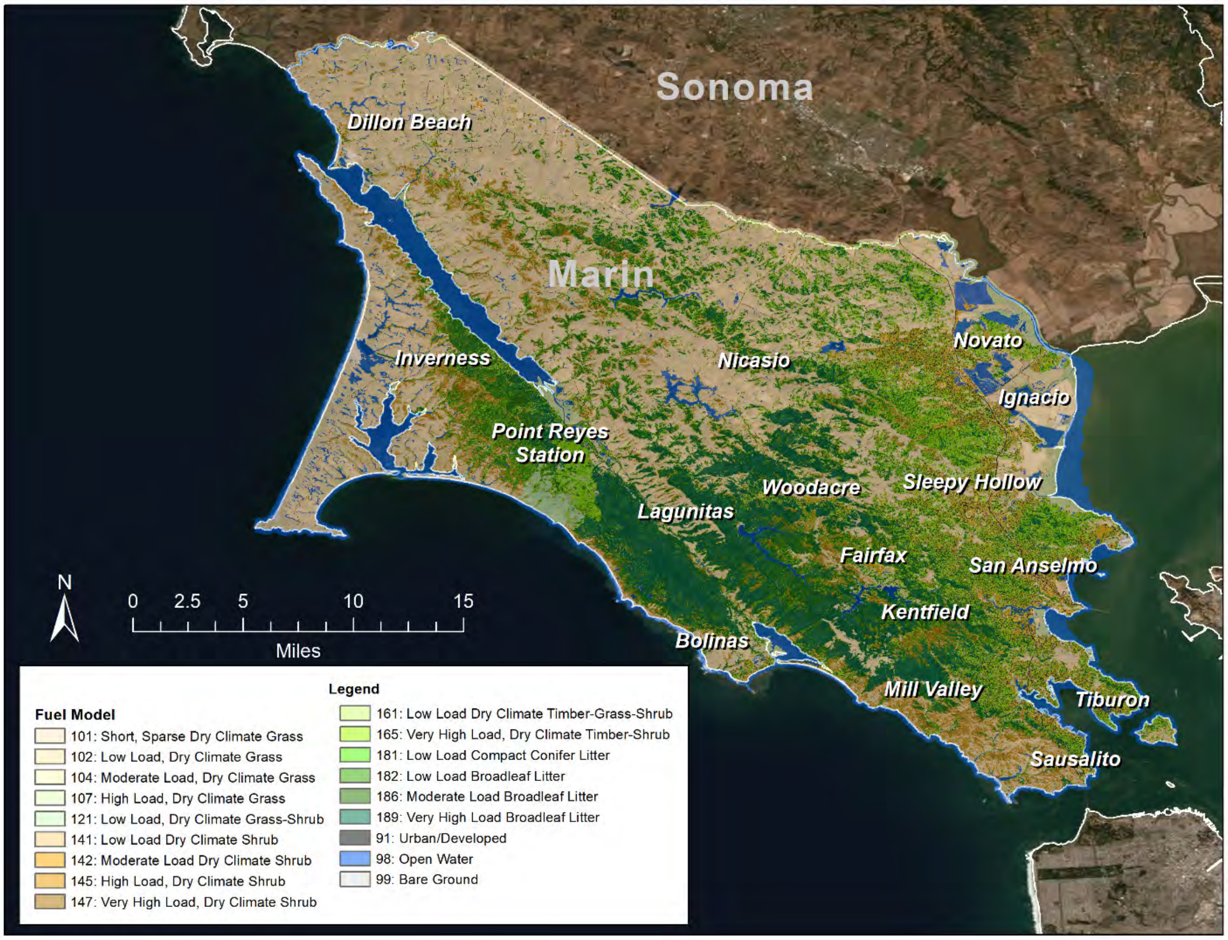

Figure 7. Updated 2018 high-resolution (5 x 5 meter) fuel model map for Marin County.

5.2.2 Vegetation Diseases and Infestations


Photo by USFS Region 5[23]

Insect infestations and plant diseases, such as California oak mortality syndrome (sudden oak death), are increasing and threaten to change the structure and overall health of native plant communities in Marin County (May & Associates Inc., 2015). Sudden oak death has no known cure and is the biggest concern; this syndrome is caused by the fungus-like *Phytophthora ramorum*, which has led to widespread mortality of several tree species in California since the mid-1990s; the tanoak (*Lithocarpus densiflorus*) in particular appears to have little or no resistance to the disease. Sudden oak death has resulted in stands of essentially dead trees with very low fuel moistures. Studies examining the impacts of sudden oak death on fire behavior indicate that while predicted surface fire behavior in sudden oak death stands seems to conform to a common fuel model already in use for hardwood stands, the very low moisture content of dead tanoak leaves may lead to crown ignitions more often during fires of "normal" intensity (Lee, 2009).

Two other plant diseases prevalent in Marin County are pitch canker (which affects conifers such as Bishop pine and other pine species), and madrone twig dieback (which affects Pacific madrones). Pitch canker is caused by the fungus *Fusarium circinatum* (*F. subglutinans, F. sp. pini*), which enters the tree through wounds caused by insects. While some trees do recover, most infected trees are eventually killed by the fungus. Management of this disease largely focuses on containment to reduce the fungus' spread to other trees. Pitch canker is a particular issue in the NPS lands of Pt. Reyes National Seashore, where many acres of young Bishop pines that were seeded on the Inverness Ridge by the Mount Vision Fire of 1995 have been infected. These dead and dying trees have created large swaths of land with dense and dry fuel loads. Madrone twig dieback is caused by the native fungus *Botryosphaeria dothidea* and appears to be getting worse throughout the county due to drought effects on Pacific madrones.

[25] "Dead Coast Live Oak in Marin.Steve Swain[1]" (https://www.flickr.com/photos/usfsregion5/5812704230/) by the USFS Region 5 (https://www.flickr.com/photos/usfsregion5/) is licensed under CC BY 2.0 (creativecommons.org/licenses/by/2.0/legalcode). No changes were made to this image.

Three additional threats to trees common to Marin County include:

- Bark and ambrosia beetles (*Monarthrum dentiger* and *monarthrum scutellare*), which target oak and tanoak trees. Sudden oak death may be exacerbating the effects of beetle infestations, which prey on trees already weakened by this disease.
- Root rot, caused by oak root fungus (*Armillaria mellea*), is primarily associated with oaks and other hardwoods but also attacks conifers. These fungal infestations cause canopy thinning and branch dieback and can kill mature trees. As with the beetle infestations, sudden oak death may be exacerbating the effects of root rot fungus in the county forests.
- Velvet-top fungus (*Phaeolus schweinitzii*) is a root rot fungus affecting Douglas fir and other conifers, with the infection typically occurring through a wound.

5.3 Topography

Topography characterizes the land surface features of an area in terms of elevation, aspect, and slope. Aspect is the compass direction that a slope faces, which can have a strong influence on surface temperature, and more importantly on fuel moistures. Both elevation and aspect play an important role in the type of vegetation present, the length of the growing season, and the amount of sunlight absorbed by vegetation. Generally, southern aspects receive more solar radiation than northern aspects; the result is that soil and vegetation on southern aspects is warmer and dryer than soil and vegetation on northern aspects. Slope is a measure of land steepness and can significantly influence fire behavior as fire tends to spread more rapidly on steeper slopes. For example, as slope increases from 20% to 40%, flame heights can double and rates of fire spread can increase fourfold; from 40% to 60%, flame heights can become three times higher and rates of spread can increase eightfold.[26]

Marin County is topographically diverse, with rolling hills, valleys, and ridges that trend from northwest to southeast. Elevation throughout the county varies considerably, with Mt. Tamalpais'

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[26] Adapted from the S-290 Intermediate Wildland Fire Behavior course material (National Wildfire Coordinating Group, http://training.nwcg.gov/courses/s290.html).

peak rising 2,574 feet above sea level and many communities at or near sea level. Correspondingly, there is considerable diversity in slope percentages. The San Geronimo Valley slopes run from level (in the valley itself) to near 70%. Mt. Barnabe has slopes that run from 20% to 70%, and Throckmorton Ridge has slopes that range in steepness from 40% to 100%. These slope changes can make fighting fires extremely difficult.

5.4 Fire History

Understanding fire history is important when predicting potential future fire frequency, fire behavior, and ignition sources. The historical record shows that many large wildfires (greater than 500 acres) have occurred in Marin since 1850. Many more frequent and smaller fires have occurred throughout Marin and this knowledge helps us understand the likely processes, scenarios, and locations of future fires.

Marin's native vegetation evolved with the presence of frequent wildfires, ignited both by natural causes (primarily lightning) and by native peoples. Relatively short intervals of 2 to 20 years between wildfires promoted the health and regeneration of native grasslands, oak woodlands, and forests, favoring plant (and animal) species that were best adapted to fire. These low-intensity and relatively frequent wildfires are generally considered to have been "beneficial" to the landscape, supporting and expanding native grasslands and increasing biodiversity and productivity of chaparral and coastal scrub ecosystems (Sugihara et al., 2006).

The most frequently burned landscapes in California prior to 1850 were ignited, often on a nearly annual basis, by Native Americans (Lewis et al., 1993; Keter, 1995) and were generally near villages or where vegetation was cultured for food and basketry materials, such as grasslands and oak woodlands. In general, the most frequent fires occurred in grasslands and oak woodlands in areas like the GGNRA headlands. Lightning fires were common and would burn large swaths of the landscape, with research showing that the average wildfire interval in Marin County before the arrival of Europeans was less than seven years (Stephens et al., 2007; Jacobs et al., 1985).

Fire records for Marin are incomplete, but historic newspaper articles and old fire planning studies document an active fire history going back to the early 20th century. Throughout its history, Marin County has experienced many wildland fires. The most recent fire in Marin was the Woodward Fire which started on August 17, 2020 by lightning from a rare dry lightning weather event. The Woodward Fire was contained by October 9, 2020 at 4,929 acres.[27] The last fire in Marin that resulted in significant structure loss was the Vision Fire in 1995, which destroyed 48 structures in the community of Inverness. In 1929, the base of Mt. Tamalpais—specifically the community of Mill Valley—experienced a significant fire known as the Great Mill Valley Fire. That fire's footprint is now developed with more than 1,100 homes (valued at over $1 billion) which have significantly altered the natural vegetation through urban and suburban development. **Figure 8** shows a map of fires larger than 200 acres that have occurred in Marin from 1878 to 2019 (CAL FIRE California Fire Perimeters 1878 to 2019).[28] Note that the map in Figure 6 also shows the perimeter of the Woodward Fire, which occurred in 2020.

[27] https://www.nps.gov/pore/learn/management/firemanagement_woodwardfire.htm.

[28] https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=6fd0d8d6f47d414da7bcb1dcd0539999.

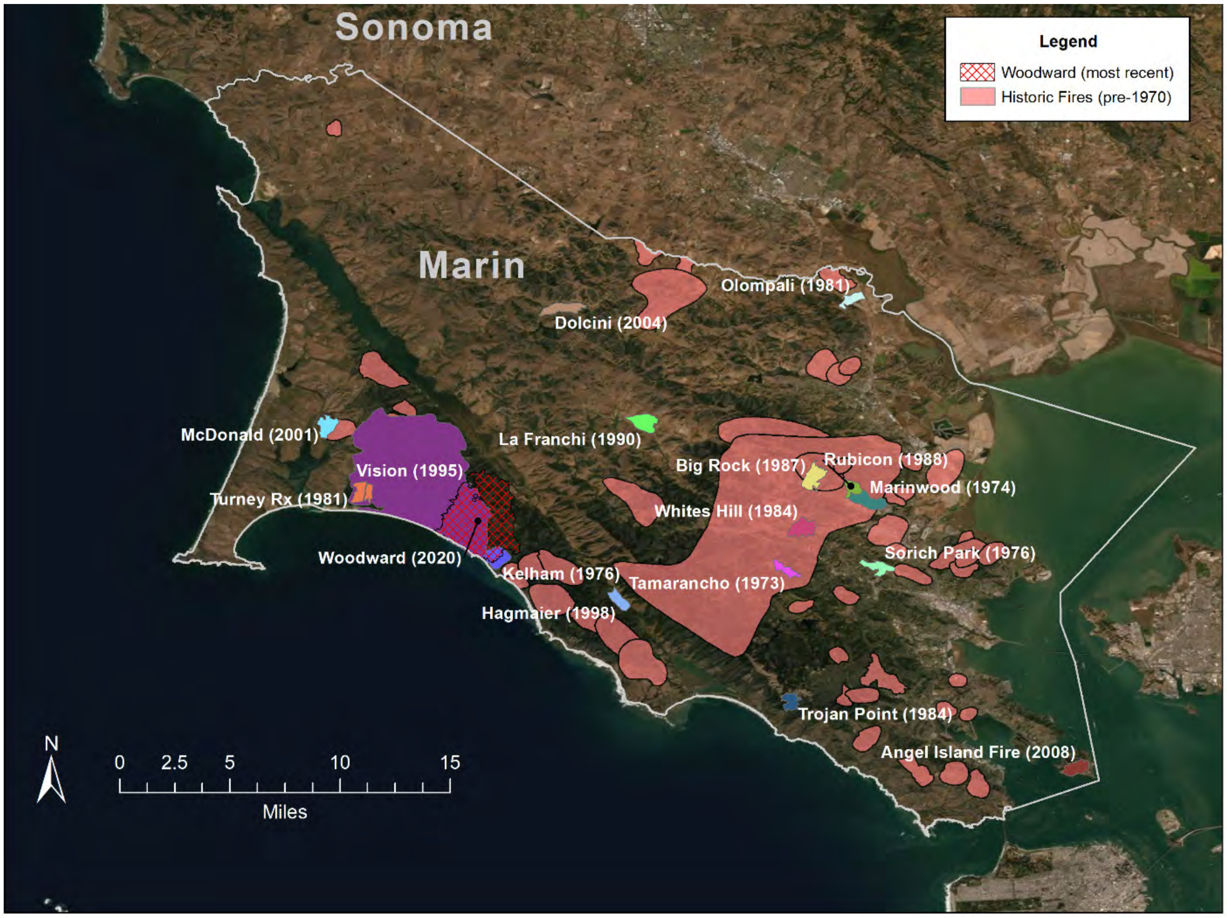

Figure 8. Map of fires larger than 200 acres that have occurred in Marin from 1828 to 2019. Note that the map also shows the perimeter of the Woodward Fire, which occurred in 2020.

5.5 Ignition History

Ignition data from CAL FIRE were mapped to evaluate ignition sources and patterns within the county. Figure 9 shows a map of the ignition history for Marin County from 2004 through 2019, classified by ignition category (CAL FIRE California Ignition History 2004 to 2019).

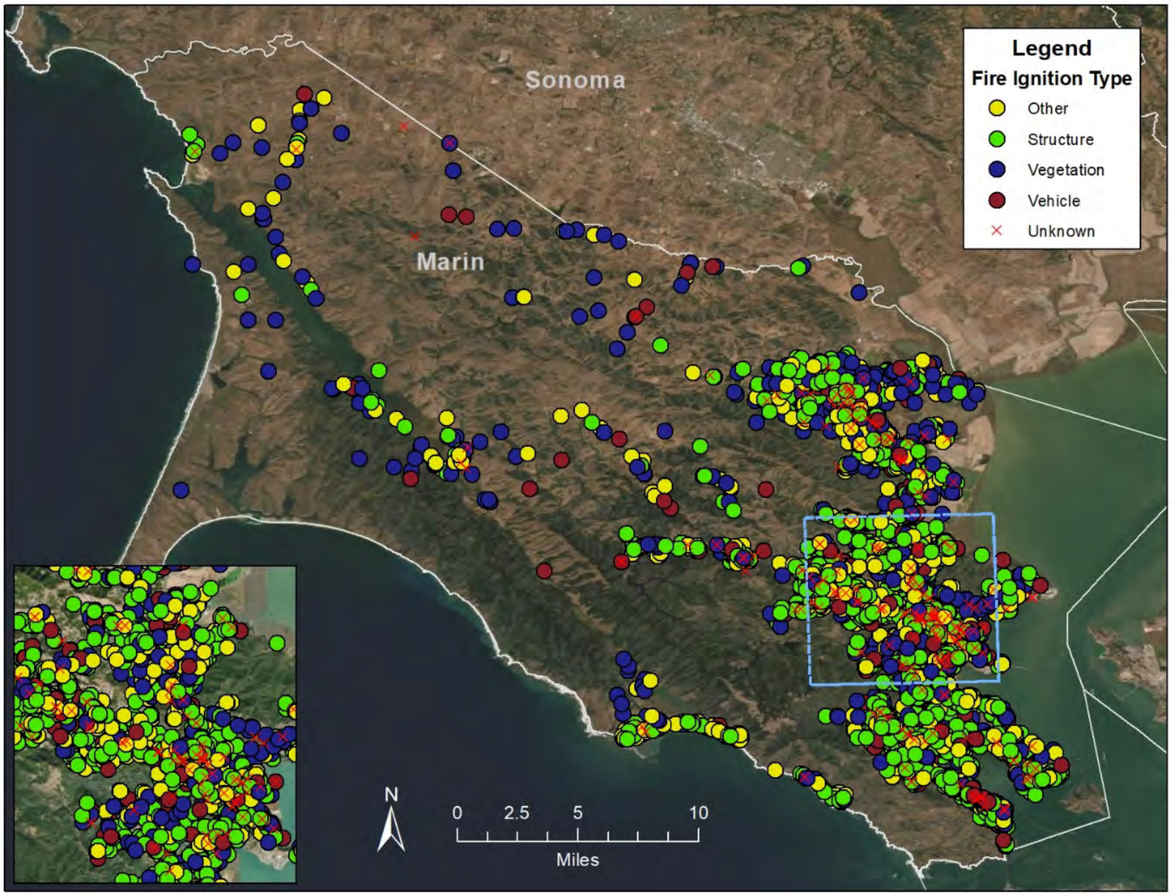

Figure 9. Map of ignition history data for Marin County from 2004 through 2019.

5.6 Climate Variability

Recent research indicates that higher summer temperatures will likely increase the area burned and fire severity in California, and particularly in Northern California (Westerling, 2018). Future changes in fire frequency and severity are difficult to predict; however, regional climate change associated with elevated greenhouse gas concentrations could alter large weather patterns and produce conditions conducive to extreme fire behavior. A warmer climate will bring drier winters, higher spring temperatures, and early snowmelt. Combined with drought conditions, this leads to drier soils in early summer, drier vegetation, and an increase in the number of days in the year with flammable fuels, all which further raise the likelihood of fires.[29] Fuel and vegetation treatments will be challenging to implement at spatial scales large enough to make a difference, especially if the number of wildfires increases greatly in the future. However, hardening homes, creating defensible space, and managing vegetation to reduce fire hazard can enhance resilience in areas with high resource and economic values such as the WUI.

[29] http://www.fs.usda.gov/ccrc/topics/wildland-fire.

The western U.S. is likely to continue its trend toward warmer and drier conditions, on average, with warmer spring and summer temperatures, reduced snowpack and earlier snowmelts, and longer, drier summer fire seasons (Westerling et al., 2006; Westerling, 2018). Models and observations predict that warming and drying conditions are likely to cause increased fire activity in the future, including reconstructions of fire and climate in the past (Swetnam, 1993); trends over the last few decades (Westerling et al., 2006); and predictive models (Westerling and Bryant, 2007). Increased drought and heat have already caused an increase in tree mortality.

Source: *Union of Concerned Scientists, Sept. 2020*

Large and destructive wind-driven fires exhibiting extreme fire behavior, such as those that occurred in 2017, 2018, and 2020 in California, are likely to continue in the coming years, emphasizing the immediate need for pre-fire planning and mitigation to protect homes, infrastructure, and other assets at risk.

Healthy forests, natural vegetation, and home landscapes sequester carbon from the atmosphere. The term "carbon sequestration" refers to the biological process where plants take carbon dioxide out of the atmosphere through photosynthesis, store the carbon in their tissues, and send carbon through roots to the soil, where it can be stored long-term. Encouraging land management practices that support carbon sequestration has the potential to help mitigate climate change.

6. County-Level Fire Hazard Assessment

In the context of wildfire hazard, the term "hazard" refers to the presence, structure, and makeup of vegetation fuels and the amount of potential energy that may be released in a given environment or weather condition. The term "risk" is the chance, high or low, that any hazard will cause harm to an asset. An "asset" is anything that has value, such as property, structures, infrastructure, natural resources, etc. The county-level hazard assessment presented in this section focuses on fire hazard relative to structures (buildings and homes) throughout the county.

CAL FIRE is required by law to map areas of significant fire hazards based on fuels, terrain, weather, and other relevant factors. These zones, referred to as Fire Hazard Severity Zones (FHSZ), influence how people construct buildings and protect property to reduce risk associated with wildland fires. The maps were last updated in the mid-1980s and early 1990s. Efforts have been underway for the past several years to update the maps to incorporate improved fire science, data, and mapping techniques. The updated FHSZ maps are expected to be completed and released in 2021 (California Department of Forestry and Fire Protection, 2020).

While the CAL FIRE FHSZ maps are useful in examining potential fire hazard severity at the state level, the underlying data and methods used to develop the FHSZ maps can be improved upon by using local (and more recent) fuel characteristics and improved fire modeling methods. The CAL FIRE FHSZ maps also do not take into account local perspectives on wildfire vulnerabilities and preparedness.

To improve upon and help supplement the state-level fire hazard assessment information, an independent hazard assessment was performed to help identify and prioritize areas within the county that are potentially at a high threat from wildfire based on recent fuels data, advanced modeling techniques, and local input. The assessment was performed by modeling potential fire behavior combined with building structure density to assess relative potential fire hazard throughout the county.

6.1 Assets at Risk

"Assets at risk" are structures, infrastructure, and other resources that can be damaged or destroyed by a wildland fire. Assets in Marin County include real estate (homes and businesses), emergency communication facilities, transportation and utility infrastructure, watersheds, protected wildlands, tourist and recreation areas, and agricultural lands. CAL FIRE's California Fire Plan identifies the following assets warranting consideration in pre-fire planning: watersheds and water; wildlife; habitat; special status plants and animals; scenic, cultural and historic areas; recreation; rangeland; structures; infrastructure; and air quality.


Photo by Miquel Vieira[28]

As discussed in Section 4, many homes in the county are located in the WUI; if a major wildland fire were to result in the loss of many homes, it could have a negative impact on Marin County's property tax base.

The Mt. Tamalpais watershed supplies central and southern Marin County with 75% of their fresh water. Given the area's seasonal rainfall, any major wildfire impacting the heavily forested watershed would result in major silting and subsequent degradation of water quantity and quality in the watershed. This watershed—as well as the lands managed by MCOSD, State Parks, and NPS—is largely contiguous. The area harbors several endangered, threatened, and special-status species, including the coho salmon and northern spotted owl. The area is also part of a major migrating bird flyway and nesting area.

Marin County is also a major tourist destination. Major parks within Marin County include California State Parks (Mt. Tamalpais, Samuel P. Taylor, and China Camp), NPS's GGNRA, Muir Woods National Monument, and Point Reyes National Seashore. An estimated 12 to 14 million tourists come to Marin each year to enjoy outdoor activities. In 2018, tourism contributed an estimated $575 million to the economy.[31] A major wildfire affecting any of these parks could have negative impacts on the local economy for years after the event.

Finally, Marin County's agricultural land base includes nearly 137,000 acres of privately owned agriculturally zoned land and 32,000 acres of federally owned land that is leased to agricultural operators. Agricultural operations include livestock and livestock products; aquaculture; field crops; and fruit, vegetable, and nursery crops. The gross value of all agricultural production was approximately $98 million in 2019 (Marin County Department of Agriculture, 2014).

To help protect people and property from potential catastrophic wildfire, the National Fire Plan identifies communities that are at high risk of damage from wildfire. These high-risk communities identified within the WUI were listed in the Federal Register in 2001. In California, CAL FIRE has the

[30] "Mt Tamalpais Watershed from Mt Tamalpais summit" (https://www.flickr.com/photos/miguelvieira/2440494686/in/photostream/) by Miquel Vieira (https://www.flickr.com/photos/miguelvieira/) is licensed under CC BY 2.0 (creativecommons.org/licenses/by/2.0/legalcode). No changes were made to this image.

[31] Marin Convention and Visitors Bureau 2019. Available at (https://issuu.com/devorahjean/docs/program_of_work_2019).

responsibility for managing the list.[32] With California's extensive WUI situation, the list of communities extends beyond just those adjacent to Federal lands; there are 1,329 communities currently on the California Communities at Risk List. Marin County has 23 of these at-risk communities, as shown in Table 9. A countywide assessment of the wildland fire threat undertaken by CAL FIRE revealed that nearly 313,000 acres (approximately 82% of the total land area of the county) are ranked as having moderate to very high fire hazard severity zone ratings.

Table 9. Marin County communities at risk and fire district jurisdiction.

Community	Fire Department/District
Bolinas	Bolinas Fire Protection District
Corte Madera	Central Marin Fire Authority
Fairfax	Ross Valley Fire Department
Inverness	Inverness Fire Department
Inverness Park	Marin County Fire Department
Kentfield	Kentfield Fire Protection District
Lagunitas-Forest Knolls	Marin County Fire Department
Larkspur	Central Marin Fire Authority
Lucas Valley-Marinwood	Marinwood Fire Department
Marin City	Marin County Fire Department
Mill Valley	Mill Valley Fire Department
Novato	Novato Fire Protection District
Olema	Marin County Fire Department
Point Reyes	Marin County Fire Department
Ross	Ross Valley Fire Department
San Anselmo	Ross Valley Fire Department
San Rafael	San Rafael Fire Department
Santa Venetia	San Rafael Fire Department
Sausalito	Southern Marin Fire Protection District
Stinson Beach	Stinson Beach Fire Protection District
Strawberry	Southern Marin Fire Protection District
Tamalpais-Homestead Valley	Southern Marin Fire Protection District
Tiburon	Tiburon Fire Protection District

[32] National Fire Plan Communities at Risk List, https://osfm.fire.ca.gov/divisions/wildfire-planning-engineering/fire-plan/communities-at-risk/ (last accessed November 13, 2020).

Community	Fire Department/District
Tomales	Marin County Fire Department
Woodacre	Marin County Fire Department

One of the objectives in updating the CWPP was to compile an updated list of priority hazard reduction strategies and projects throughout the county (see **Appendix B**). As part of the CWPP process, fire departments, land management agencies, and other stakeholders were asked to identify and provide information about the areas they are most concerned about within their jurisdictions and to catalog priority areas and hazard mitigation projects in those areas. Not surprisingly, almost all of the areas identified by stakeholders fall within or are adjacent to Marin's WUI. Many of the areas and projects identified are also along evacuation routes.

6.2 County-Level Fire Hazard Assessment

To help identify and prioritize areas within the county that are potentially at a high risk of wildfire threat, a hazard assessment was performed using recently updated fuels data and representative weather scenarios. **Figure 10** shows the steps used to perform the county-level fire hazard assessment.

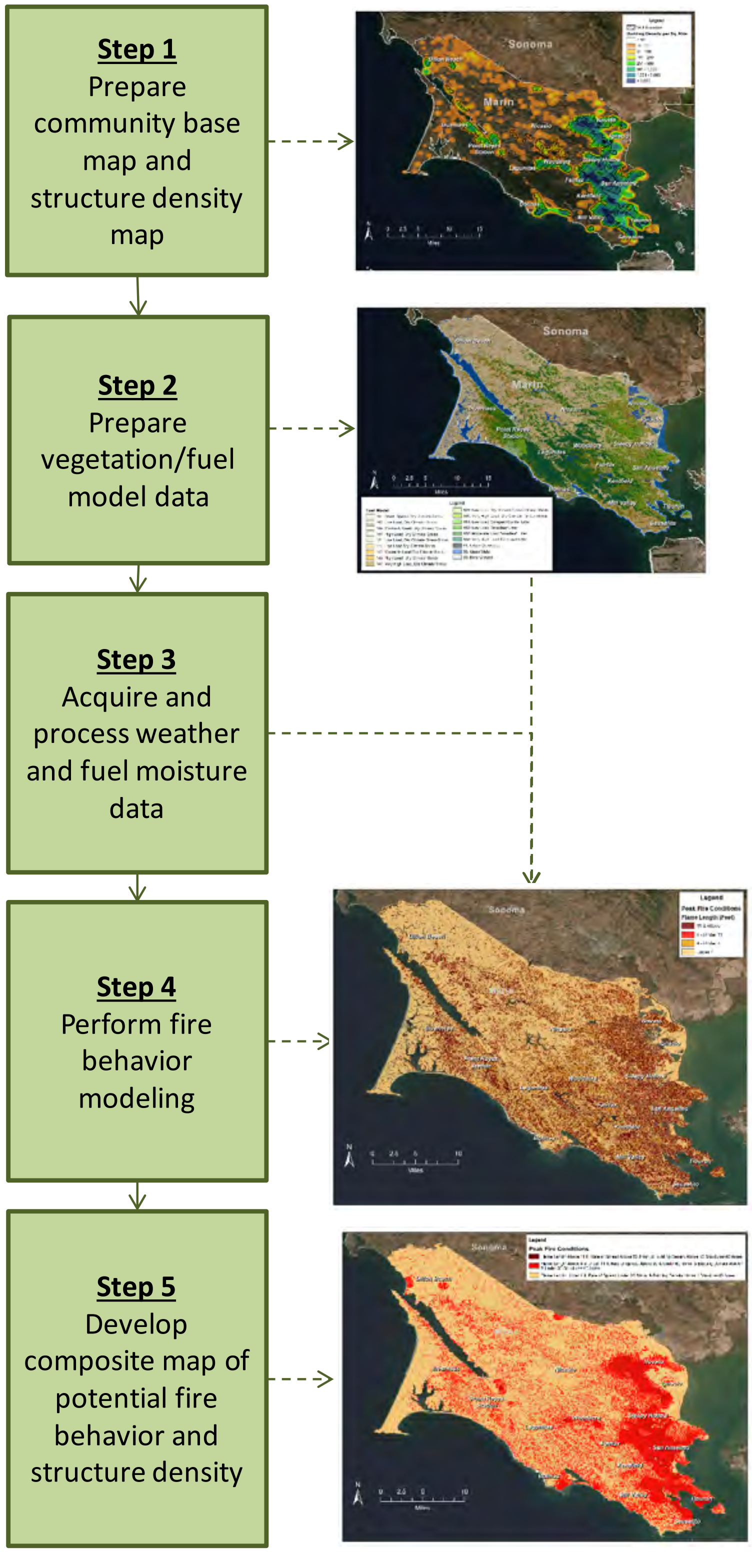

Figure 10. The steps used to perform the county-level hazard assessment.

6.2.1 County-Level Fire Hazard Assessment Methodology

Step 1: Prepare Community Base Map and Structure Density Map

A base map of Marin County was assembled using GIS data layers acquired primarily from Marin County's GIS portal, marinmap.org. The base map includes map layers of political boundaries, fire districts, land ownership, census data, infrastructure, building footprints, a parcel map, a map of structure density, and WUI boundaries.

Building footprint data for Marin County were acquired from the Marin County parcel tax assessor's dataset representing data through 2019. The building footprint data were mapped and used to identify areas with high structure density and therefore, high asset value. Figure 11 shows the structure density map for Marin County. The community base map and corresponding map layers have been made available for viewing through an ESRI StoryMap website.

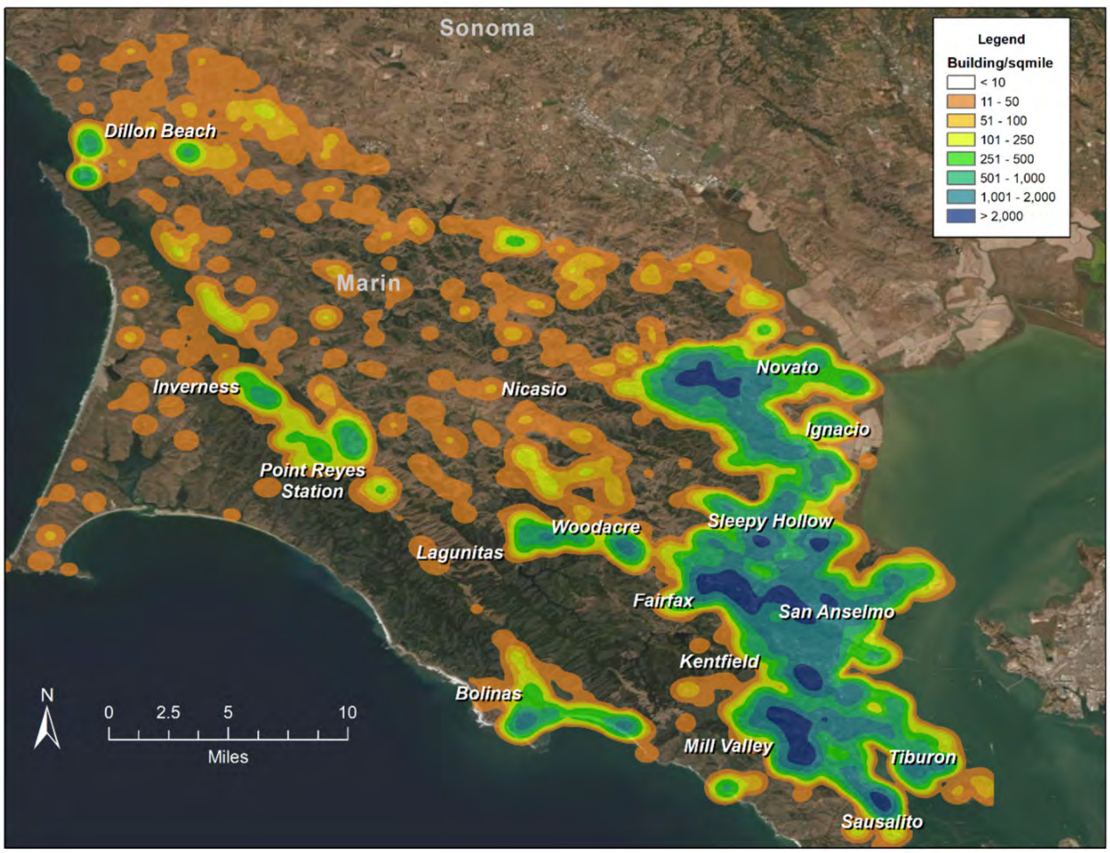

Figure 11. Structure density in Marin County.

Step 2: Prepare Vegetation and Fuel Model Data

FlamMap is a fire behavior model that can be used to predict potential fire behavior based on fuels (and fuel moisture), topography, and weather conditions. As part of the development of this CWPP, an updated, high-resolution (5 x 5 meter) gridded vegetation map was developed using a combination of ground vegetation data and recently obtained LiDAR measurements provided by the Vegetation Map and Landscape Database project (see Section 5.2.1 and Appendix A). The 5 x 5 meter fuel model data were used as input to FlamMap for modeling potential fire behavior.

Step 3: Acquire Local Weather and Fuel Moisture Data

In addition to fuel characteristics, the FlamMap fire behavior model requires information about fuel moisture and weather conditions. Three fire weather scenarios were chosen to represent seasonal wildfire conditions for (1) an average fire season, (2) peak fire conditions, and (3) extreme Diablo wind conditions representing red flag warning conditions. The average fire season scenario was created by summarizing the weather and fuel moisture parameters from April through October (a typical fire season), and was used to represent the fire weather conditions during an average summer day in Marin County. The peak fire conditions scenario was created using the 97th percentile weather data from July through October, and represents the hottest and driest time periods during the summer months when fire behavior would be intense and difficult to control. The extreme Diablo wind scenario represents the late summer through fall weather conditions under which a red flag warning would typically be declared with high temperatures, low relative humidity, and high easterly offshore winds.

The fire weather statistics model, IFT-FireFamilyPlus, available through the Interagency Fuels Treatment Decision Support System (IFTDSS), was used to summarize fuel moisture, wind speed, and wind direction data for each fire weather scenario using data from five RAWS available in the Weather Information Management System (WIMS). Weather data were summarized by station and weather scenario for the Mt. Barnabe, Big Rock, Woodacre, Middle Peak, and Robinhood RAWS stations (**Figure 12**). **Table 10** lists the fuel moisture and weather values used for the average fire season scenario, the peak fire conditions scenario, and the extreme Diablo wind scenario.

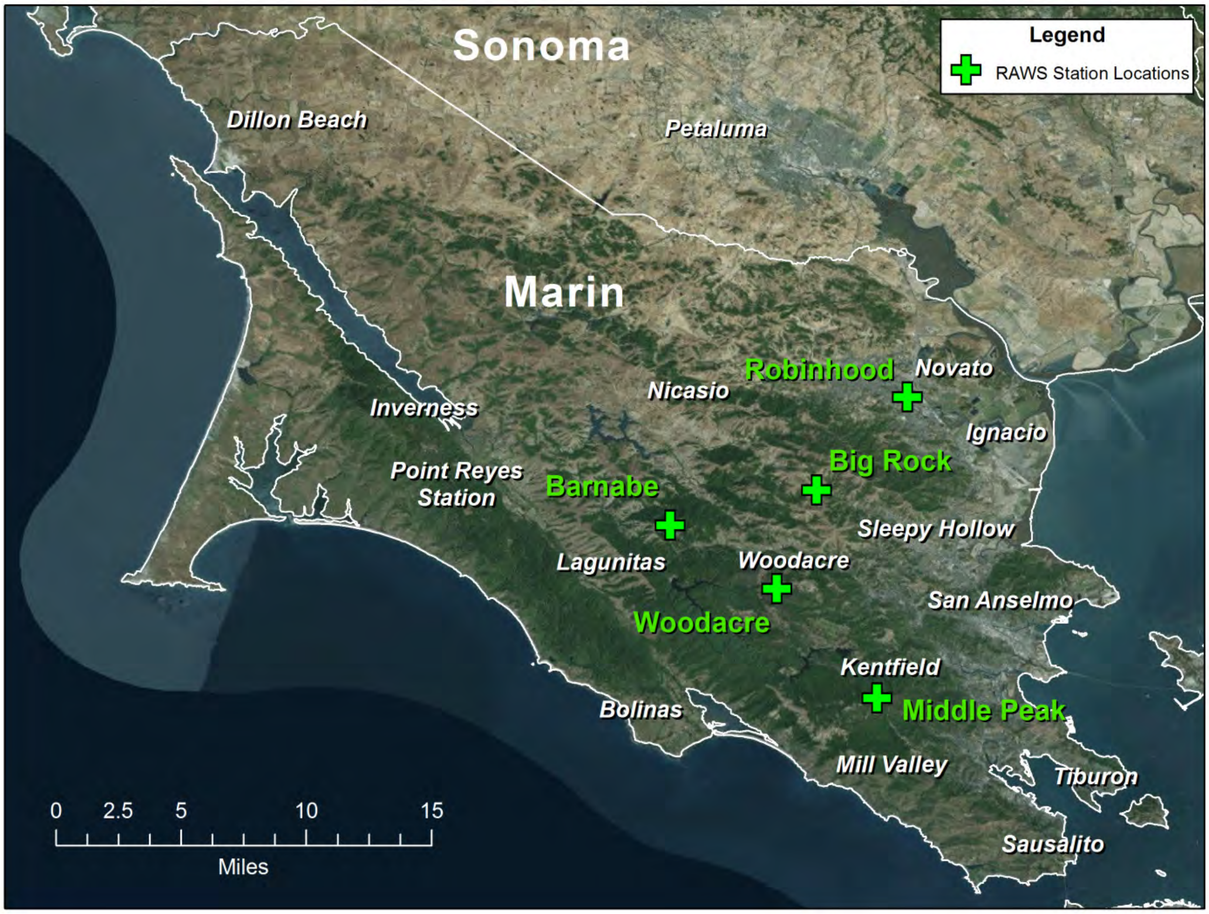

Figure 12. RAWS station locations in Marin County.

Table 10. Fuel moisture and weather values used for the average fire season, peak fire conditions, and extreme Diablo wind conditions modeling scenarios.

Parameter (units)	Average Fire Season Scenario	Peak Fire Conditions Scenario	Extreme Diablo Wind Conditions Scenario
1-hour fuel moisture	8%	3%	3%
10-hour fuel moisture	8%	4%	4%
1,000-hour fuel moisture	13%	6%	6%
Herbaceous fuel moisture	35%	4%	3%
Live wood fuel moisture	99%	68%	67%
Wind speed	6 miles per hour	13 miles per hour	30 miles per hour
Wind direction	308°	293°	45°

Step 4: Perform Fire Behavior Modeling

Wildfire modeling attempts to predict fire behavior including how quickly a fire might spread, how much heat it might generate, and in which direction it might move. Most fire behavior models require the following key inputs: (1) fuel model information, (2) fuel moisture, (3) weather, and (4) topography. The results of fire behavior modeling can indicate how difficult a fire might be to suppress and how likely the fire would be to transition from the ground to the tree canopy. When flames move into the canopy, extreme fire behavior may occur.

FlamMap was used to model flame length and rate of spread. Flame length is commonly used as an indicator of how difficult a fire may be to suppress. Table 11 shows the fire suppression interpretations of flame length; fires with lower flame lengths and rate of spread are typically easier to suppress, while fires with higher flame lengths and rate of spread are much more difficult to manage.

Table 11. Fire suppression interpretations of flame length and fire line intensity.

Flame Length (feet)	Fire Intensity (btu/feet/second)	Interpretations
0-4	0-100	Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire.
4-8	100-500	Fires are too intense for direct attack on the head by persons using hand tools. Hand line cannot be relied on to hold fires. Equipment such as bulldozers, engines, and retardant aircraft can be effective.
8-11	500-1,000	Fires may present serious control problems – torching out, crowning, and spotting. Control efforts at the head of the fire will probably be ineffective.
11+	1,000+	Crowning, spotting, and major runs are common. Control efforts at the head of the fire will probably be ineffective.

Rate of spread is an indicator of how rapidly a fire might spread, and is defined as the rate of forward spread of the fire head expressed in feet per minute. FlamMap runs were performed for the three weather scenarios identified in Table 10 using the updated fuel model data developed for Marin County (see Figure 7 in Section 5.2.1) and topographical data (slope, aspect, and elevation).

Step 5: Develop Composite Maps

The Environmental Systems Research Institute (ESRI) ArcGIS software, Spatial Analyst, was used for this analysis. Spatial Analyst is a raster- or grid-based software package that provides a platform for developing and manipulating gridded data. Spatial Analyst can be used to develop suitability models that produce maps highlighting "suitable" geographic areas based on defined model criteria and weighting schemes.

The composite maps for the hazard assessment were developed using a suitability modeling approach. Suitability modeling is a GIS-based method used for identifying areas based on specific criteria. For this work, suitability modeling was used to identify areas of high fire hazard based on fire behavior potentials and areas of high structure density.

6.3 Fire Hazard Assessment Results

The approach outlined in Section 6.2.1 was used to perform the hazard assessment modeling using the structure density data (Figure 11) and the weather and fuel moisture data for the average fire season, peak fire conditions, and extreme Diablo wind conditions scenarios (Table 10). The remainder of this section discusses the modeling results.

Average Fire Season Modeling Results

The average fire season modeling scenario is based on the fuel moisture and weather data shown in Table 10. Modeled flame length for the average fire season scenario is shown in **Figure 13**; dark red and red show potential flame lengths greater than 8 feet, indicating areas that might exhibit more extreme fire behavior and/or be relatively more hazardous from a fire suppression perspective.

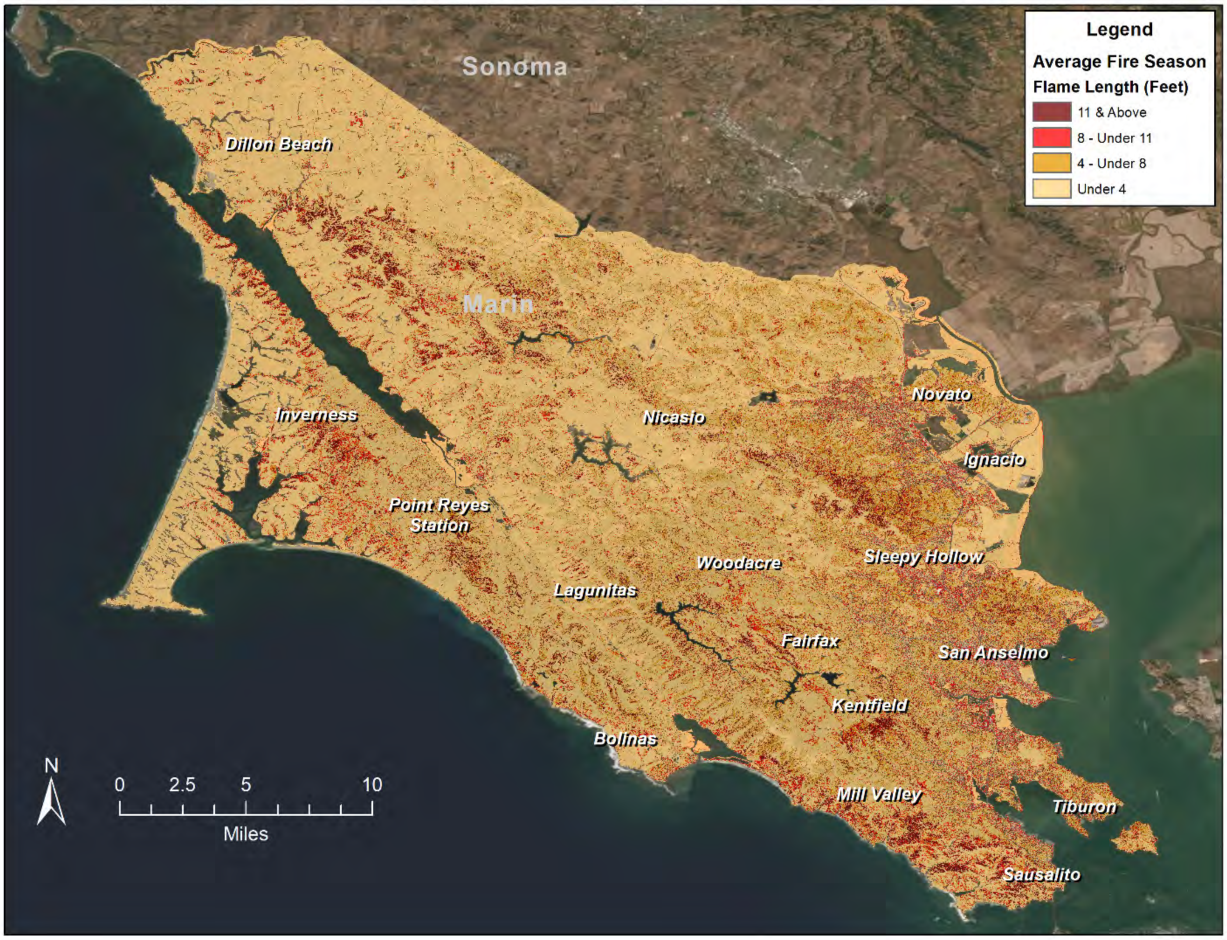

Figure 13. Potential flame length for the average fire season weather scenario.

Rate of spread is defined as the rate of forward spread of the fire head expressed in feet per minute. The higher the rate of spread, the more difficult a fire is to suppress. The rate of spread model output for the average fire season scenario is shown in Figure 14; dark red and red show areas where more extreme fire behavior is likely given an ignition.

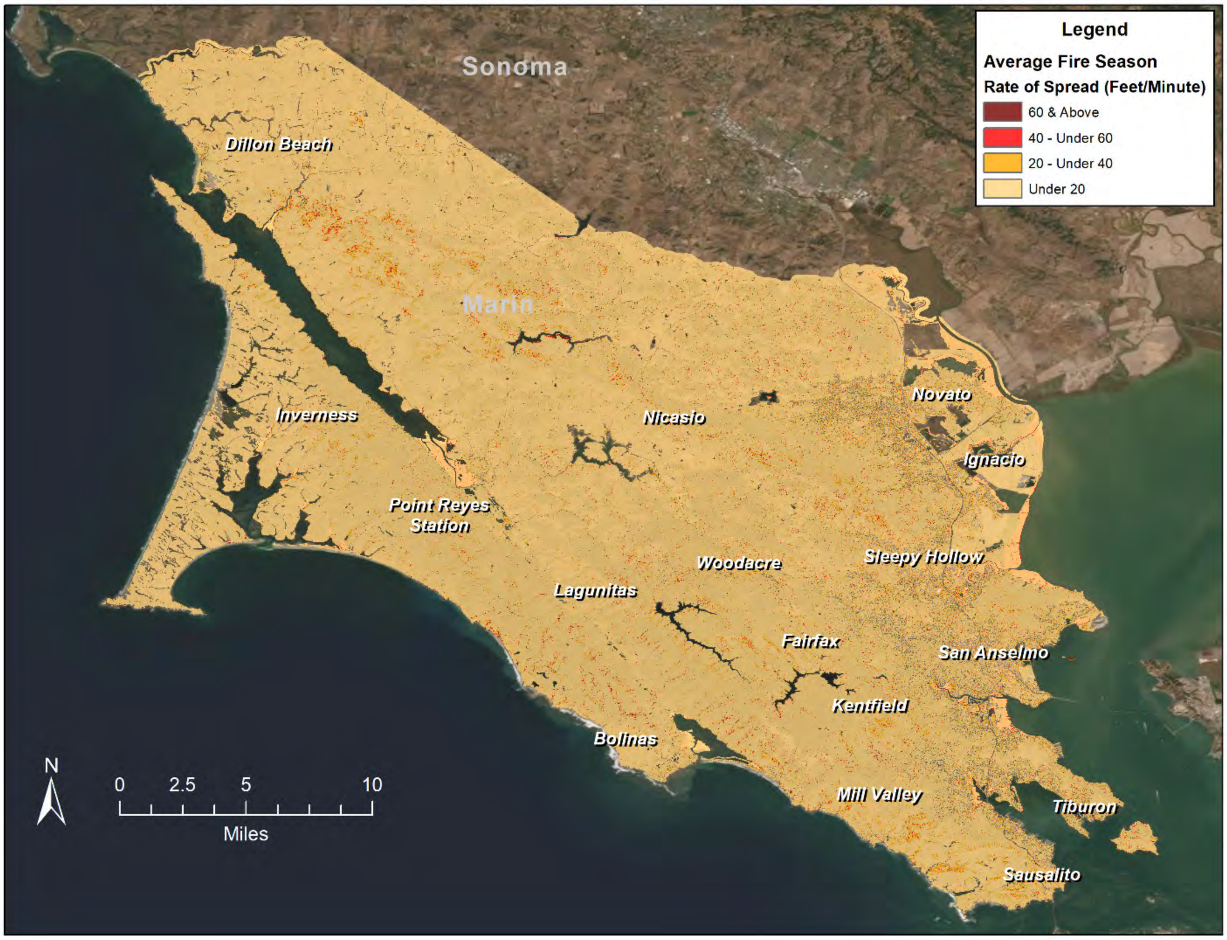

Figure 14. Predicted rate of spread for the average fire season weather scenario.

Using GIS data processing techniques (see Section 6.2.1), the structure density, flame length, and rate of spread maps were merged and processed to identify areas that have very high structure density, flame lengths, and rate of spread. Figure 15 shows this composite map; dark red and red show areas of very high to high structure density, flame length, and rate of spread. These are areas of high asset value where fire behavior is likely to be extreme under the defined weather conditions.

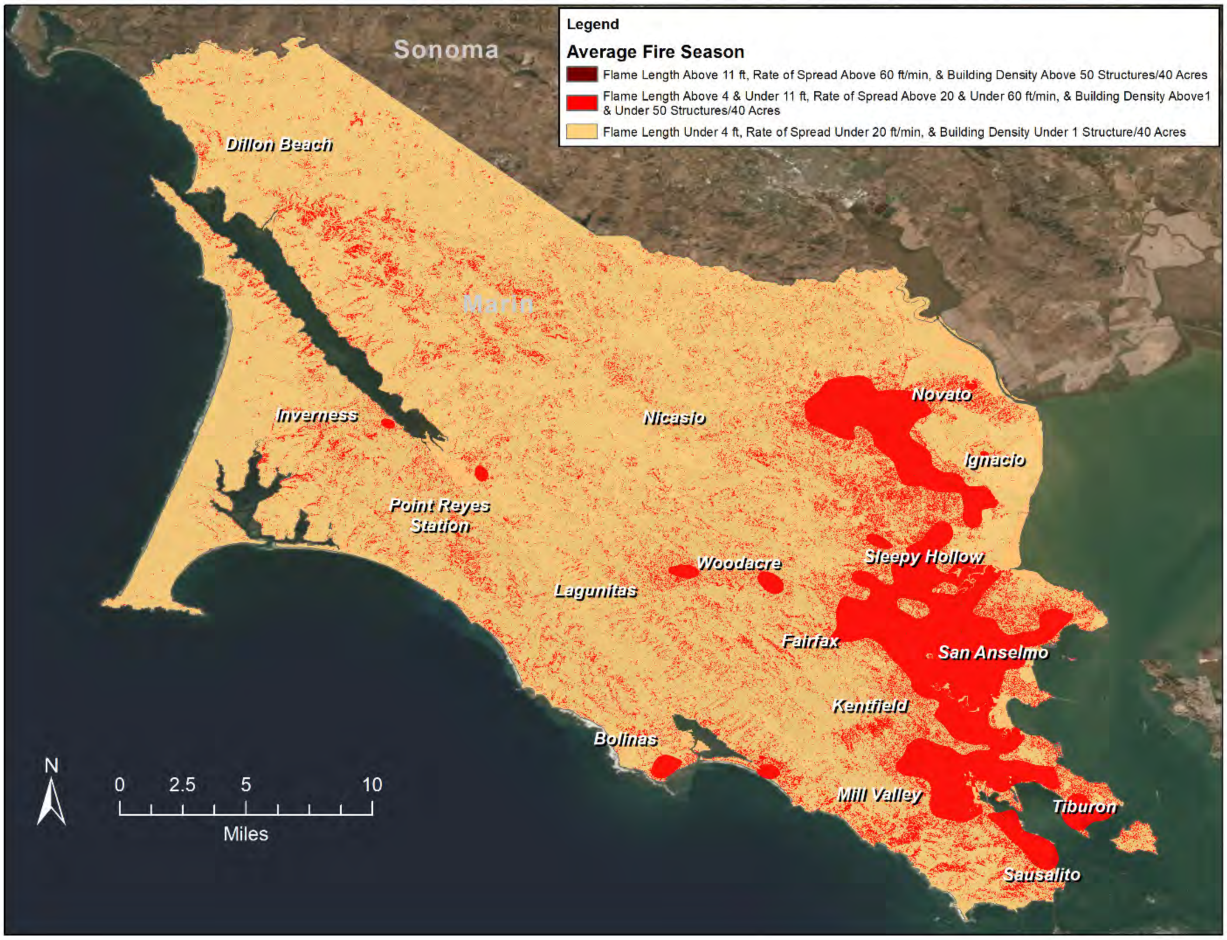

Figure 15. Composite map of structure density, flame length, and rate of spread for the average fire season model scenario.

Peak Fire Conditions Modeling Results

The peak fire conditions modeling scenario is based on the fuel moisture and weather data shown in Table 10. Modeled flame length for the peak fire conditions scenario is shown in Figure 16; dark red and red show potential flame lengths greater than 8 feet, indicating areas that would likely exhibit more extreme fire behavior and be relatively more hazardous from a fire suppression perspective (see Table 11). Note that for the peak fire conditions scenario, much more of the county area has flame lengths above 8 feet compared to the average fire season scenario shown in Figure 13.

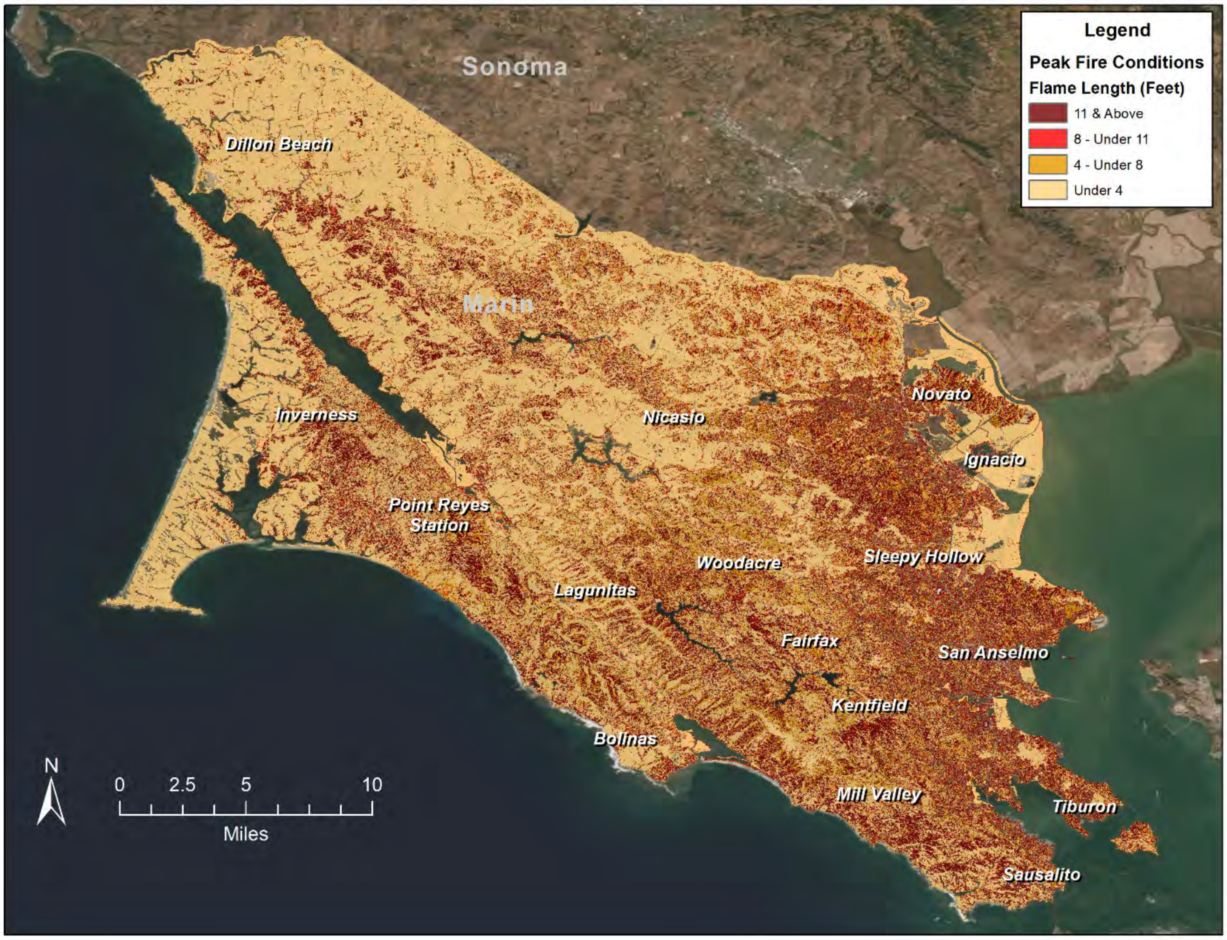

Figure 16. Potential flame length for the peak fire conditions scenario.

The rate of spread model output for the Peak Fire Conditions scenario is shown in Figure 17; dark red and red show areas that are likely to exhibit more extreme fire behavior and faster rates of spread.

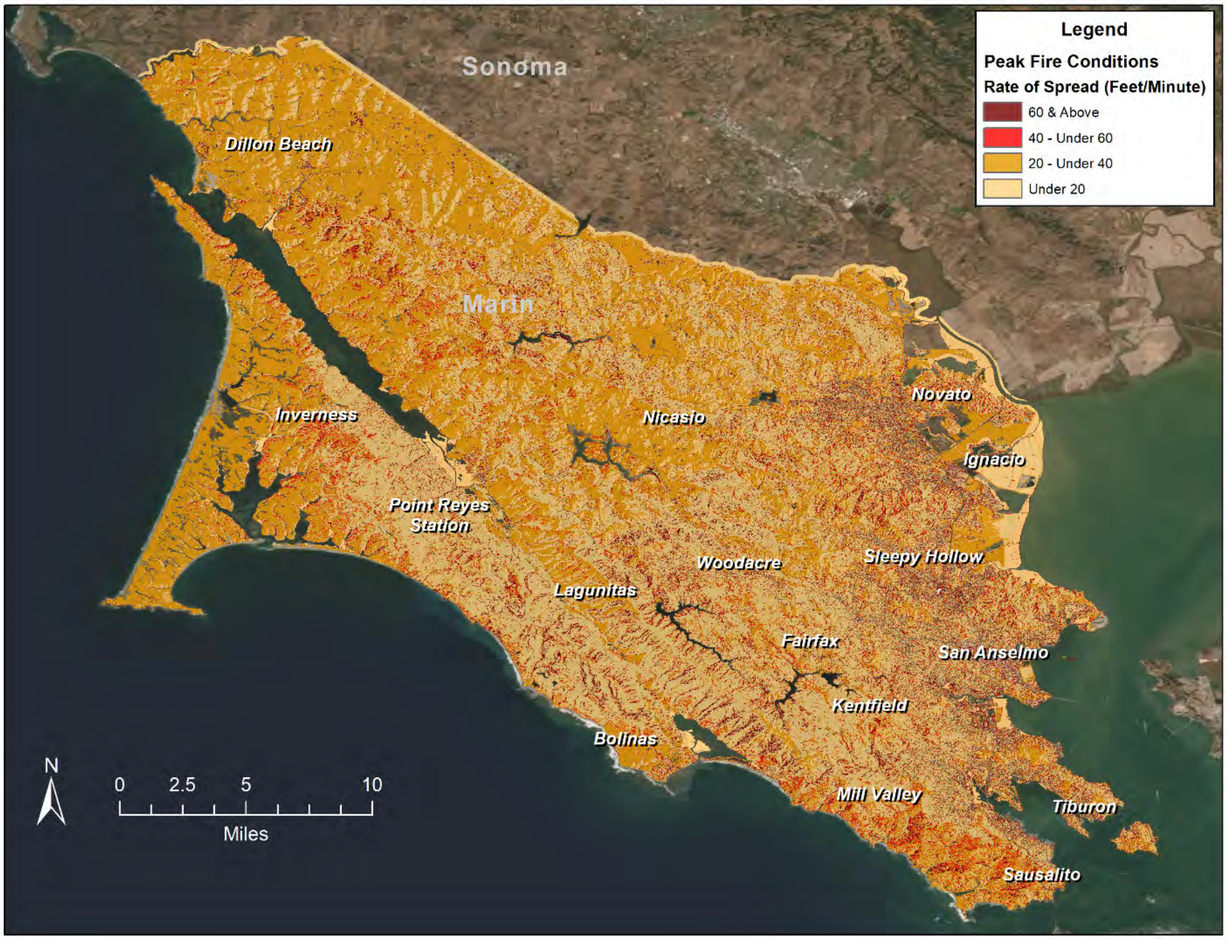

Figure 17. Predicted rate of spread for the peak fire conditions scenario.

Using GIS data processing techniques (see Section 6.2.1), the structure density, flame length, and rate of spread maps were merged to identify areas that have very high structure density, flame lengths, and rate of spread. Figure 18 shows this composite map for the peak fire conditions scenario; dark red and red show areas of very high to high structure density, flame length, and rate of spread. Again, for the peak fire conditions scenario, much more of the county area is located in red areas compared to the average fire season scenario shown in Figure 15.

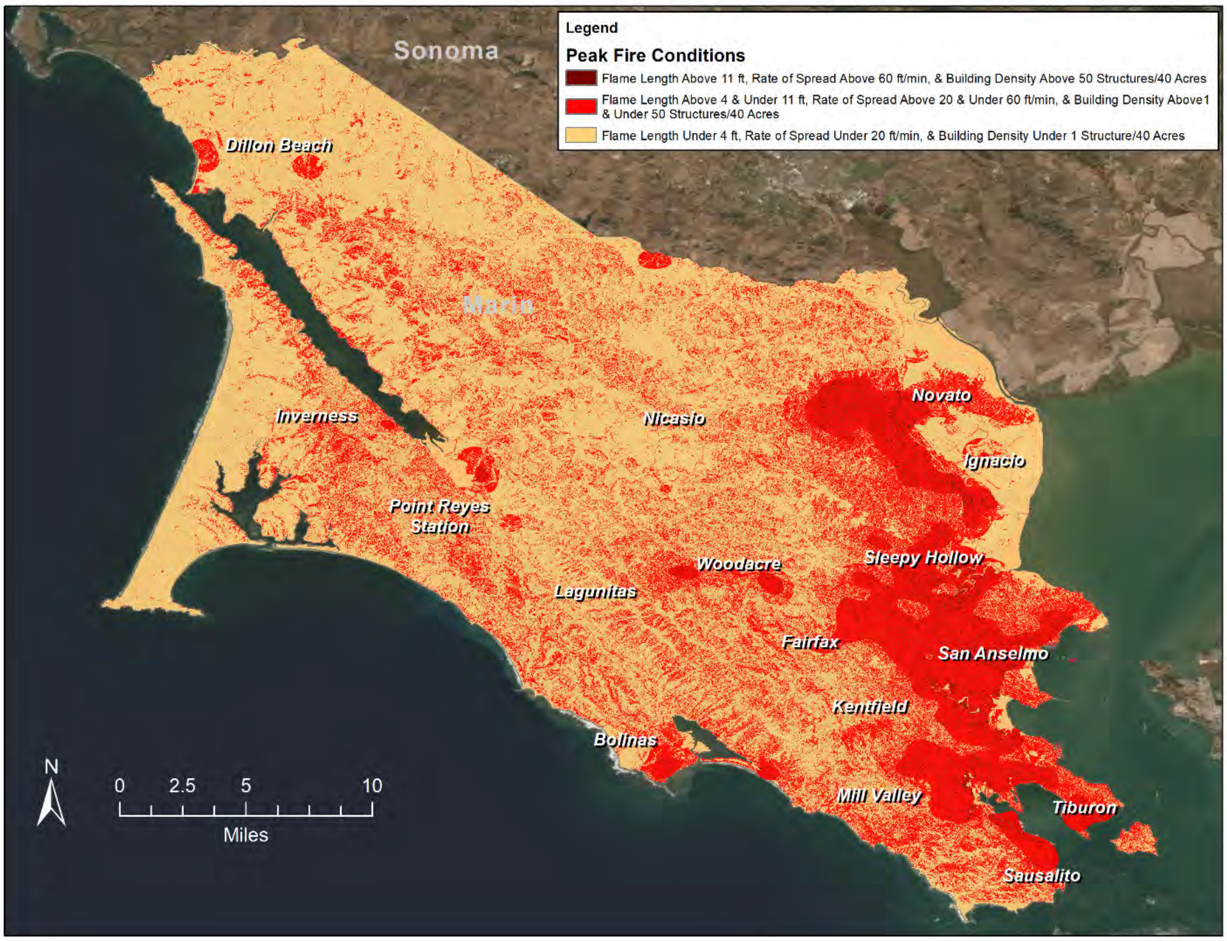

Figure 18. Composite map of structure density, flame length, and rate of spread for the peak fire conditions scenario.

Extreme Diablo Wind Conditions Modeling Results

The extreme Diablo wind conditions modeling scenario is based on the fuel moisture and weather data shown in Table 10. Modeled flame length for the extreme Diablo wind conditions scenario is shown in Figure 19; dark red and red show potential flame lengths greater than 8 feet, indicating areas that would likely exhibit more extreme fire behavior and be relatively more hazardous from a fire suppression perspective (see Table 11). Note that under the extreme Diablo wind conditions, much more of the county area has flame length above 8 feet compared to the peak fire conditions scenario shown in Figure 16.

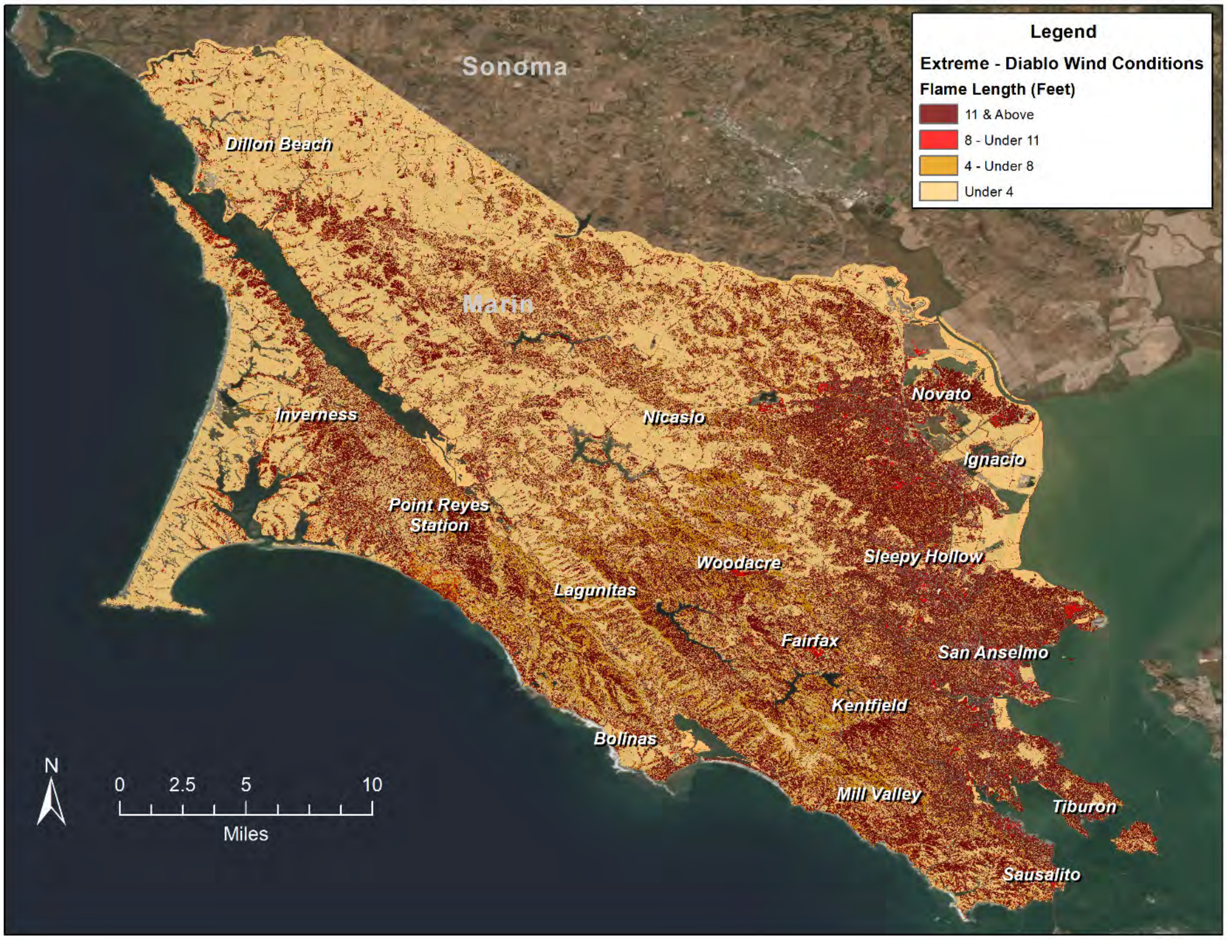

Figure 19. Potential flame length for the extreme Diablo wind conditions scenario.

The rate of spread model output for the extreme Diablo wind conditions scenario is shown in Figure 20; dark red and red show areas that are likely to exhibit more extreme fire behavior.

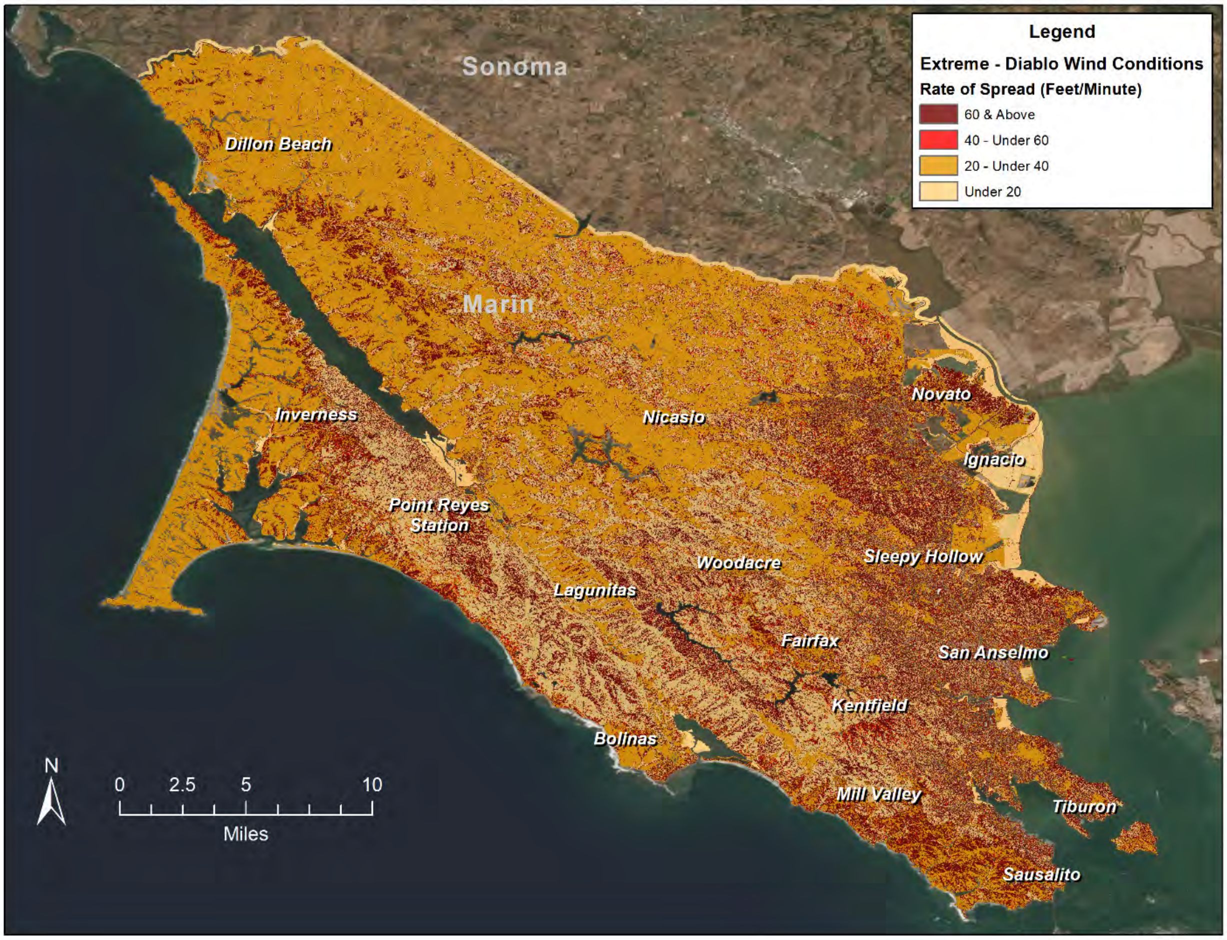

Figure 20. Predicted rate of spread for the extreme Diablo wind conditions scenario.

Using GIS data processing techniques (see Section 6..2.1), the structure density, flame length, and rate of spread maps were merged to identify areas that have very high structure density, flame lengths, and rate of spread. Figure 21 shows the composite map for the extreme Diablo wind conditions scenario; dark red and red show areas of very high to high population density, flame length, and rate of spread. Again, note that under the extreme Diablo wind conditions scenario, much more of the county area is located in these very high to high condition areas compared to the peak fire season scenario shown in Figure 18.

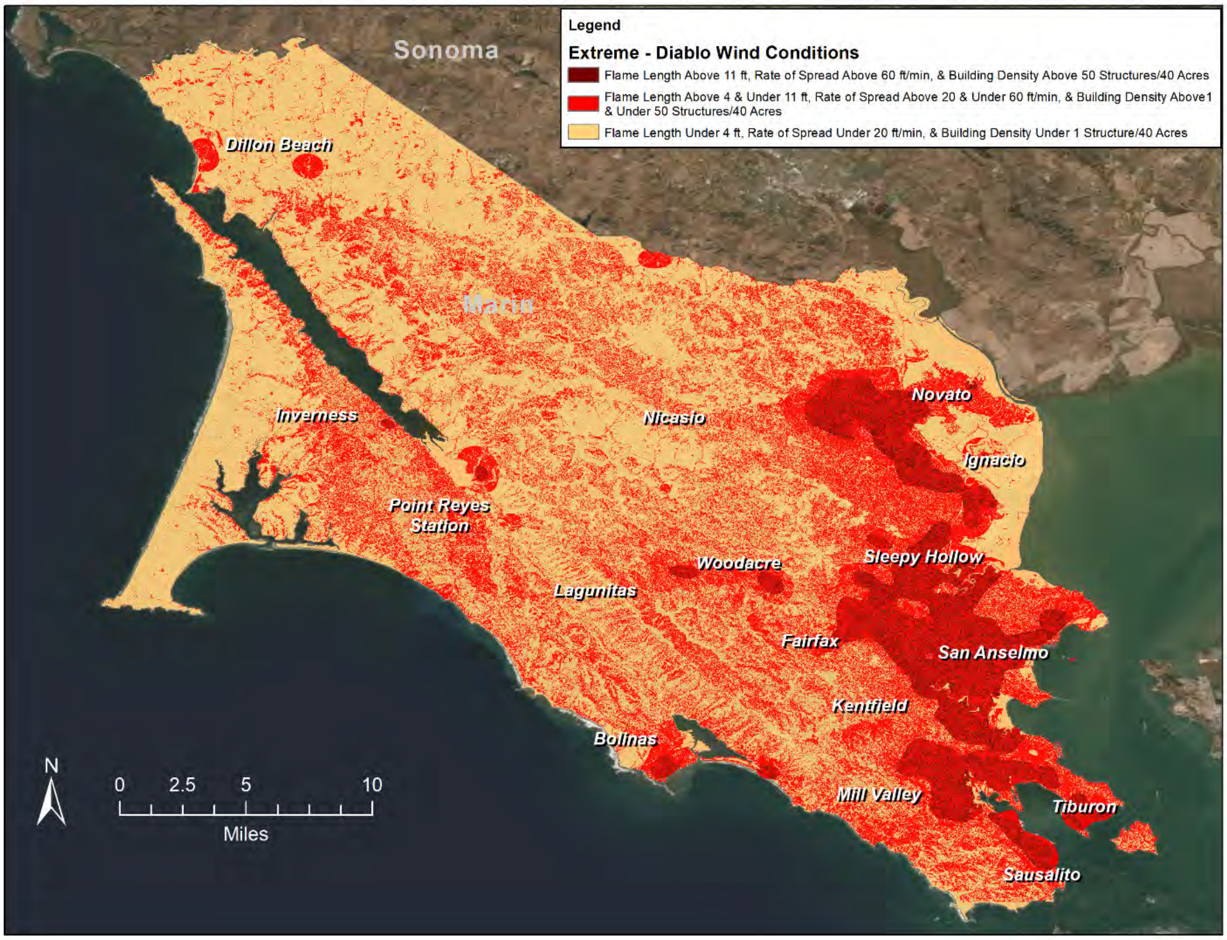

Figure 21. Composite map of structure density, flame length, and rate of spread for the extreme Diablo wind conditions scenario.

The results of the county-level hazard assessment for the peak fire conditions scenario was overlaid with fire agency jurisdiction boundaries, and the total burnable area falling into each of the three categories was calculated. The category definitions are

1. **Category 1.** Flame Length Under 4 feet, Rate of Spread Under 20 feet/minute, & Building Density Under 1 Structure/40 acres

2. **Category 2.** Flame Length Above 4 feet & Under 11 feet, Rate of Spread Above 20 feet/minute & Under 60 feet/minute, & Building Density Above 1 & Under 50 Structures/40 acres

3. **Category 3.** Flame Length Above 11 feet, Rate of Spread Above 60 feet/minute, & Building Density Above 50 Structures/40 acres

Figure 22 shows the peak fire conditions modeling scenario composite map results overlaid with fire agency jurisdiction boundaries. **Table 12** lists the number of total burnable acres, and the percentage of acres in Categories 1, 2, and 3 for the peak fire conditions composite map, by fire jurisdiction. **Figures 23 and 24** show the data in Table 12 (excluding MCFD and NFPD); the number of total burnable acres, and the percentage of acres in Categories 1, 2, and 3 for the peak fire conditions composite map, by fire jurisdiction.

The results show that MCFD and NFPD have the largest area of burnable acres. For MCFD, approximately 25% of the total burnable area falls into Categories 2 and 3 of the county-level hazard maps. For Novato, approximately 45% of the total burnable area falls into Categories 2 and 3. With the exception of Bolinas, Stinson, and Inverness, the majority of burnable acreage in all other areas falls into Categories 2 and 3.

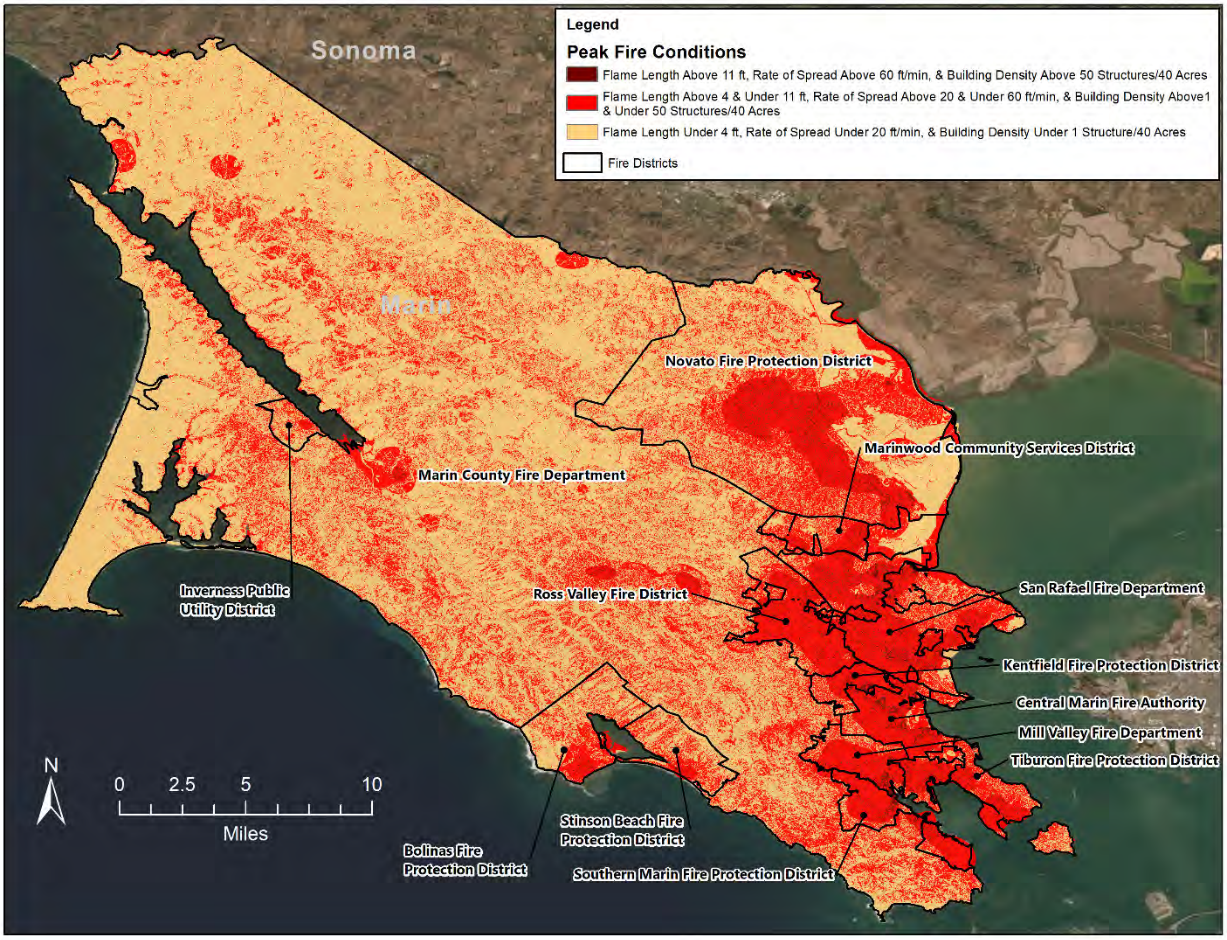

Figure 22. Composite map of structure density, flame length, and rate of spread for the peak fire conditions scenario overlaid with fire agency jurisdiction boundaries.

Table 12. Number of total burnable acres, and the percentage of acres in Categories 1, 2, and 3 for the peak fire conditions composite map, by fire jurisdiction.

Fire Jurisdiction	Total Burnable Acres	% Composite Category 1	% Composite Category 2	% Composite Category 3
Marin County Fire Department	243,448	76%	24%	0.2%
Novato Fire Protection District	45,992	56%	41%	3%
San Rafael Fire Department	10,763	14%	76%	11%
Bolinas Fire Protection District	5,947	59%	40%	1%
Ross Valley Fire District	5,742	14%	78%	8%
Southern Marin Fire Protection District	4,645	10%	81%	9%
Central Marin Fire Authority	4,075	9%	79%	13%
Stinson Beach Fire Protection District	3,707	57%	42%	1%
Mill Valley Fire Department	3,080	13%	78%	8%
Tiburon Fire Protection District	2,690	17%	76%	6%
Marinwood Community Services District	2,608	28%	67%	5%
Kentfield Fire Protection District	1,748	14%	77%	9%
Inverness Public Utility District	1,352	60%	40%	0.5%

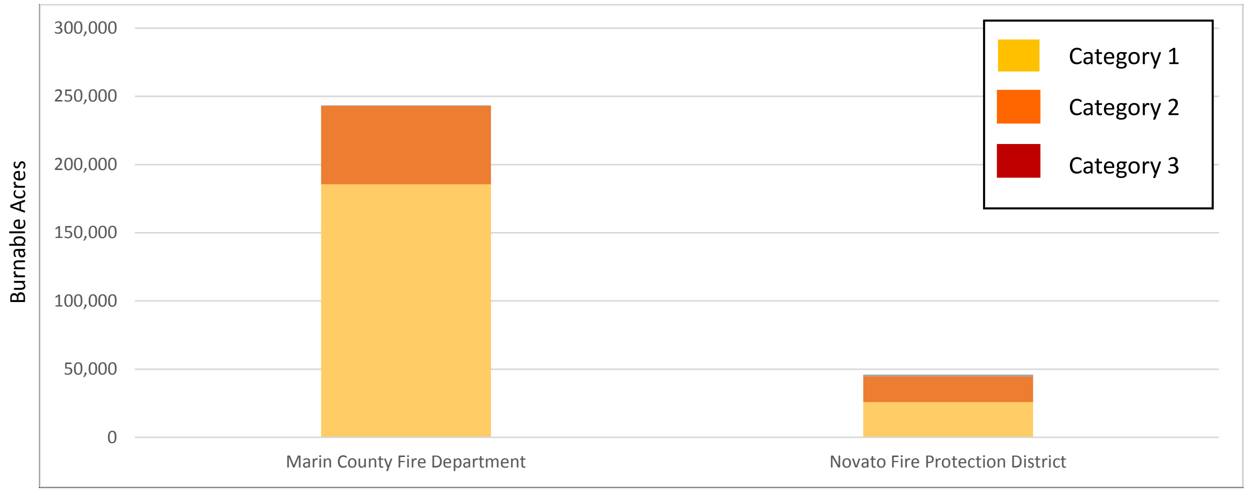

Figure 23. Number of total burnable acres, and the percentage of acres that fall into Categories 1, 2, and 3 under the peak fire conditions scenario for Marin County Fire Department and Novato Fire Protection District.

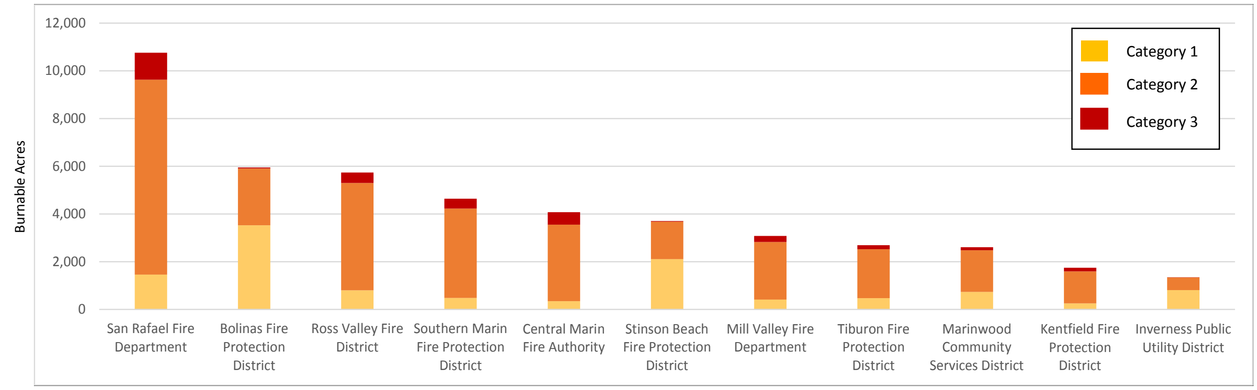

Figure 24. Number of total burnable acres, and the percentage of acres that fall into Categories 1, 2, and 3 under the peak fire conditions scenario by fire agency jurisdiction.

On a relative basis, Category 3 represents a higher hazard rating than Category 2, and Category 2 represents a higher hazard rating than Category 1. The data in Figure 22 should be viewed at a finer scale within each fire agency jurisdiction and community to get a proper context of the areas of concern at a local scale. It is important to note that the modeling performed in this section does not account for factors such as sensitive habitats, plant species, practical implementation of fuel reduction projects, or reductions in project costs. Fire protection and land management agencies should work collaboratively to determine which areas to focus efforts on, and what projects and prescriptions best serve specific areas.

7. Parcel-Level Fire Hazard Assessment

Structures can ignite during wildfires from ember (also called firebrand) penetration, direct flame contact, and/or radiant heat. Many wind-driven wildfires spread through firebrands, which are burning materials that are blown by wind from one place to another. Winds can blow firebrands more than a mile away from their source, starting new fires wherever they land. Flames often occur within columns of heat known as convection columns and can ignite anything flammable that they come into contact with. Radiation is the process by which wildfires heat up the surrounding area. Radiant heat from a wildfire can ignite combustible materials from distances of 100 feet or more.[33]

Embers can be blown through the air and can travel miles. They can result in the rapid spread of wildfire by spotting (in which embers are blown ahead of the main fire, starting other fires). When embers land on or near a house, they can easily ignite nearby vegetation or accumulated debris or enter the home or attic through openings or vents, igniting furnishing or combustible debris in those locations.[34] Recent research about home destruction versus home survival in wildfires indicates that embers and small flames are the primary source of structural ignition in wildfires.[35]

Post-fire studies have shown homes ignite due to building materials, construction, the condition of the home, and surrounding vegetation and debris. The Home Ignition Zone (HIZ) is defined as the area within 200 feet of a home. To provide maximum wildfire protection for your home, a combination of near-home vegetation management, appropriate building materials, and related design features must be used.[36] In several of the most recent and large fires in suburban areas, including the Tubbs fire in Santa Rosa in 2017, thousands of structures were lost due to the close proximity of homes and fire spreading from structure to structure. In these situations, fire behavior and spread can become very difficult to predict and manage. In recent years, much more focus has been directed at home hardening to help reduce structural ignitability.

Homeowners must be actively involved in fire hazard mitigation on and around their properties. Defensible space requirements help reduce vegetation and fuels in and around structures. Home

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[33] Federal Emergency Management Agency (https://emilms.fema.gov/IS320/WM0102020text.htm).
[34] FIRESafe MARIN (https://www.firesafemarin.org/how-homes-ignite).
[35] National Fire Protection Association (https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/Preparing-homes-for-wildfire#:~:text=home%20survival%20in%20wildfires%20point,homes%2C%20debris%20and%20other%20objects).
[36] FIRESafe MARIN (https://www.firesafemarin.org/home-hardening).

hardening helps make homes more fire resistant and can protect a structure from igniting in the presence of embers. Defensible space and property inspections are currently the best way to assess potential fire hazard on properties; however, using available vegetation, fire behavior, and structure information can also provide a way to approximate potential fire hazard at the parcel level.

Parcel-level wildfire hazard maps and threat ratings have been developed for many parts of the country. While typical wildfire hazard maps incorporate fire behavior information including fuels, topography, and potential fire behavior, parcel-level fire hazard maps include information about building characteristics such as the age and size of the structure. Parcel-level fire hazard ratings can be useful for prioritizing the properties that need to improve defensible space and reduce structural ignitability.

To expand on the county-level hazard assessment, parcel-level maps were developed to provide a composite threat rating (by land parcel) based on potential flame length, rate of spread, burn probability, fire history, the year the structure was built, total building square footage, and building perimeter length.

7.1 Parcel-Level Fire Hazard Assessment Methodology

The parcel-level wildfire threat map was developed based on a variety of input datasets that characterize hazards, including the (1) likelihood of wildfire impact and (2) living unit structure characteristics within a given parcel. The following data inputs were used for this assessment.

Fire information layers:

1. FlamMap flame length for peak fire season conditions
2. FlamMap rate of spread for peak fire season conditions
3. Randig burn probability based on 25,000 random ignitions for peak fire season conditions
4. Parcel-based fire history (to determine if a parcel has burned in the past)

Building characteristics layers:

- The year the structure was built
- Total square footage of the living unit area and garage
- Total perimeter length of the living unit and garage

The fire behavior layers for flame length and rate of spread were obtained from the FlamMap fire behavior modeling performed for the county-level hazard assessment for the peak fire season modeling scenario. Burn probability is defined as the likelihood that a given location on a landscape will burn if provided an ignition. Burn probability data were obtained using the Randig module within FlamMap for the same peak fire season modeling scenario (see Table 10. Fire history data were acquired from CAL FIRE from 1970 through 2020 (a subset of the same data set shown in Figure 8).

The land parcel and building footprint data were acquired from the Marin county tax assessor's records for 2019.

The input data layers were processed using ESRI's ArcGIS geospatial processing software. Figure 25 shows the steps used to process the input data files and develop the parcel-level fire hazard maps.

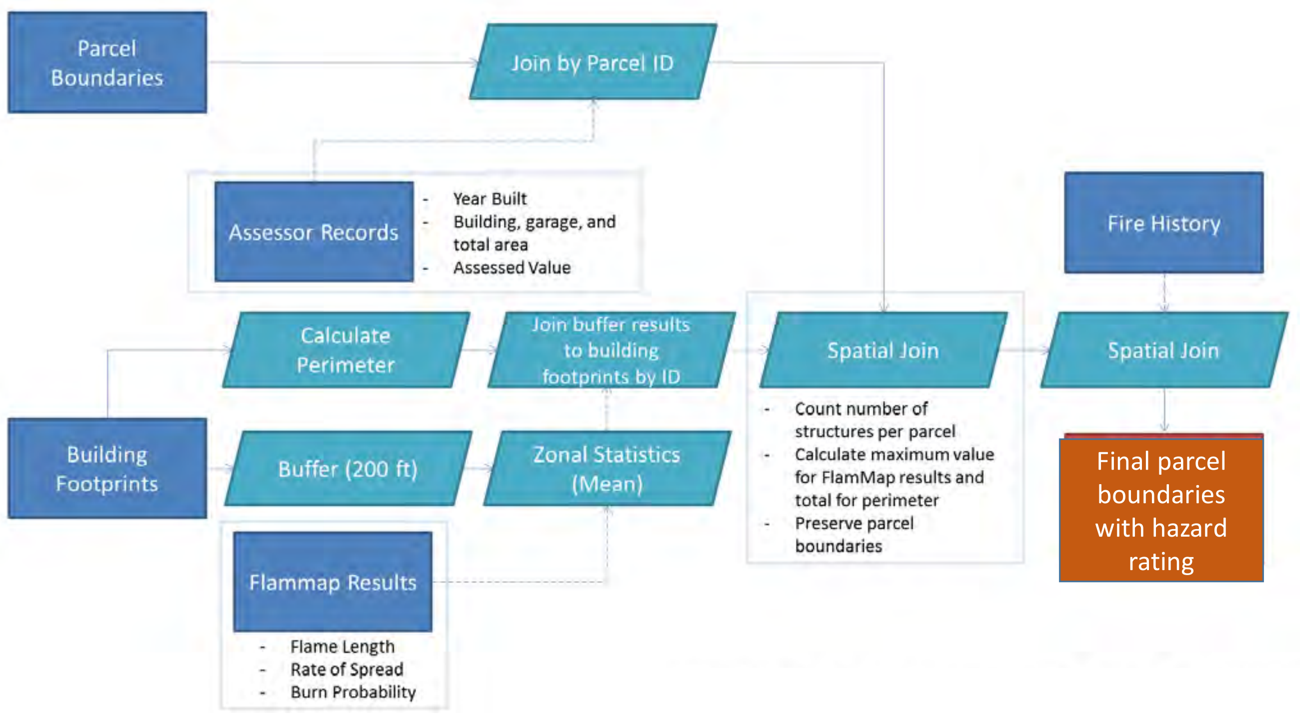

Figure 25. Data processing steps used to develop the parcel-level fire hazard map.

7.1.1 Step 1: Prepare the Building Footprint and Parcel Data for Analysis

The parcel and building footprint data obtained from the tax assessor data set was validated and analyzed for completeness. The data used for this assessment is from 2019 and is the most recent data available. The data were mapped and examined for completeness and to identify data gaps.

7.1.2 Reclassify the Input Data Sets

Suitability analysis requires all data sets to be in the same units and scale. Because each of the data sets used as input to the analysis are in different units, the input data layers were reclassified to a scale of classes 1 through 4. For example, the data layer for flame length is a gridded data set that provides a value for flame length for each grid cell in the data layer. Flame length is reported in units of feet. To reclassify the flame length data layer, the following translation was used

- Class 1 = flame length less than or equal to 4 feet
- Class 2 = flame length greater than 4 feet and less than or equal to 8 feet
- Class 3 = flame length greater than 8 feet and less than or equal to 12 feet
- Class 4 = flame length greater than 12 feet

Class 1 represents low flame lengths while Class 4 represents the highest flame lengths. All of the input data sets were reclassified to this scale. Table 13 lists the input data layers, corresponding units (in parentheses), and the reclassification scheme for each data layer.

Table 13. Reclassification scheme used for the parcel-level assessment input data layers.

Input Data Layer (units)	Class 1	Class 2	Class 3	Class 4
Flame length (feet)	<= 4	> 4 & <= 8	> 8 & <= 12	> 12
Rate of spread (chains/hour)	<= 5	> 5 & <= 10	> 10 & <= 30	> 30
Randig burn probability	<= 0.0001	> 0.0001 & <= 0.0005	> 0.0005 & <= 0.001	> 0.001
Parcel-based fire history (has parcel burned in the past?)	No	--	--	Yes
Year structure was built (year)	2009–2018	1992–2008	1968–1991	Pre 1968
Total area of living and garage space (square feet)	<= 1,500	> 1,500 & <= 2,500	> 2,500 & <= 4,000	> 4,000
Building perimeter (feet)	<= 100	> 100 & <= 300	> 300 & <= 500	> 500

7.1.3 Calculate the Parcel-Level Hazard Rating for Each Parcel

After the input data layers were reclassified, a suitability analysis was performed. Suitability analyses mathematically combine the input data layers to arrive at an output map that represents one composite map based on the defined classifications. The suitability model algorithm (1) adds the reclassified data layers together, grid cell by grid cell; (2) divides the total value of each grid cell by the number of input layers (in this case, seven); and (3) produces one output map. In the output map, the fire threat ratings are relative; Category 1 represents a low fire threat rating, Category 2 represents a moderate fire threat rating, and Category 3 represents a high fire threat rating.

7.1.4 Results of Parcel-Level Fire Hazard Assessment

The results of the parcel-level fire hazard assessment for the county are shown in Figure 26. In relative terms, Category 1 represents a low fire threat rating, Category 2 represents a moderate fire threat rating, and Category 3 represents a high fire threat rating. Figure 27 shows the results of the parcel-level assessment for Mill Valley and Fairfax.

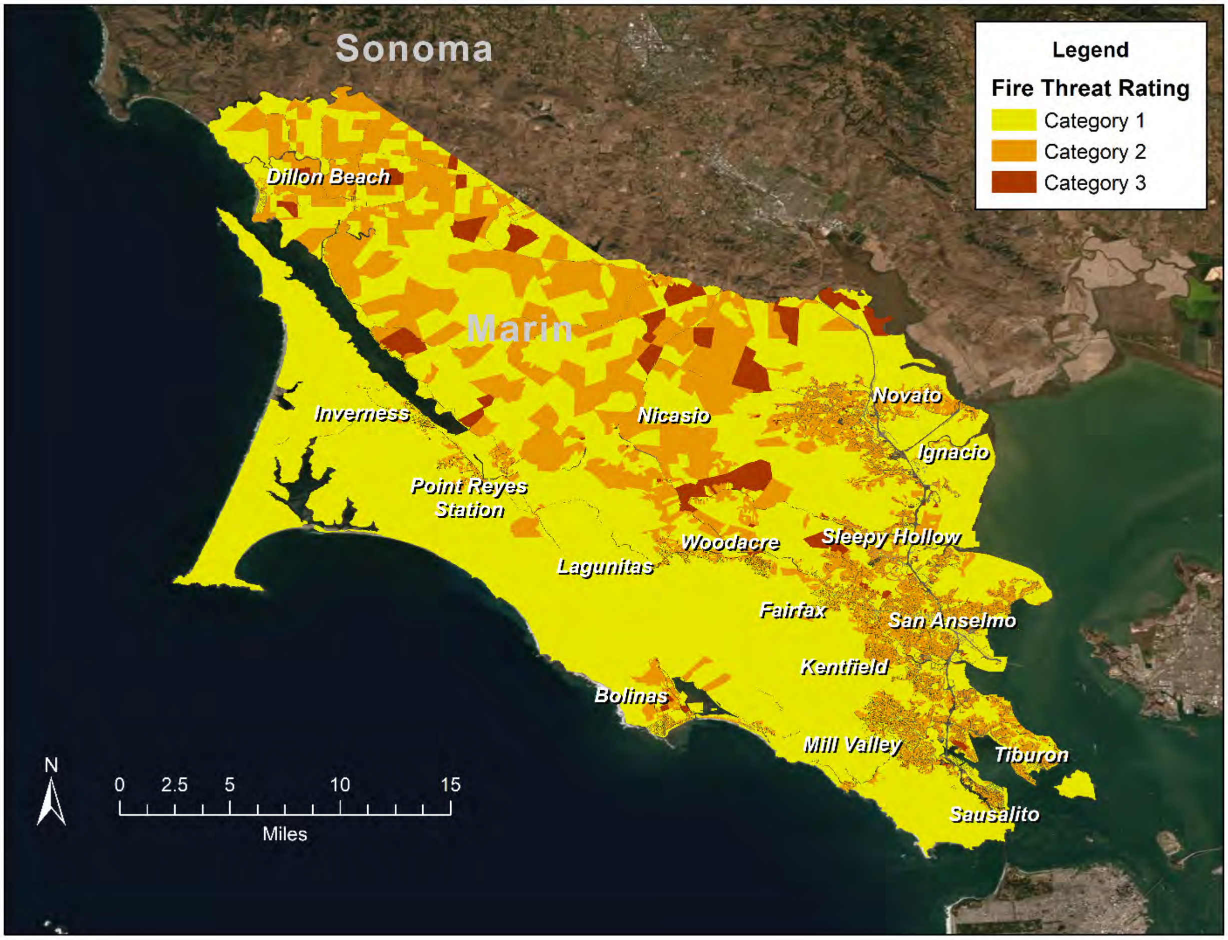

Figure 26. Results of the parcel-level fire hazard assessment for Marin County.

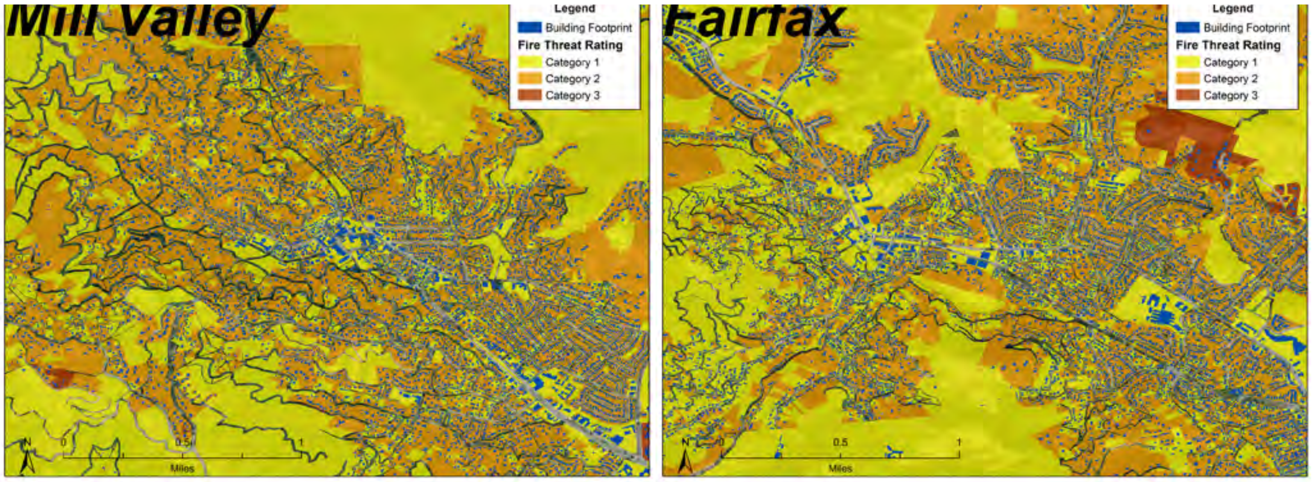

Figure 27. Results of the parcel-level fire hazard assessment for the communities of Mill Valley and Fairfax.

Based on the results of the parcel-level assessment, many parcels in Marin fall into Category 2. When interpreting the parcel-level hazard analysis results, it is important to consider property type. For example, is the property located in an urban or a rural environment and if it is in a rural environment, is it in the wildland urban interface (i.e., directly adjacent to dense wildland vegetation) or in the intermix where vegetation and structures are intermixed? This is important to consider because fires in the intermix tend to spread from vegetation-to-homes while fires in the interface tend to spread from home-to-home. Another consideration is how far homes are from the WUI boundary and proximity to natural vegetation.

Topography, which describes the shape and dimensions of a landscape, plays an important role in fire behavior. Topographical features can help accelerate or slow the spread of fire. Elevation and aspect can determine how hot and dry a given area will be. For example, higher elevations may be drier than lower elevations, and a north-facing slope will be slower to heat up and dry out than a south-facing slope. Slope can also determine how quickly a fire will move uphill. For example, if a fire ignites at the bottom of a steep slope, it will spread much more quickly up the slope because it can pre-heat the fuel/vegetation in its path with rising hot air, and upward drafts are more likely to create spot fires.[37]

[37] National Park Service (https://www.nps.gov/articles/wildland-fire-behavior.htm).

8. Mitigation Measures and Strategies

This CWPP provides county-scale planning information but also recognizes and supports more focused fire planning efforts to address specific city, community, or neighborhood-scale needs. The CWPP provides guidance for localized plans prepared to more specifically address site-specific issues, fuels treatment options, specific vegetation prescriptions, refined or redefined community and WUI boundaries, emergency preparedness, and other issues important to community wildfire safety. Localized plans have priority and authority over county-level recommendations.

Marin County fire agencies take a holistic approach to pre-fire and fuels management by implementing a variety of practices and programs focused around the WUI where the wildfire threat to human life and property is greatest. The objective of developing mitigation strategies is to establish a multifaceted approach, recommendations, and options to minimize the risk of catastrophic wildfire within the WUI while ensuring the protection and enhancement of economic and ecological values and resources. The mitigation measures discussed in this section are focused on

- Public and community outreach
- Wildfire preparedness and planning
- Reducing structural ignitability
- Defensible space
- Vegetation management
- Evacuation planning and preparation
- Implementing ESPs and increased public awareness of ecological processes and natural resource management

Mitigation strategies may be addressed in multiple plans, reports, and documents, making consistency important when pre-planning for wildfires and other disasters.

8.1 Public Education and Community Outreach

Effective mitigation strategies for achieving countywide protection and consistency require acceptance throughout the county. Homeowners, land managers, and fire officials must work together to achieve these goals. The community must have the desire and ability to manage wildfire risk and maintain a dialogue with local fire officials.

FIRESafe MARIN supports fire agencies and communities throughout Marin by hosting a number of public outreach and community workshops each year to educate Marin residents about wildfire preparedness. *Living With Fire* is a wildfire preparedness education program developed by FIRESafe MARIN in conjunction with the Marin County Fire Chiefs Association, Marin County Fire Prevention Officers Association, and wildfire and home hardening experts. The *Living With Fire* program covers:

- Personal preparedness, safety, and evacuation
- Home hardening and reducing structural ignition
- Defensible space and firescaping
- Community and neighborhood preparedness including Firewise USA® and *Ready, Set, Go!*
- ESPs may be considered as part of the *Living with Fire* program, or by another means of public outreach, to educate and ensure the protection of the natural environment of Marin while protecting it from wildfire

In 2019, FIRESafe MARIN produced a *Living With Fire in Marin County* booklet. The 55-page booklet is available on the FIRESafe MARIN website (**www.firesafemarin.org**). The FIRESafe MARIN website is also a good source of information for the public to learn about wildfire preparedness and available resources.

While FIRESafe MARIN hosts many outreach and education events throughout the county, it is also important to engage the public at the community level to build awareness of local issues and to encourage community members to work together to make their homes and neighborhoods more fire resilient.

8.2 Wildfire Preparedness and Planning

Wildfire preparedness and planning measures help protect buildings, homes, and neighborhoods from wildfire. While large, landscape-scale fuel treatments can change fire behavior, research has shown that the area around a house and the flammability of the house itself are the most important drivers of wildfire hazard in the WUI. The following summarizes some of the key research findings that have led to modern-day home hardening and defensible space guidelines:

- The density and flammability of houses themselves is a key determinant of wildfire spread in the WUI (Spyratos et al., 2007).

- Firebrands, lofted burning embers carried by the wind from the main fire, are a major cause of house destruction (Reinhardt et al., 2008).

- Structure-to-structure spread has been a driver of home loss in a number of fires (Mell et al., 2011).

- Attributes such as roofing material can predispose a house to ignition, and then to destruction, under wildfire conditions (Cohen and Quarles, 2011).

- Creating and maintaining a 0- to 5-foot noncombustible zone around a building, including the entire footprint of attached decks, protects from ignitions that can result from wind-blown embers accumulating at the base of exterior walls, and from exposure to radiant heat or direct flame contact (Hedayati et al., 2018).
- Within 30 feet, fire can produce sufficient radiant heat to cause combustion (Cohen, 2004).
- The presence of herbaceous fuel near houses can result in loss during wildfire (Syphard et al., 2014).
- Thinning vegetation within 100 feet of houses can significantly reduce house ignitions (Soret et al., 1996).

A wildfire-resistant home must be impervious to ignition from wind-blown embers. Even if the flames never reach a house, the structure must be able to withstand exposure to millions of tiny embers that can be carried a mile or more ahead of a wildfire. These embers can penetrate vents, screens, and gaps in wood and enter the home where they can ignite materials inside the home. To make a structure more fire resilient, a combination of structural design features, appropriate building materials, debris clearance, and vegetation management must be used.

8.3 Reducing Structural Ignitability

Coordinated pre-fire management efforts occur continuously throughout the county and across fire agencies. These activities include business and home inspection programs, land development plan reviews and construction inspections, fire alarm and suppression system plan reviews, fire investigations, inspections of hazardous and assembly occupancies, reviews of vegetation management plans (VMPs) a requirement for all new construction and substantial remodels in the WUI, and building code and standard development. Because most of Marin is built-out, remodeled homes account for a significant change to home hardening, More information about Marin's building codes and standards for reducing structure ignitability are discussed below.

Reducing structural ignition is the highest priority when considering mitigation strategies to reduce the likelihood of urban conflagration. High-intensity wildfires in the WUI typically do not spread directly through residential developments. Access roads, driveways, utility corridors, and home sites produce gaps in the forest and shrub canopy sufficient to discontinue high-intensity canopy fires. Home destruction largely results from direct firebrand ignitions, or lofted burning embers, and fires spreading on the ground within the community. When homeowners take action to lessen the ignitability of the home ignition zone, they dramatically increase the survivability of their home (Cohen and Quarles, 2011).

Fire-resistant building materials and designs are extremely effective at reducing structural ignitions. These include a wide variety of materials combined with engineering and design choices for nearly every aspect of home construction. They range from relatively expensive materials such as tempered glass and upgraded roofing to simple, inexpensive, but effective features such as fine wire mesh covering attic and basement vents. Many of these features can be retrofitted or applied to new construction.

While new construction and substantial remodels are required to use ignition-resistant materials meeting the standards of Chapter 7A of the CBC, owners of existing homes should be encouraged to make simple but effective upgrades. By reducing structural ignitability, in conjunction with improved defensible space and vegetation maintenance in open spaces, overall community risk can be dramatically reduced.

Building Codes to Reduce Structural Ignitability

MCFD and Community Development jurisdictions have identified that fire protection modifications to locally adopted codes including the California Building Code, California Residential Code and California Fire Code, are reasonably necessary because of Marin's local climate and topography. The climatic seasonal reduction in vegetative moisture content, combined with Marin's populated steep terrain, require enhanced fire protection measures.

California Building Code (CBC) Chapter 7A specifically addresses the wildland fire threat to structures by requiring the use of fire-resistant materials and construction techniques. New buildings, additions and exterior remodels to buildings located in any FHSZ or any WUI fire area designated by the enforcing agency constructed after the application date shall comply with the provisions of chapter 7A as amended. These requirements only apply to new construction and do not address existing structures or remodels and additions to existing structures.

There are several strategies to identify and implement regulatory and nonregulatory approaches to reduce structural ignitability.

- Encouraging individual responsibility
- Zoning regulations
- Development standards
- Building codes
- Fire prevention codes
- Fire department response

Various laws and regulations govern hazard mitigation in the WUI. These laws and regulations are the basis for prescribing best practices for creating defensible space and increasing wildfire preparedness.

California State Regulations, Adopted Locally

New editions of the California Building Standards Code are published every three years in a triennial cycle with supplemental information published in other years. Publication of triennial editions of the CCR began in 1989. The most recent version of the code is the 2019 edition published January 1, 2020. Please refer to the most recently adopted and locally amended code.

California Code of Regulations (CCR), Title 24, Parts 1-12

- CA Building Code, Chapter 7A, Materials and Construction Methods for Exterior Wildfire Exposure, (CCR, Title 24, Part 2, v1)
- CA Fire Code Chapter 49, Requirements for Wildland-Urban Interface Fire Areas, (CCR, Title 24, Part 9)
- CA Building Code Chapter 17, Special Inspections and Tests (CCR, Title 24, Part 2, v2)

Fire Safe Regulations

- California Code of Regulations, Title 19. Public Safety. Division 1. State Fire Marshal
- California Code of Regulations, Title 14, Division 1.5, Department of Forestry and Fire Protection
- 2018 International Wildland-Urban Interface Code
- California Public Resources Code §4290 & §4291

Local Ordinances

At the sub-county level, communities may consider the adoption of local ordinances to address specific concerns not covered by existing codes or amendments. For example, in 2007, the City of San Rafael adopted an ordinance that requires property owners in the WUI to remove or trim away junipers. This code is under Chapter 4 of the San Rafael Municipal Code. Similarly, in 2019, the City of Mill Valley adopted a ban on several specific fire-hazardous plants that include (but may not be limited to) Italian cypress, bamboo, juniper, and acacia. In other parts of California, there are examples of ordinances adopted at the local level to reduce fire hazard and structure ignitability; for instance, the City of Big Bear Lake in San Bernardino County passed an ordinance for wood or shake roof replacement.

Current codes (including PRC4291 and CAFC 4907.2) already adopted or applicable within the district, when enforced, can provide effective mitigation of vegetation hazard in the defensible space zones around structures.

Federal Regulations

At the Federal level, the Federal Disaster Mitigation Act of 2000 (DMA 2000) provides the "legal basis for the Federal Emergency Management Agency (FEMA) mitigation planning requirements for state and local governments as a condition of mitigation grant 12 assistance." The DMA 2000 requires localities to adopt a Local Hazard Mitigation Plan (LHMP) in order to obtain FEMA and federal grant eligibility. The LHMP is administered at the county level.

In addition to the LHMP, California requires a Safety Element as part of any General Plan. The goal of the Safety Element is to "reduce the potential risk of death, injuries, property damage, and the economic and social dislocation resulting from hazards." The Safety Element is used to develop action-oriented policies and implementation measures that should correspond with the data collected, and other examples such as access and evacuation routes, road and structural identification, roadway widths, and water supply. An example of a policy that might appear in the Safety Element is that "no development shall be approved unless the local government can determine that development is reasonably accessible and served in the case of a wildfire."

Ignition-Resistant Roofing to Reduce Structural Ignitability

Disaster examinations reveal that most destroyed homes are not ignited directly by intense wildfire (Mell et al., 2011). This indicates that flame contact from surface fires and direct firebrand (lofted burning embers) ignitions are the cause. Firebrands that result in roof ignitions commonly originate from a fire over ½ mile away depending on the fire intensity and the type of fuel burning.

For a home, the roof is the most common structural fuel bed for ignition by firebrands or embers. For this reason, materials used to construct a roof are of great importance to the home. Homeowners should be aware of the dangers associated with having wood shingle (shake) rather than fire-resistant roof types. All newly constructed homes are required to utilize roof materials of Class-A or better. Many roofing materials meet the Class-A standard, allowing flexibility in achieving architectural aesthetics while providing fire resistance. While Class-A roofing materials are considered the most fire-resistant, even a Class-A roof may be vulnerable to fire if leaf litter or needles are allowed to accumulate.

Typical Class-A roofing products include (but are not limited to):

- Asphalt Shingles
- Metal
- Concrete (standard and lightweight)
- Clay Tile
- Synthetic
- Slate
- Hybrid Composites

Wood and Shake Roofs in Marin County

Inspection data collected over the past two years for approximately 8,700 properties indicates that about 3% of residential roofs in Marin County are made of wood shingles or shakes, making these properties among the most vulnerable to ignition by firebrands. Because wood shake roofing is relatively long lasting, with a lifespan of 20-50 years, the existing structures are likely to remain highly combustible for many years unless the roofing is replaced. Figure 28 shows a map of the locations where inspections have been conducted by MCFD over the past two years. Figure 29 shows a map of the homes that have wood roofing. Because of the ignitability of wood roofing, fire agencies throughout Marin should consider providing incentives for homeowners to replace wood roofs.

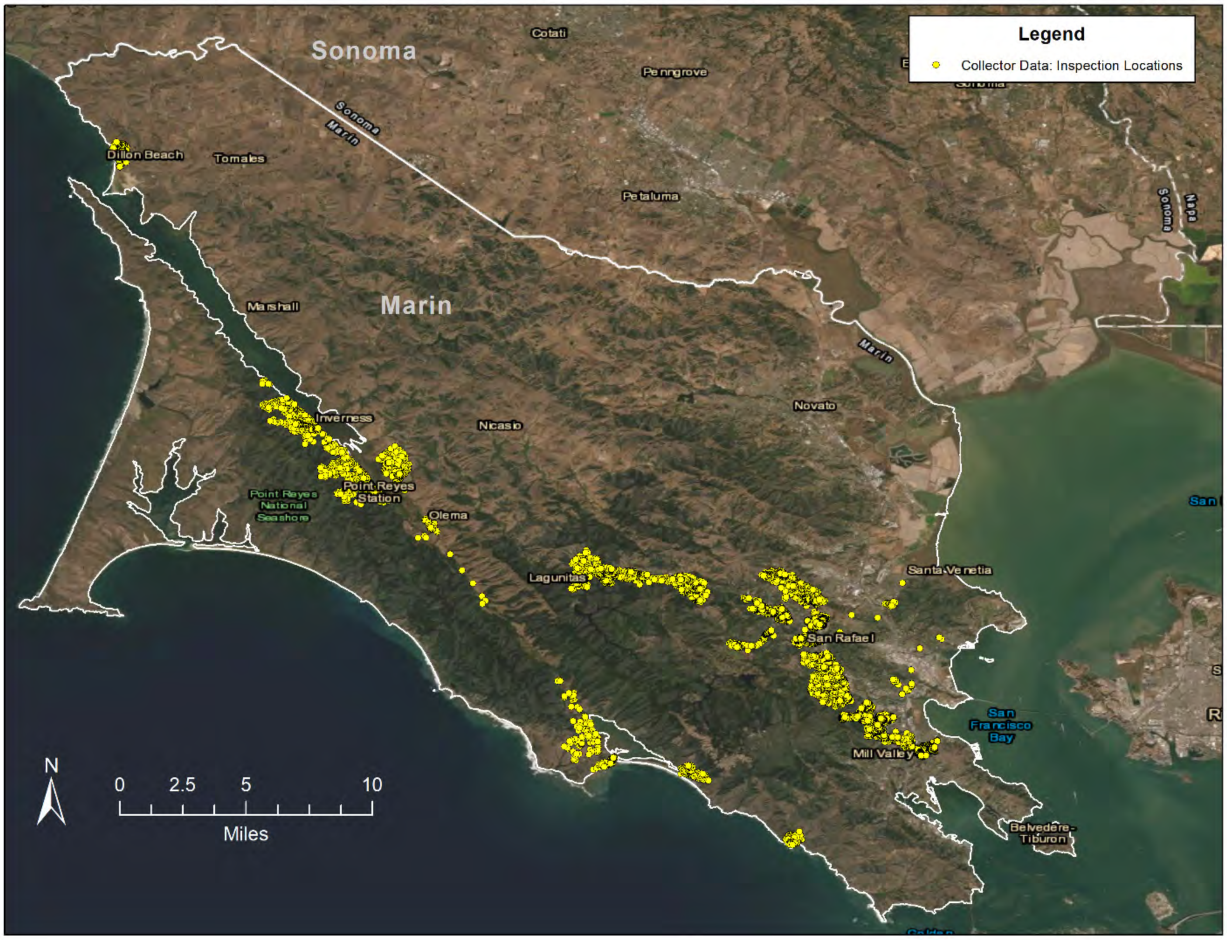

Figure 28. Locations of properties that have been inspected in the past two years.

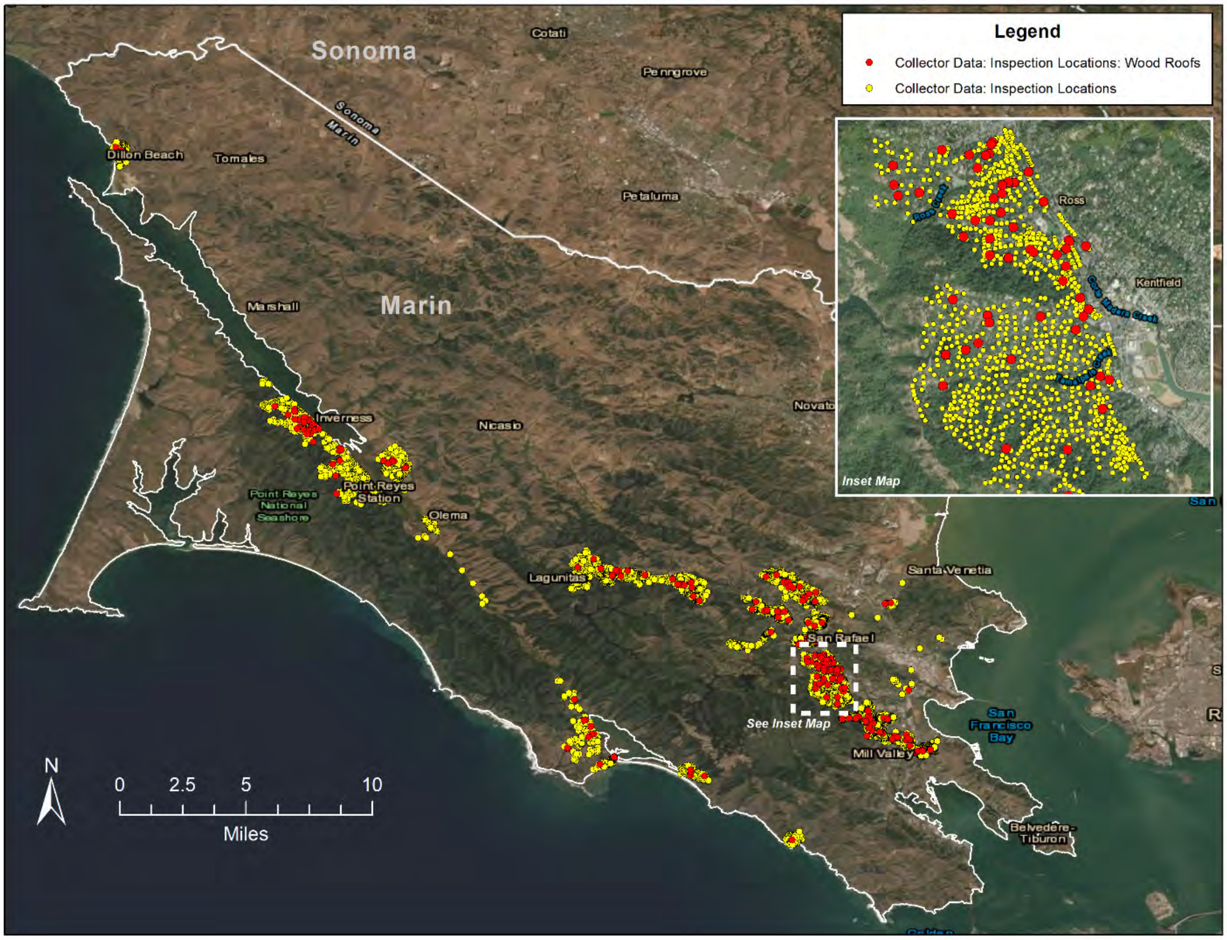

Figure 29. Locations of homes with wood roofing (shown in red).

Design, Construction, and Building Material Upgrades to Reduce Structural Ignitability

The building design and construction process provides one of the most cost-effective means of addressing wildfire risk (Schwab et al., 2005). The new construction and remodel process is governed by building codes, design criteria, architecture, and soils and landscaping considerations. Most often code criteria that support risk reduction apply only to new construction, substantial renovation, or renovation to change the type or use of the building. The construction process offers other opportunities to use fire-resistant building materials such as stone, tile, and stucco, and incorporate new technologies and design features to help homes resist and survive wildfires.

8.4 Defensible Space

Landscaping is particularly critical in areas of potential wildfires because vegetation close to structures can become fuel for a fire. Clearing, grading, and siting all have potential impacts to soil stability and erosion and can be included as part of a design or building permit review process. The use of "hardscape" features such as retaining walls and stone pathways can also be used to engineer an attractive landscape that helps structures survive wildfires, and should be encouraged. FIRESafe MARIN recommends "firescaping" which is landscape design that reduces house and property vulnerability to wildfire. Individual homeowners are ultimately responsible for the protection of their homes from wildfire. In a severe wildfire event, the fire service cannot protect all homes at risk. Individual responsibility and preparation taken long before a wildfire starts is of paramount importance.

8.4.1 Improve Defensible Space Around All Structures

Defensible space of 100 feet is required by law (California Fire Code 4907.2, PRC 4291, Title 14 CCR). Residents and landowners must be encouraged to develop, enhance, and maintain defensible space annually. Property owners are ultimately responsible for maintaining defensible space; however, in some instances, rental contracts or lease agreements may subrogate responsibility for landscaping or building maintenance. FIRESafe Marin recommends zones that make up the 100 feet of defensible space around a home. The most important zone is the 0-5 feet zone immediately surrounding a home. Vegetation, wood, and other materials in this 0-5 feet zone can ignite in a wildfire and pose a threat to homes. **Figures 30 and 31** illustrate and describe the zones that make up the 100 feet of defensible space required by law (Source: FIRESafe MARIN).[38]

There are opportunities to provide enhanced environmental conditions through defensible space actions. For example, through public education for residential defensible space the use of native and other pollinator friendly plants, guarding soil health, and retaining large trees and shrubs in a fire-smart manner ecological values can be improved. ESP is actively considering best practices in these areas. As mentioned in Section 4.7.1, the recently revised state defensible space code (AB3074) requires CAL FIRE to develop guidelines that provide "regionally appropriate vegetation management suggestions that preserve and restore native species that are fire resistant or drought tolerant, or both, minimize erosion, minimize water consumption, and permit trees near homes for shade, aesthetics, and habitat." Similar guidelines for Marin could be developed and included in public outreach materials.

[38] FIRESafe MARIN (**https://www.firesafemarin.org/defensible-space**).

Figure 30. The zones that make up the 100 feet of defensible space required by law (**https://www.firesafemarin.org/defensible-space**).

ZONE 0

0'-5'

Zone Zero, sometimes referred to as the "Immediate Zone" is the area nearest your house, 0'-5', including the surfaces of the structure itself. There should be ZERO combustibles in this zone! **Take steps to 'harden' your home with fire and ignition resistant materials and design!**

This zone extends 0'-5' from your house. It's the area closest to your house, including plants, decks, outdoor furniture, and the outside walls and coverings. This area is most vulnerable and should be more aggressively maintained for fire resistance.

- Remove combustible outdoor furniture. Replace with metal or non-combustible varieties.
- Replace jute or natural fiber doormats with heavy rubber or metal grates.
- Remove or relocate all combustible materials including garbage and recycling containers, lumber, trash, and patio accessories.
- Clean all fallen leaves and needles.
- No vegetation is recommended within 5' of any structure.
- Remove tree limbs that extend into this zone. Fire prone tree varieties should be removed if they extend into this zone.
- Do not store firewood, lumber, or combustibles here, even (especially) under decks or overhangs. Move stored combustibles inside or at least 30' from any structure.
- **Use only inorganic, non-combustible mulches such as stone or gravel.**
- Hardscaping is strongly recommended around the base of structures.

ZONE 1

5'-30'

Zone 1, sometimes referred to as the "Intermediate Zone" extends from your house's exterior walls to a distance of 30'. The "Lean, Clean, and Green" zone.

This extends 0'-30' out from buildings, structures, decks, etc, and overlaps the Home Ignition Zone described above.

- Remove all dead grasses, weeds, plants, & foliage.
- Remove all fallen leaves, needles, twigs, bark, cones, and small branches.
- Remove "Gorilla Hair" or shredded bark mulch.
- **Use only compost or heavy bark mulch to maintain soil moisture, or for erosion control.**
- Choose only **fire-smart plants**, and keep them healthy and well irrigated.
- Remove **fire-hazardous plants**.
- Provide spacing between shrubs, at least 2 times the height of the mature plant. Add space on steeper slopes.
- Trim trees to remove limbs 6' to 10' from the ground.
- Remove branches that overhang your roof or within 10' of chimneys.
- Move firewood & lumber out of Zone 1, or cover in a fire resistant enclosure.
- Remove combustibles around and under decks and awnings.
- Clear vegetation around fences, sheds, outdoor furniture, play structures.
- Outbuildings and LPG storage tanks should have at least 10' of clearance.
- Maintain regularly, focusing on the areas closest to structures.

ZONE 2

30'-100'

Zone 2, sometimes referred to as the "Extended Zone," extends from 30' to at *least* 100' - more Defensible Space may be required based on topography, vegetation, or building construction (for example, if you live on a hill, in a drainage, or an area surrounded by unusually dense or flammable vegetation, or have a wood shake roof, 150' or more may be required). California and local laws usually do not require you to create Defensible Space on property you don't own (check with your local fire agency if you're not sure). Work with your neighbors to gain permission to clear defensible space on their property if it will help protect your home!

Extending from 30'-100' or to your property line at a minimum (you may be required to provide more clearance due to steep slopes, nearby vegetation conditions, and/or other conditions identified by the fire department). This zone should include at a minimum:

- Cut or mow annual grass down to a maximum height of 4 inches.
- Create horizontal spacing between shrubs and trees. (See diagram)
- Create vertical spacing between grass, shrubs and trees. (See diagram)
- Remove fallen leaves, needles, twigs, bark, cones, and small branches. However, they may be permitted to a depth of 3 inches if erosion control is an issue.
- Remove all piles of dead vegetation.

ZONE 3

ACCESS ZONE: 0'-10'

Zone 3, the "access" zone, extends from 0' to at *least* 10' horizontally from the edge of roads and driveways, and 14' overhead.

Property owners are responsible for vegetation adjacent to roads and driveways. Access roads are critical for evacuation and first responder access. Maintenance is required year-round.

- Property owners are responsible for vegetation adjacent to roads and driveways.
- Clear vegetation 14' overhead and 10' from sides of roads and driveways in the same manner as Defensible Space Zone 1.
- Maintain 12' of unobstructed pavement for passage of vehicles.
- Within this zone, plantings shall be well maintained and must not extend into the roadway.
- 14' of clearance is required above the roadway for emergency vehicle access.
- Address numbers must be clearly visible from the road, with at least 4" numbers on a contrasting background. Reflective or lighted numbers are best.
- Create vertical spacing between shrubs, and lower tree limbs. Cut all grasses.

Figure 31. Description of the zones that make up the 100 feet of defensible space required by law (**https://www.firesafemarin.org/defensible-space**).

Field observations reveal that virtually no property in Marin is in strict compliance with defensible space requirements. Additionally, only structures built or substantially remodeled since 2008 are likely to meet current ignition resistance standards of Chapter 7A of the California Building Code. Many of the recommendations in other sections of this report overlap with defensible space recommendations. Additional fuel reduction space within 100-200 feet of a structure could be considered an improvement of defensible space. In this section, specific recommendations for the 0-100 foot defensible space zone are addressed.

Each fire agency is responsible for defensible space inspection and enforcement within its jurisdiction. In order to improve high compliance with defensible space requirements throughout the County, the following is recommended:

- Continue to provide community "Chipper Days" throughout the county
- Conduct annual inspections and provide hazard notifications for all parcels out of compliance throughout the county
- Recommend enhanced defensible space up to 200 feet to property boundary
- Support removal of specific non-native, fire-hazardous species (i.e., juniper, Italian pampas grass, bamboo) commonly found in residential landscaping
- Support maintenance of mature native trees in defensible space zones, and incentivize maintenance and/or replacement of non-native, fire-hazardous trees

Community Chipper Days

All fire agencies and departments throughout the county should encourage and support community Chipper Days, especially in Firewise USA® sites. Community Chipper Days have been shown to promote community involvement and provide a highly accessible mechanism to dispose of large quantities of hazardous vegetation. Annual Chipper Days also help neighborhoods meet annual Firewise USA® recognition and renewal requirements.

Hazard Inspections and Notices

During the public meetings conducted in 2016, when the CWPP was last updated, there was (and continues to be) public concern about a lack of compliance and enforcement for defensible space and vegetation management. One of the goals of the MWPA is to allocate funds "to expand and enhance defensible space home evaluations to ensure homes meet fire and building codes, as well as education to reduce the vulnerability of a home." Enforcement can be geared toward working with property owners to help make their properties and homes more resilient to wildfire.

Recommend Enhanced Defensible Space to 200 feet for Boundary Properties

The parcel-level hazard assessment performed as part of this CWPP update shows that many properties in Marin fall into Category 2 (of three). Parcels adjacent to large parcels of open space (public or private) and large tracts of contiguous vegetation are at particular threat from wildfire.

Some properties at the boundary of large parcels of open space (private or public) should be encouraged to maintain up to 200 feet of fuel reduction.

Vegetation management in these areas may include cutting grass, thinning tree canopies, enhancing the spacing of landscaping plants, and thinning native vegetation up to 200 feet from all structures on the side(s) facing contiguous vegetation.

Priority Parcels for Fire Hazard

Although many parcels in Marin meet the accepted definition of WUI, some parcels may be at particular threat from wildfire. The analysis fire hazard at the parcel-level (Section 7) shows that many of the parcels in Marin fall into Category 2 (of three). Priority parcels for fire hazard reduction should focus on parcels in Categories 3 and 2 that are in high risk intermix areas and properties immediately on the interface boundaries aligned with the most severe fire behavior predictions. Priority should also be given to those parcels that have homes with wood roofing and/or overgrown vegetation.

Support Removal of Hazardous Plant and Tree Species

Some non-native plant and tree species common to residential landscaping share characteristics that make them more likely to ignite readily and burn intensely. During recent fires in northern California, firefighters have observed certain plants including juniper, cypress, pampas grass, broom, and bamboo (to name a few) igniting and burning in the defensible space zones near homes. For this reason, these plants are poor choices for landscaping. Local fire departments may require removal of certain plants within 30 -100 feet of structures. FSM maintains a list of hazardous plant and tree species; however, the list is not a substitute for the experience of a professional as it does not take into consideration the condition of each home, and property characteristics such as slope, aspect, moisture, or soils, which can all influence a plant's response to fire. Fire agencies throughout the county should work with residences to support the removal of hazardous plant and tree species.

Removal of live plants should focus on recognized fire-hazardous, non-native plants. To protect biodiversity, habitat, and native landscapes, native plant species present in the defensible space zones around structures should typically be maintained, rather than removed. Maintenance may consist of regular pruning to remove dead material, irrigation during the dry season to increase plant hydration, and spacing and/or limbing to provide ground to canopy separation.

Resale Inspections to Enforce Defensible Space and Vegetation Management

Ross Valley Fire Department (RVFD), takes a novel approach to vegetation management enforcement through its “Resale Inspection” program. Resale Inspections are vegetation hazard inspections that occur whenever a property is (re)sold in the towns of San Anselmo, Fairfax, or Ross in central Marin County’s Ross Valley. Fire inspectors visit properties listed for sale to conduct vegetation hazard inspections prior to sale. Current vegetation management standards and codes are included with property sale disclosures, and the vegetation hazard and mitigation requirements become part of the listed “disclosures” during the sale of the property. Mitigation actions and cost are shared by the seller and buyer and must be completed as outlined in the related fire and municipal codes.

Resale inspections provide valuable access to fire department inspectors and ensure that property owners and buyers understand the wildfire risk and conform to standards to reduce hazards on their property. Fire departments throughout the county could adopt a local ordinance, modeled after the RVFD, to require Resale Inspections for real estate sales in their jurisdictions as a strategy to enforce defensible space and vegetation management.

Support for Firewise USA Recognition

The national Firewise USA® program grew out of a partnership between the United States Forest Service (USFS), the U.S. Department of the Interior (USDI), and the National Fire Protection Association (NFPA). In 1997, NFPA launched the Firewise USA® website with information on wildfire safety for homes (NFPA 2015). The Firewise USA® community recognition program started in 2002 and now includes over 1,500 communities across the country. Marin County is home to more Firewise USA® sites (more than 60 as of November 2020) than any other county in the United States. Figure 32 shows a map of Marin's Firewise USA® communities.

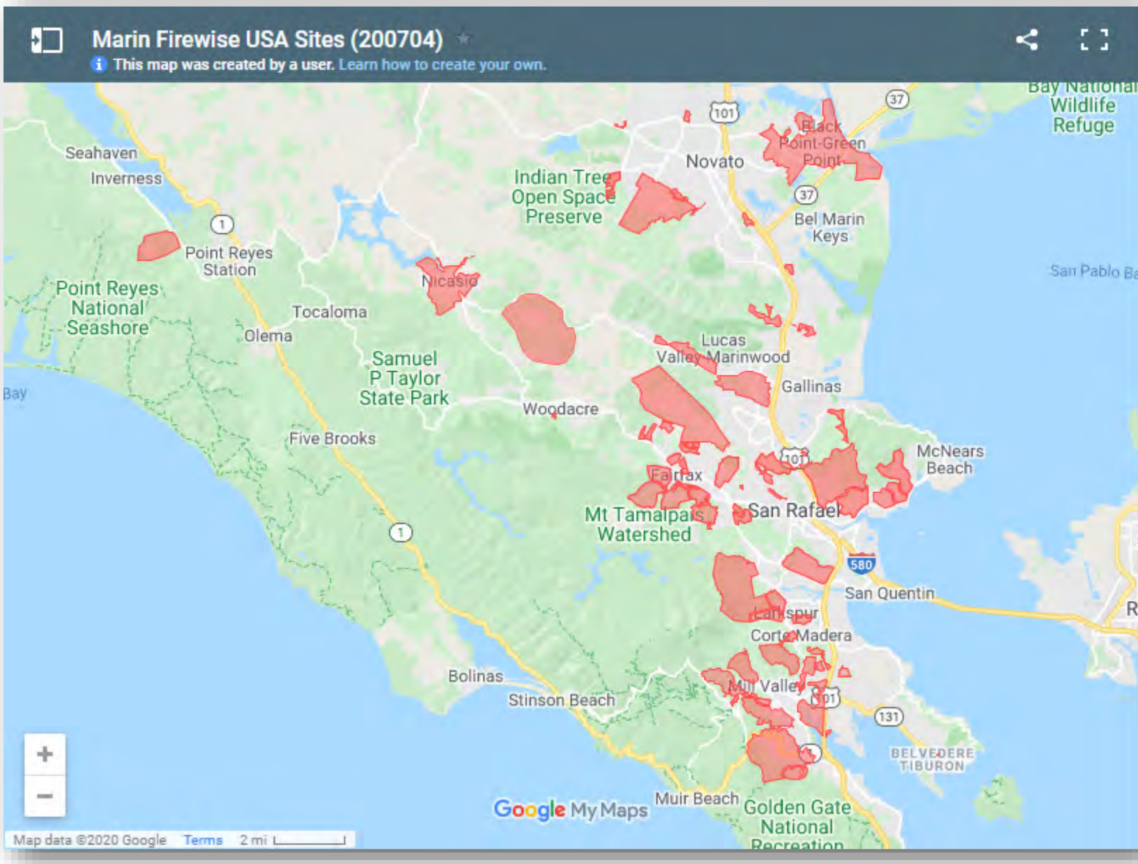

Figure 32. Map showing Marin County's Firewise USA® sites [Source: FIRESafe Marin: (**https://www.firesafemarin.org/firewise**)].

A similar movement started in California after the 1991 Oakland-Berkeley Hills Fire and developed into the fire-safe councils that now operate in over 100 California communities.[39] Fire-safe councils work to include local agencies and fire departments in planning to reduce fire hazard beyond the residents' mitigations on which the Firewise USA® program focuses. Many communities in California have both a fire-safe council and Firewise USA® designation.

Firewise USA® incorporates many of the home mitigation and defensible space elements discussed in previous sections of this CWPP. Research and post-wildfire assessments have shown these mitigation measures to be successful. New research is beginning to assess the effect of Firewise

[39] California FireSafe Council (**https://cafiresafecouncil.org/**).

USA® practices on home survivability specifically. A careful analysis of 74 homes lost during the 2007 Witch Fire in San Diego, California, demonstrated that the majority of the Firewise USA® treatments evaluated appeared to be applicable even if individually they were not fully effective (Maranghides et al., 2013). More specifically, treatments such as having fire-resistant plants within 30 feet of the home, lawns or gravel fuel breaks, pruning, removing overhanging branches, fire-resistant construction materials, clearing dead wood within 30 feet, and removing attached wood fences were all associated with reduced damage (Maranghides et al., 2013).

Firewise USA® recognition provides direct and indirect benefits to the community. Educational programs may improve awareness and individual accountability, and annual fuel mitigation efforts measurably reduce hazards. Financial benefits may include property insurance discounts, while FEMA gives Firewise USA® communities priority in consideration for pre-disaster mitigation planning and project grants.

8.5 Non-Residential Vegetation Management

This section provides information and recommendations for vegetation treatment goals and guidelines to be used when selecting and implementing fuel reduction actions for reducing wildfire hazards in Marin County's communities on non-residential land. It is important to recognize that fire agencies are not landowners and do not have the ability to conduct direct fuel modification treatments without landowner permission. All proposed fuel treatments on non-residential land should be achieved through a cooperative process with landowners or enforcement of existing (or proposed) regulations such as the adopted amendments to the WUI Code, California Fire Code, PRC 4291, or Title 14 CCR.

After many years of fire suppression, ecosystems that rely on fire for health become strained and overgrown. Plants and trees become stressed by overcrowding and become more susceptible to disease; fire-dependent species disappear; and flammable fuels build up and become hazardous. Prescribed fire has many benefits, including[40]

- reducing hazardous fuel loads;
- protecting communities from catastrophic fires;
- reducing the spread of plant and tree diseases and invasive species;
- encouraging the health of fire-dependent native vegetation and animal species;
- encouraging palatable and nutritious forage for domestic livestock in timbered and open range;
- enhancing aesthetic value by increasing occurrence and visibility of flowering annuals and biennials; and

[40] https://www.goodfires.org/.

- improving access to areas previously inaccessible because of thickets or dead and down wood.

Prescribed fires can be a very effective tool for hazard mitigation and ecosystem restoration. Conducting effective prescribed burns requires a burn plan that considers temperature, humidity, wind, moisture of the vegetation, and conditions for the dispersal of smoke.

8.5.1 Roadside Vegetation Management

Vegetation management along roadways and driveways is critical to safe access and egress during any emergency event. Narrow roads with unmaintained vegetation create considerable challenges for responding fire apparatus. Under current vegetation conditions, some roads and areas in Marin are not safely accessible to fire emergency equipment and may create congestion for residents attempting to evacuate.

Roadside vegetation clearance is ultimately the responsibility of individual landowners when property lines extend to the edge of the right-of-way. In certain situations, right-of-way maintenance, such as annual mowing, drainage maintenance, and hazard tree removal, may fall on the local or county Departments of Public Works. For roads not maintained by the County, the adjacent property owner or local neighborhood association has responsibility for roadside vegetation management.

Funding for enhanced vegetation maintenance should be prioritized for the public right-of-way to reduce vegetation that may threaten evacuation or impede fire apparatus access. Because roadway vegetation maintenance is largely the responsibility of individual landowners, the county could consider encouraging voluntary improvements through incentive programs such as hazard tree removal matching grants, hazard vegetation removal matching grants, and/or sponsorship of vegetation management/fuel crews to conduct vegetation removal in the highest hazard areas and adjacent to evacuation routes, with property owner permission.

8.5.2 Other Access/Egress Issues

Road Width and Turnouts

Road width and clearance is critical for allowing access/egress during an emergency or evacuation situation. Many roads in Marin, especially in the WUI, are narrow and potentially interfere with fire engine access. Where roadways are narrower than 15 feet, paved turnouts are important to allow incoming fire apparatus and evacuating passenger vehicles to pass safely. Where turnouts are not available, vegetation clearance along roadways and driveways should be enhanced to reduce the threat of direct flame impingement upon the roadway and to improve visibility.

Fire Road Gate Access

Vegetation clearance near fire road gates is imperative for fire department access. Fuel treatments should be similar to those recommended for roadways, but should extend a minimum of 30 feet from road edges near gates. Grasses should be cut annually near gates, ground fuels (i.e., fallen wood, brush) should be removed, and gates should be functionally inspected and maintained. Fire agencies should work with landowners (GGNRA; MMWD; MCOSD; private) to ensure gate clearance is maintained and that gates are keyed and locked appropriately.

8.5.3 Open Space and Common Space Vegetation Management

Vegetation management on open space and common space should be a collaborative effort among fire agencies and landowners. Large landowners such as GGNRA, MMWD, and MCOSD all have vegetation management and fire hazard reduction programs in place. Fire agencies should work collaboratively with large landowners to help implement these plans when appropriate.

The ability of firefighters to operate safely and conduct fire suppression along ridgetop and mid-slope roads is critical to the rapid containment of wildfires. Maintaining or reducing fuels along fire roads in the Tiburon Ridge and Ring Mountain Preserves to levels that allow safe access for firefighters might make the difference between catastrophic wildfire or containment. Modeling confirms the value of these locations for fuel maintenance and minor modifications.

Work with Public and Private Landowners to Maintain Fuels

The presence of several large public and private parcels in strategic locations presents an opportunity for fuel reduction partnerships to achieve mutually beneficial goals and reduce community wildfire hazard. The parcel-level hazard assessment can be used to identify certain parcels where fuel treatment might provide the greatest benefit.

Engagement with landowners in strategic locations to coordinate fuel reduction projects that will benefit the community as a whole is critical. Appropriate treatment techniques should be used for the vegetation present, such as prescribed burns, reducing ground and ladder fuels, creating shaded fuel breaks, thinning canopies, maintaining existing grasslands, cutting annual grasses, and maintaining private fire roads. Cost sharing, matching grants, or direct funding are strategies that can result in community-wide benefits.

Prescribed Fire to Reduce Fuels and Promote Healthy Ecosystems

As discussed in Section 3.4, Marin's native vegetation evolved with the presence of frequent wildfires. Native Americans used fire for protection, agriculture, and forest health. Low-intensity prescribed fires can be beneficial to the landscape and support biodiversity and productivity of chaparral and coastal scrub ecosystems (Sugihara et al., 2006). Prescribed fires support the natural ecological processes in most plant communities, and therefore help to conserve biological diversity. Improving the health of the land and forests can also help sequester carbon.[41] Prescribed fires can also help reduce the catastrophic damage of wildfire on our lands and surrounding communities by reducing excessive amounts of brush, shrubs and trees and encouraging the new growth of native vegetation. Prescribed fire can be a very effective tool for preventing wildfires and managing the intensity and spread of wildfires and should be considered as a tool for mitigating fire hazard.[42]

Grazing to Reduce Fuels

Since 2016, herds of goats and sheep have been used to graze in open space areas as part of a large-scale fire hazard reduction project spearheaded by local landowners. The goat grazing program has been a collaborative effort to address key locations for fuel reduction to reduce the impact of wildfires in Marin communities. Over the past three years, this multi-agency project has successfully reduced hazardous fuels on hundreds of acres of high-hazard grassy woodlands throughout central Marin. Some grazing practices are known to import and/or expand non-native plant species. Therefore, grazing practices should be monitored and managed to avoid potentially negative impacts to native plant diversity and other ecological attributes.

Maintain Existing Fire Roads and Conditions

Maintenance of existing fire roads that provide a strategic advantage for fire containment efforts and access for fire equipment, specifically, a 100 foot corridor of continuous grass along fire roads—provides safe working conditions for firefighters. With the support of firefighting aircraft, which are highly effective along ridgetop grasslands, containment of a fire in the first hour may be possible. Fire agencies are encouraged to work with large landowners to ensure that conditions support safe working conditions for fire suppression and potential fire containment lines.

Fire for Invasive Species Control

Fire is also a tool used to manage ecosystems by removing vegetation. In some grassland areas, prescribed burning at precise stages of native and non-native plant growth may reduce weedy, invasive plants and increase the range of native grasses. In other cases, burning may damage natives and create gaps for the establishment of invasive plants. Like all

Photo by Dana L. Brown[40]

[41] CAL FIRE (https://www.fire.ca.gov/programs/resource-management/resource-protection-improvement/landowner-assistance/forest-stewardship/carbon-sequestration-and-a-changing-climate).

[42] **https://smokeybear.com/en/about-wildland-fire/benefits-of-fire/prescribed-fires**

[43] "Hard work: the Fuels Crew is reducing wildfire risk while protecting biodiversity in partnership with the Marin County Fire Department and Marin Open Space District" (**https://www.flickr.com/photos/danalbrown/48135385571/**) by Dana L. Brown

other weed control practices such as herbicides, mowing, or tilling the soil, burning has to be utilized properly and should be integrated with other methods. In some cases, intentional fires can be incorporated with re-vegetation of native plants. Burning is also a good way to remove dead biomass and expose target plants to follow-up herbicide treatments. After a fire, the majority of plant material is consumed, so access to the areas can be much easier. This can provide an opportunity to employ weed control for much less cost and effort (Bell et al., 2009).

8.6 Evacuation Planning and Preparation

Rapid and timely evacuation is critical to protect lives and property. Residents should be encouraged to evacuate as soon as possible after becoming aware there is a fire, since the presence of citizens in the fire zone only serves to slow firefighting efforts and puts lives at risk. Early evacuation increases the safety of evacuating residents, reduces the involvement of fire suppression personnel in evacuation (allowing firefighting resources to commit to fire suppression), and reduces the likelihood that evacuees might become trapped on roadways and subjected to reduced visibility, smoke, heat or direct flame impingement.

FIRESafe MARIN provides evacuation guidelines and terminology for the public.[44] The terms "voluntary" and "mandatory" are often incorrectly used to describe evacuations. In Marin, fire agencies and law enforcement will use the terms Evacuation Order, Evacuation Warning, and Shelter-In-Place to alert you to the significance of the danger and provide basic instructions. The following defines each term

- **Evacuation Order.** Leave now! Evacuate immediately, do not delay to gather belongings or prepare your home. Follow any directions provided in the evacuation order.
- **Evacuation Warning.** Evacuate as soon as possible. A short delay to gather valuables and prepare your home may be ok (see Evacuation Checklist) may be ok. Leave if you feel unsafe.
- **Shelter in Place.** Stay in your current location or the safest nearby building or unburnable area. May be required when evacuation isn't necessary or is too dangerous

The County of Marin, through the Sheriff's Office of Emergency Services (Marin OES) and local fire agencies, has adopted a "Mutual Threat Zone Plan" with detailed evacuation maps intended for emergency managers and responders (**https://www.marincounty.org/depts/fr/divisions/operations/wildfire-evacuation-zones**). Marin public officials are considering incorporating the current evacuation maps with traffic control points to allow for more effective management of traffic during an emergency and to develop a model that is consistent across the Bay Area.

(**https://www.flickr.com/photos/danalbrown/**) is licensed under CC BY 2.0 (**http://creativecommons.org/licenses/by/2.0/legalcode**). No changes were made to this image.

44 FIRESafe MARIN (**https://www.f).iresafemarin.org/evacuation/guide**)

8.6.1 Roadway Clearance and Roadside Vegetation

Roadway clearance and managing roadside vegetation is critically important to secure safe evacuation routes and provide access for firefighting resources. Vegetation within 10 feet of roadways should be maintained in the same manner as Defensible Space Zone 1 (5 feet to 30 feet). Additional vegetation clearance—from 10 feet to 30 feet or more—may be necessary to protect critical roadways, especially when terrain features such as steep slopes, drainages, or certain vegetation fuels might impact roadways with direct flames and/or radiant or convective heat.

Roadside vegetation management is a statutory responsibility for landowners under the CA Fire Code, as adopted by local agencies (in Marin, typically Sections 4907.2 and 4907.8) and other local ordinances; code enforcement is critical to achieving this recommendation. In locations where there is no responsible landowner under the fire code (some undeveloped parcels, CALTRANS right-of-way, some public right-of-way, and some tax-exempt parcels), fire agencies should develop plans to encourage vegetation maintenance and consider funding partnerships to execute those plans.

Vegetation management in the vicinity of roadways and driveways is critical to safe access and egress during a wildfire event. Narrow roads with unmaintained vegetation create considerable challenges for responding fire apparatus. Under current vegetation conditions, some roads and areas in Marin are not safely accessible to fire crews and may entrap residents attempting to evacuate.

Roadside Vegetation Clearance Responsibility

Roadside vegetation clearance is ultimately the responsibility of individual landowners when property lines extend to the edge the right-of-way. In certain situations, right-of-way maintenance, such as annual mowing, drainage maintenance, hazard tree removal, may fall on the local or county Departments of Public Works. For roads not maintained by the County, the adjacent property owner or local neighborhood association has this responsibility.

8.6.2 Promote Integrated Alert and Warning Systems and Procedures

Integrated alert and warning systems, well-defined protocols, and improved public information and pre-planning allow the public to better access and act on the most current information during an emergency. During an emergency, it is critical that the public (1) is prepared for evacuation, (2) knows how and where to evacuate, and (3) knows where to obtain current information during and after an event. The following should be implemented to prepare the public for a wildfire emergency:

- Incorporate the public facing Marin County Emergency Portal website (**https://emergency.marincounty.org**) into alert and warning message templates and protocols to allow the public to access the most current information during an emergency.

- Conduct a comprehensive update of pre-planned evacuation zones, including a 'know your zone' component and accompanying public education and outreach, to inform the public about which mutual threat zone (MTZ) they live and/or work in and which evacuation routes to take.

- Develop a public outreach strategy to inform the public on (1) how to sign up for *AlertMarin* (**www.alertmarin.com**), (2) how to determine which MTZ people live and/or work in, and (3) how to use the Marin County Emergency Portal website (**https://emergency.marincounty.org**) to obtain information during an emergency.

During Public Safety Power Shutoffs (PSPS), PG&E turns off power to help prevent wildfires and during wildfires, there can be a loss of electrical power due to damage to power poles and electrical distribution infrastructure. Cordless phones and phone recorders do not work if there is no electricity. Firefighters do their best to prevent the disruption of service; however, it is recommended that all homes keep at least one hard-wired telephone that will work without electricity or if no other device is registered to receive *AlertMarin* notices.

8.6.3 Increase Community Situational Awareness

Fire weather notifications and Red Flag Warnings are issued by the National Weather Service (NWS) to notify fire agencies and the in advance of critical weather patterns that may contribute to extreme fire danger and/or extreme fire behavior. A Red Flag Warning is issued for weather events which may contribute to extreme fire behavior and that will occur within 24 hours (or when these conditions are currently being observed). A Fire Weather Watch is issued when weather conditions could exist in the next 12-72 hours. A Red Flag Warning is the highest alert.[45] Red Flag Warnings help improve public awareness of fire weather conditions and encourage residents to be cautious and modify their behavior during these conditions.

Fire agencies and FIRESafe MARIN use various media channels including the FIRESafe MARIN website, social media, Red Flag Warning signage, emergency alerts, and PulsePoint to increase situational awareness during fire weather conditions.

8.6.4 Promote Adoption of NOAA Alerting Weather Radios

National Oceanic and Atmospheric Administration (NOAA) Weather Radios are excellent sources of information during emergencies, especially when power and/or communications infrastructure is disabled. Prices vary depending on the model, and start at $20. Many receivers have an alerting feature that will trigger audible and visual alarms when weather warnings, evacuation notices, or other emergencies are transmitted. Most models are battery operated, and often have solar, hand crank, or other backup charging options.

[45] FIRESafe MARIN (**https://www.firesafemarin.org/fire-weather**).

In Marin, OES officials have established protocols to send an evacuation alert through the NOAA Weather Radio system. Local agencies may issue evacuation notices through this radio based system as well (using Marin OES as an intermediary), providing a backup notification system to homes that may be without power or out of cellular communication range and are unable to receive AlertMarin notices. Multiple NOAA evacuation alerts were successfully transmitted in Sonoma County during the October 2019 Kincade Fire. Fire agencies should encourage local adoption of these radios. FSM recently acquired several NOAA radios.

8.6.5 Long Range Acoustic Devices for Evacuation Alerts

There are potential benefits of installing Long Range Acoustic Device(s) (LRAD) for wildfire and disaster evacuation alerts. The LRAD is an acoustic hailing device developed to send voice messages and warning tones over long distances at high volume for alerting residents and visitors in at risk locations. When considering LRAD or other audible warning systems like “air-raid” sirens or horns, it’s important to understand their limitations and use cases. These devices are typically audible outdoors for up to 1KM or more in ideal conditions (low ambient noise, calm air, clear skies). Testing shows that LRAD is audible indoors only within 100-300 meters of the transmitter. LRAD systems can provide an effective way to alert the public of an emergency event.

8.6.6 Create and Distribute Neighborhood-Scale Evacuation Maps

Two areas of Marin, Novato and Fairfax, are developing neighborhood-scale evacuation maps. The “Fire Clear” evacuation preparedness program develops, prints, and distributes custom educational pamphlets outlining evacuation best practices; mapping evacuation routes for communities; and highlights evacuation steps recommended by FSM and neighboring agencies. The Fire Clear wildfire evacuation maps and brochures are 11 x 17 full-color brochure, bifold, printed on both sides on heavy paper with a UV laminate for durability. One side contains a full-color evacuation map of the target neighborhood (following MTZ evacuation zones), highlighting primary and secondary evacuation routes, direction of travel, potential safety zones, and community refuge areas. The other side contains text information including evacuation checklists, and emergency contact numbers.

8.6.7 Evacuation Drills

To prepare the public for an evacuation situation, fire agencies throughout Marin have been conducting evacuation drills in cooperation with the Marin County Sheriff's Office and MCFD. Modeled around the multi-agency examples set in Mill Valley, Kentfield, and Novato, these drills have proven to be an excellent education opportunity for both residents and fire service and law enforcement personnel. Marin Humane and the American Red Cross should be invited to attend and/or participate as well.

8.6.8 Designate Temporary/Community Refuge Areas

FSM and many Marin fire agencies, cities and towns, and other partners are working together to develop improved wildfire evacuation maps and messaging for residents in Marin's WUI communities. These "Fire Clear" maps, funded by fire agencies, cities and towns, and a grant from CAL FIRE, will be published as they are completed over the course of 2020. The maps currently available can be found on the FSM website (**https://www.firesafemarin.org/evacuation/maps**).

Temporary/Community Refuge Areas are locations where evacuating residents may seek temporary shelter during a wildfire if evacuation is not possible. In the unlikely event that the primary evacuation or secondary routes could be compromised during a wildfire, formal alternate safety zones should be established. Potential candidate locations for safety zones may include open, irrigated playing fields at local public and private schools, community centers, parks and open spaces, large parking lots, and other locations near a valley floor where residents may be able to shelter more than 100 feet from exposed vegetation or other combustibles.

8.6.9 Prepare for Animal Evacuation

Recent catastrophic fire events in rural areas where people are likely to have large animals or pets identified the need to provide animal evacuation and sheltering. During disasters, emergency managers have learned that many people refuse to leave their pets behind, and sometimes do not evacuate early (when conditions are safer) when they are unable to locate their animals or are not prepared for animal evacuation. Refusals or delays to evacuate may begin a chain of events that can seriously jeopardize or cause a total breakdown of an overall evacuation. Additionally, large numbers of pets and large animals (i.e., horses and livestock) are often left behind or otherwise become stray during wildfires. Minimizing the likelihood of animals becoming stray improves animal, public, and firefighter safety, and may facilitate a more rapid recovery following disasters.

During a wildland fire, local animal rescue organizations (primarily Marin Humane) will work with law enforcement and fire departments to rescue as many animals as they can. While fighting a wildfire, firefighters will attempt to protect animals, but they are not responsible for evacuating animals. Firefighters may cut fences or open gates to free trapped animals. FSM provides information and guidelines for evacuating pets (**https://www.firesafemarin.org/evacuation/pets**) and large animals (**https://www.firesafemarin.org/evacuation/large-animals**).

9. Recommendations and Action Plan

This CWPP is intended to facilitate multi-agency collaboration and cooperation for fire protection and preparedness planning efforts in Marin County. This CWPP is considered a living document which will be reviewed and revised periodically as needed. The following recommendations were developed based on the mitigation objectives and strategies of Marin's fire agencies in coordination with FIRESafe MARIN and the MWPA for reducing wildland fire hazard. Since 2016, many of these actions have been implemented throughout the county and should continue to be encouraged and supported.

9.1 Recommended Actions

The recommendations and action plan outlined below are aligned with the mitigation strategies described in Section 8.

1. **Continue to encourage and support public and community outreach** to educate landowners, residents, and business owners about the risks and personal responsibilities of living in the wildland, including applicable regulations, prevention measures, and preplanning activities.
   - 1.1 Support and promote the efforts of FIRESafe MARIN and public outreach to achieve consistency in messaging and awareness of wildfire preparedness
   - 1.2 Engage community members to work together and make their homes and neighborhoods more fire resilient
   - 1.3 Promote *Ready, Set, Go!* and Firewise USA® collaboration
   - 1.4 Support and promote efforts to educate the public on environmentally sound practices and their implementation
2. **Improve and encourage actions to reduce structural ignitability** to make homes and structures throughout the county more fire resilient.
   - 2.1 Develop an inventory of structures with wood/shake roofing and consider a roof matching grant program for these structures
   - 2.2 Encourage fire-resistant building construction
3. **Continue to improve defensible space** to reduce fire hazard and threat to communities and homes.
   - 3.1 Improve defensible space around all structures considering ecologically sound practices
   - 3.2 Continue to support and conduct Chipper Days to encourage and assist residents with removing and disposing of flammable, dead and dying vegetation

3.3 Continue to identify and increase opportunities to assist landowners with green waste disposal

3.4 Continue to conduct defensible space inspections and streamline enforcement processes

3.5 Encourage removal of hazardous plants within the 0-5 feet zone around structures

3.6 Enhance defensible space on priority parcels identified through inspections and the parcel-level hazard assessment

3.7 Support removal of hazardous plants and trees

3.8 Require resale inspections for defensible space requirements

3.9 Encourage and support Firewise USA® recognition

3.10 Develop a hazardous tree removal grant program

3.11 Encourage the use of native plants in landscapes in accordance with AB3074

4. **Continue to improve vegetation management practices** to reduce fire hazard and threat in and around non-residential areas.

4.1 Encourage and support roadside vegetation management

4.2 Collaborate with land management agencies to manage vegetation in open space and common space areas

4.3 Promote the use of prescribed fire as a way to reduce fuels and restore health ecosystems

4.4 Continue to encourage and support grazing to reduce fuels in appropriate areas

4.5 Continue to maintain fire roads

4.6 Continue to use fire as a means to control invasive plant species

4.7 Use ESPs in vegetation management activities as identified by the ESP partnership for MWPA.

4.8 Continue to improve management techniques to conserve Marin's valuable wildlife habitats and ecosystem health while also reducing fire hazard

5. **Continue to focus efforts on improving alert and warning systems and evacuation planning**

5.1 Improve roadway clearance and vegetation along evacuation routes

5.2 Promote *AlertMarin*

5.3 Promote the use of NOAA radios and AM/FM radio stations

5.4 Promote LRADs in areas that could benefit from the technology

5.5 Create neighborhood-scale evacuation maps and information

5.6 Conduct community evacuation drills

5.7 Designate temporary refuge areas

5.8 Provide guidance and support for evacuation of pets and large animals

5.9 Specific roadside treatment recommendations

- 5.9.1 Remove all dead trees and limbs that might obstruct roadways or impact utility lines
- 5.9.2 Remove all conifer stems 6 inches and smaller in diameter within 10" feet horizontally from road edges
- 5.9.3 Tree canopies extending over the roadway should be raised to a minimum of 15 feet above the road surface to provide safe clearance for fire apparatus
- 5.9.4 Tree canopies on opposite sides of a road should not meet. Limbing or removal of specific trees may be necessary to achieve discontinuity of canopies
- 5.9.5 Roadside trees should be limbed up so the lowest point of lower limbs is at least 10 feet above grade
- 5.9.6 Fine "ignition fuels" such as grass and weeds along road edges should be removed annually, before June 1, or prior to the declared start of the fire season
- 5.9.7 Transition zones (from grass and weeds to shrubs and from low branches to tree canopies) should be disrupted by mowing grass and herbs, removing brush, brambles (blackberries) and limbing up trees
- 5.9.8 Roadway turnouts should be mowed as necessary to prevent catalytic converter ignitions. Mowing may occur once or more per fire season, as needed
- 5.9.9 Tree stands adjacent to roadways should be thinned to create crown separations. Always favor fire-resistant plants over fire-prone plants when thinning fuels (favor oaks, madrones, and redwoods versus bays, Monterey pine, or Douglas fir)
- 5.9.10 Remove dead branches and clean up down and dead debris within 30 feet of all roadways

5.10 When Applicable and Appropriate, Implement Environmentally Sound Practices and Climate Mitigation into Planning and Operations

- 5.10.1 Lower GHG emissions, sequester carbon
- 5.10.2 Support green resource management
- 5.10.3 Promote biomass recovery solutions
- 5.10.4 Conserve biological diversity
- 5.10.5 Decrease invasive non-native plants

5.10.6 Restore structure and diversity of native plant communities

5.10.7 Protect critical habitat and special status species

5.10.8 Prevent erosion and effects of actions on watersheds

9.2 Continue to Identify and Evaluate Wildland Fire Hazards

In addition to the recommendations and actions outlined above, efforts to collect data and state-of-the-science analyses should continue in order to continuously identify and evaluate wildland fire hazards. To facilitate planning for fire agencies and other jurisdictions implementing CWPP projects the mapping information used to evaluate wildfire risk will be available online. The data will include the map layers used to develop the county-level and parcel-level hazard maps (landscape data, structure density, etc.). This will help facilitate project evaluations. Specific actions include

- Continue to collect, analyze, and maintain multi-agency hazard and resource GIS data.
- Maintain an accessible online GIS portal to store and share the ArcGIS Online (AGOL) maps and data developed throughout this CWPP and allow public and educational access as part of the process.
- Utilize the GIS information and modeling results presented in Sections 6 and 7 of this CWPP for pre-fire planning, and to collaboratively develop priorities for projects throughout the county.
- Consider ways to use drone technology for fire intelligence gathering.

9.3 Continue to Support the Collaborative Development and Implementation of Wildland Fire Protection Plans

Since 2016, several communities and fire districts have developed local fire hazard mitigation plan and/or local-scale assessments including Sleepy Hollow, Southern Marin Fire Protection District, Novato Fire Protection District, and Ross Valley. These efforts should be continued and supported to address community-specific issues. Specific actions include

- Work collaboratively with county, local, and regional agencies and landowners to develop fuel reduction priorities and strategies based on this CWPP, local plan, and/or other regional plans.
- Support the development and implementation of local-scale fire hazard mitigation plans.

- Provide a collaboration mechanism between private property owners (and Home Owners Associations) and large landowners (i.e., MCOSD, MMWD, NPS).
- Consider the creation of transition zones (areas between developed residential areas and open space areas) where additional defensible space or additional vegetation clearance is needed.

9.4 Plan Management

The fire agencies, land management agencies, and private landowners responsible for managing vegetation in Marin County are encouraged to submit project ideas that focus on reducing fire hazards in priority areas. Appendix B provides an initial list of priority projects but should be considered a starting point for continued collaboration and coordination.

To ensure continued collaboration and the long-term success of this CWPP effort, FSM—in collaboration with the MCFCA and the MWPA—will lead the effort to continue to evaluate, update, and maintain this CWPP as needed. The contents of the CWPP will be reviewed and evaluated every three to five years and the action plan will be reviewed and updated annually. This plan will be updated with input from the community and local fire and land management agencies as necessary. Updates to the plan will be documented in Table 1.

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Appendix A: Updated Fuel Map Generation

This appendix provides the methods used to develop the dataset for the fuel model types described in Section 5.2.1.

A.1 Processing Overview

Fire behavior modeling requires a spatially explicit fire behavior fuel model map as input, combined with other datasets such as topography and weather information. As part of the development of this CWPP, an updated 5-meter resolution fire behavior fuel model map covering Marin County was developed. The map was derived from newly available surface vegetation, LiDAR data, and aerial imagery. In addition, data were acquired for the presence of structures, roads, and waterbodies. These maps provide a critical tool for fire hazard mitigation planning for Marin County and were used to conduct analyses of fire risk and fire hazard reduction projects described elsewhere in this document.

A.2 Input Datasets

To develop fuel model data, the two key data inputs are (1) data representing ground vegetation and (2) data that can help to characterize canopy fuels (i.e., the tree canopy). Ground vegetation was available from the Marin County lifeform map, which is a 22-class land use and land cover map of Marin County, reflecting the state of the landscape in summer 2018.[46] Data from the new LiDAR survey were used to characterize canopy characteristics in the fuel model data set. The LiDAR data collection was accomplished using a Reigl VQ-1560i sensor system mounted in a Cessna Caravan. Details of the LiDAR data collection can be found in a technical data report (Quantum Spatial, Inc. 2019).

In order to refine vegetation information for Marin County, vector data that reflected building footprints, waterbodies, and road networks were obtained from MarinMap[47] and were used to refine vegetation information for Marin County. The building footprint dataset was produced using 2018 orthoimagery stereo pairs. The waterbody and road datasets were derived from U.S. Census TIGER files, and the road dataset was refined using 2004 orthoimagery.

[46] Information about the lifeform data is available via https://www.nps.gov/articles/marin-vegetation-mapping-project-reaches-new-milestone.htm.
[47] **http://www.marinmap.org.**

A.3 Image Processing

LiDAR and NAIP imagery for Marin County were combined to provide information about vegetation cover and topography across the county. All rasters produced for use in this project were aligned to the datasets derived from raw LiDAR point clouds, projected to UTM zone 10N using the NAD83 datum with a cell size of 5 meters.

LiDAR tiles were combined and processed using standard ArcGIS geoprocessing tools to derive bare earth elevation, slope, aspect, vegetation height, and vegetation percent cover. Vegetation height and vegetation cover on the 5 m grid were calculated using the internal point classification, which groups vegetation and building returns together. To differentiate between buildings and vegetation, Normalized Difference Vegetation Index (NDVI) values derived from NAIP imagery were used to mask locations, with an NDVI less than 0 representing non-vegetation. To exclude shrubs and other low-lying vegetation from the percent canopy cover calculation, all pixels in the percent canopy cover that had a canopy height of less than 3 meters were assigned a percent canopy cover value of 0%.

The vegetation and topographic information derived from these datasets were used as inputs to produce fuel model information for Marin County.

A.4 Fuel Model Crosswalk

To obtain the fuel information required for fire behavior modeling, the LiDAR- and NAIP-derived datasets were integrated with the vector information reflecting vegetation type, building footprints, waterbodies, and roads. The result of this analysis was a 5-meter resolution dataset providing 40 Scott and Burgan fire behavior fuel model assignments for all of Marin County (Scott and Burgan, 2005).

The three sources of vegetation type information were then combined. The lifeform dataset provided county-wide vegetation type information. To assign fuel models, aspect, vegetation height, percent vegetation cover, and vegetation type datasets were used in a crosswalk. A crosswalk assigns a fuel model to each pixel based upon the information from the datasets. The details of how the fuel model crosswalk was developed are included in Appendix C.

A.5 Fuel Model Adjustments

The fuel model map described above was modified to better account for the location of roads, structures, and waterbodies. All locations falling within a waterbody were modified to an unburnable fuel model. In addition, a series of filtering steps were applied to reflect the presence of flammable vegetation in urban/developed areas. To account for the flammable vegetation that was initially classified as unburnable, canopy cover and canopy height were used to reassign all urban/developed fuel model areas with an NDVI greater than 0 to a flammable vegetation class.

Next, the road location information was used to assign pixels to the unburnable urban/developed fuel model or to a timber litter fuel type model based upon the presence of canopy cover. Large roads (freeways and highways) were buffered to 10 meters, while small roads (local roads) were buffered to 5 meters; the percent canopy cover of each pixel falling within the buffered roads was obtained. Roads with greater than 30% canopy cover were classified as burnable because fuel overhanging the road may allow fire to spread over that road. Roads with less than 30% cover were classified as unburnable.

A similar approach was used to address vegetation overhanging buildings. The building footprints and percent canopy cover data were used to assign a fuel model to all building locations. Buildings with 20-40% canopy cover were classified as a timber litter fuel type model, and buildings with greater than 40% canopy cover were assigned a timber-understory fuel type model. Buildings with less than 20% canopy cover were classified as unburnable.

A.6 Landscape File Creation

A landscape file (.lcp) is required by commonly used fire behavior models such as FlamMap to simulate fire behavior. A landscape file consists of eight layers of vegetation and geophysical information. The geophysical layers include elevation, slope, and aspect, while the vegetation layers include fuel model, vegetation height, percent vegetation cover, canopy bulk density, and canopy base height.

The development of all layers has been described above, with the exception of the canopy bulk density and canopy base height layers. The canopy base height layer was assigned a universal value of 3′ for all pixels assigned either a timber-understory or a timber litter fuel type model, based on our knowledge of local vegetation. In lieu of actual field measurements of canopy fuels in Marin County, canopy bulk density was estimated for pixels with a timber-understory or a timber litter fuel type model using plot data collected for ponderosa pine/Douglas-fir and Sierra Nevada Mixed Conifer forest types in the Interior West (Scott and Reinhardt, 2005). For each fuel model and canopy cover bin, a canopy bulk density value was assigned. ArcFuels[48] was used to compile the 5 m rasters of the eight data layers into a landscape file.

A.7 References

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Appendix B: List of Priority Projects

This appendix provides a list of priority projects for hazard mitigation provided by stakeholder agencies as of December 15, 2020. This list is intended to provide a catalog of projects throughout the county that may be in various stages of planning or implementation. All projects listed here are not necessarily ready for implementation. Environmental consideration and compliance may be required for many of the projects listed.

Appendix B

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Bolinas Fire District	Bolinas Evac. Route Improvement	High	Roadside evac. route	Improve evacuation route		High
Bolinas Fire District	Bolinas Chipper Days	High	Fuel reduction	Reduce fire hazard to a community		N/A
Central Marin Fire	Corte Madera Chipper Program	Moderate	Defensible space	Community risk reduction		N/A
Central Marin Fire	Larkspur Juniper Removal	Moderate	Defensible space	Reduce fire hazard to a structure	$50,000	Moderate
Central Marin Fire	Corte Madera Juniper Removal	High	Defensible space	Reduce fire hazard to a structure	$50,000	Moderate
Central Marin Fire	Middle Summit Fire Road Ingress	High	Fire road/Ridge access	Fire road/Ridge access	$100,000	High
Central Marin Fire	Granada Park	Moderate	Fuel break/Defensible space	Improve or create defensible space	$100,000	Moderate
Central Marin Fire	Citron Bowl	High	Fuel break/Defensible space	Improve or create defensible space	$100,000	High
Central Marin Fire	Meadowcrest	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$75,000	High
Central Marin Fire	East Corte Madera Dspace	Moderate	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$75,000	High
Central Marin Fire	Elmcrest & Palm Hill Fuel Reduction	High	Fuel break/Defensible space	Improve or create defensible space	$100,000	High
Central Marin Fire	LRAD Warning System	High	Planning	Community risk reduction	$300,000	N/A
Central Marin Fire	Sycamore Cyn/Blue Rock Evac Route	High	Roadside evac. route	Improve evacuation route	$100,000	High
Central Marin Fire	Baltimore Cyn/Madrone Cyn Evac Route	High	Roadside evac. route	Improve evacuation route	$125,000	High
Central Marin Fire	Marina Vista Evac Route	High	Roadside evac. route	Improve evacuation route	$75,000	High
Central Marin Fire	Christmas Tree Hill Evac Route	High	Roadside evac. route	Improve evacuation route	$125,000	High
Central Marin Fire	Chapman Park Evac Route	High	Roadside evac. route	Improve evacuation route	$100,000	High
Central Marin Fire	Maadowsweet Evac Route	High	Roadside evac. route	Improve evacuation route	$55,000	High
Central Marin Fire	Palm Hill Evac Route	High	Roadside evac. route	Improve evacuation route	$50,000	High
Central Marin Fire	East Corte Madera Evac Route	High	Roadside evac. route	Improve evacuation route	$50,000	High
Central Marin Fire	Lower Summit Fire Road Egress	High	Roadside evac. route	Improve evacuation route	$100,000	High
Central Marin Fire	Corte Madera Ave	High	Roadside evac. route	Improve evacuation route	$90,000	High
Central Marin Fire	Greenbrae Evac Route	Moderate	Roadside evac. route	Improve evacuation route	$100,000	Moderate
Central Marin Fire	William Bike Path	Moderate	Roadside evac. route	Improve evacuation route	$30,000	Moderate
Central Marin Fire	Magnolia to King Mountain	High	Shaded fuel break	Reduce fire hazard to a community	$350,000	High
Central Marin Fire	Corte Madera Ridge Fire Road	High	Shaded fuel break	Fuel break	$350,000	High
Central Marin Fire	Sycamore Cyn/Blue Rock Evac Route	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$50,000	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Central Marin Fire	Baltimore Cyn/Madrone Cyn Large Parcel Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$125,000	High
Central Marin Fire	Marina Vista Large Parcel Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$75,000	High
Central Marin Fire	Christmas Tree Hill Large Parcel Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$125,000	High
Central Marin Fire	Chapman Park Large Parcel Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$100,000	High
Central Marin Fire	Maadowsweet Large Parcel Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$55,000	High
Central Marin Fire	Palm Hill Large Parcel Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$50,000	High
Central Marin Fire	Greenbrae Large Parcel Fuel Reduction	Moderate	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$100,000	High
FIRESafe MARIN	Chipper program	High	Defensible space	Improve or create defensible space	$1,000,000	N/A
FIRESafe MARIN	Public Education	High	Public Education	Increase public education/information	$650,000	N/A
FIRESafe MARIN	Demonstration Gardens	High	Public Education	Increase public education/information	$250,000	N/A
FIRESafe MARIN	Red Flag Warning	High	Public Prepardness	Reduce fire hazard to a community	$100,000	N/A
FIRESafe MARIN	NOAA Radio	High	Public Prepardness	Reduce fire hazard to a community	$100,000	N/A
Marin County Fire	Tamarancho Evac BSA Evac Route	High	Fire road/Ridge access	Improve evacuation route	$100,000	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Marin County Fire	Cedars Textile Art Ctr - Adult Day Care Dspace	High	Defensible space	Improve or create defensible space	$20,000	High
Marin County Fire	San Geronimo Valley Evac Route Project	High	Roadside evac. route	Improve evacuation route	$100,000	High
Marin County Fire	Senior & AFN Dspace Assistance	High	Defensible space	Improve or create defensible space	$50,000	N/A
Marin County Fire	Inverness Evac Route Improvement	High	Roadside evac. route	Improve evacuation route	$30,000	High
Marin County Fire	Misc County Lands not managed	Moderate	Fuel reduction	Reduce fire hazard to a neighborhood	$30,000	Moderate
Marin County Fire	Dspace Home Hardening Grant	Moderate	Reduce structural ignitability	Reduce structure ignitability	$50,000	N/A
Marin County Fire	Golden Gate Village MC Dspace	High	Defensible space	Improve or create defensible space	$30,000	High
Marin County Fire	MERA site Dspace	High	Defensible space	Protect critical infrastructure	$30,000	High
Marin County Fire	Burnt Ridge Fuel break	High	Fuel break	Strategic Fuel Reduction	$50,000	High
Marin County Fire	Baywood Canyon	Moderate	Fuel break/Defensible space	Reduce fire hazard to a neighborhood		Moderate
Marin County Fire	Dspace Home Hardening Inspections	High	Defensible space	Improve fire preparedness	$300,000	N/A
Marin County Fire	Paradise Ranch Estates (PRE) Dead Tree Removal	High	Dead tree removal	Improve or create defensible space	$100,000	High
Marin County Fire	Paraside Ranch Estates Vacant Lot Project	Moderate	Fuel reduction	Reduce fire hazard to a neighborhood	$75,000	Moderate
Marin County Fire	Paradise Ranch Estates (PRE) Evac Route Veg Removal	High	Roadside evac. route	Improve evacuation route	$50,000	High
Marin County Fire/San Rafael Fire/State Parks	McNear Drive Shaded Fuel Break	Moderate	Shaded fuel break	Improve or create defensible space	$30,000	Moderate
Marin County Fire/State Parks/MMWD	Throckmorton Ridge Fuel Reduction	High	Fuel reduction	Improve fire preparedness	$100,000	High
Marin Water	Bon Tempe Treatment Plant	High	Fuel break/Defensible space	Reduce fire hazard to a structure	$100,000	High
Marin Water	Railroad Grade Fuelbreak	Moderate	Shaded fuel break	Reduce fire hazard to a community	$75,000	Moderate
Marin Water	Deer Park/Meerna Fuelbreak	Moderate	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$150,000	Moderate
Marin Water	Watershed douglas fir thinning	Moderate	Fuel reduction	Protect critical infrastructure	$75,000	Moderate
Marin Water	Watershed wide ladder fuel reductio	Moderate	Fuel reduction	Reduce fire hazard to a community	$150,000	Moderate
Marin Water	Rocksprings/Potrero Forest fuel redu	High	Fuel reduction	Reduce fire hazard to a community	$250,000	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Marin Water	Lake Lagunitas Forest Fuel Reducti	High	Fuel reduction	Reduce fire hazard to a community	$250,000	High
Marin Water	Lagunitas Meadow Perscribed Burn	Low	Fuel reduction	Reduce fire hazard to a community	TBD	Low
Marin Water	Watershed Prescribed Burning	Low	Fuel reduction	Improve fire preparedness	TBD	Low
Marin Water	Water Tender	Moderate	Planning	Community risk reduction	TBD	Moderate
Marin Water	Fuel Reduction Project Coordinator	Moderate	Fuel reduction	Improve fire preparedness	$75,000	Moderate
Marin Water	Bon Tempe and San Geronimo Water Treatment Plant Hardening Plan	High	Planning	Reduce structure ignitability	$35,000	High
Marin Water	Treatment Plant Hardening Impleme	High	Defensible space	Reduce structure ignitability	$300,000	High
Marinwood Fire Department	Goat Grazing (Idylberry)	High	Fuel break/Defensible space	Fuel break	$15,000	High
Marinwood Fire Department	Elvia Court Fuel Break	Moderate	Fire road/Ridge access	Fuel break		Moderate
Marinwood Fire Department	Ellen Drive Dspace/Fuel Break	Moderate	Fuel reduction	Reduce fire hazard to a neighborhood		Moderate
Marinwood Fire Department	Limestone Grade Dspace/Fuel Break	Moderate	Fuel break/Defensible space	Reduce fire hazard to a neighborhood		Moderate
MCFD/State Parks/IPUD	Seahaven Fuel Reduction	High	Fuel reduction	Improve or create defensible space	30,000-100,000	High
MCOSD	Montezuma Drive	Moderate	Defensible space	Improve or create defensible space		High
MCOSD	King Mountain: 51 Olive to 33 Redwood	Moderate	Defensible space	Improve or create defensible space		High
MCOSD	Del Casa/Valle Vista	Moderate	Defensible space	Improve or create defensible space		Moderate
MCOSD	Taylor Road	Moderate	Defensible space	Improve or create defensible space		Moderate
MCOSD	Underhill/Mill Valley Bike Path	Low	Fuel reduction	Improve or create defensible space		Low
MCOSD	Camino Alto Wide Area Fuelbreaks	High	Fuel break/Defensible space	Fuel break	$18,000	Moderate
MCOSD	Alto Bowl Wide Area Fuelbreak	Moderate	Fuel break/Defensible space	Fuel break	$6,000	Very High
MCOSD	Hillside Wide Area Fuelbreak	Moderate	Fuel break/Defensible space	Fuel break	$6,000	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
MCOSD	Blithedale Ridge Fuelbreak	High	Fuel break	Fuel break	$10,000	Very High
MCOSD	Corte Madera Ridge Fuelbreak	Moderate	Fuel break	Fuel break	$20,000	Very High
MCOSD	Crown to Coronet Fuelbreak	Moderate	Fuel break/Defensible space	Fuel break	$15,000	High
MCOSD	H-Line Fire Road	High	Fire road/Ridge access	Fire road/Ridge access	$100,000	Very High
MCOSD	Middle Summit Fire Road Ingress	Moderate	Fire road/Ridge access	Fire road/Ridge access	$5,000	High
MCOSD	King Mountain Wide Area Fuelbreak	High	Fuel break/Defensible space	Fuel break	$30,000	High
MCOSD	Kent Woodlands Defensible Space Fuelbreak	High	Fuel break/Defensible space	Fuel break		High
MCOSD	Kent Woodlands Wide Area Fuelbreak	Moderate	Shaded fuel break	Fuel break		High
MCOSD/MCFD	Greenwood Fire Road	High	Fire road/Ridge access	Fire road/Ridge access		High
MCOSD/MCFD	Cascade Fire Road	High	Fire road/Ridge access	Fire road/Ridge access		High
MCOSD/MCFD	Toyon Fire Road	High	Fire road/Ridge access	Fire road/Ridge access		High
MCOSD/MCFD	Glen / Oak Manor Fire Road	High	Fire road/Ridge access	Fire road/Ridge access		High
Mill Valley Fire	Monthly Paved Road Fuel Red.	High	Monthly list of streets scheduled	Improve access/egress/evac	TBD	Very High
Mill Valley Fire	Chipper Program	High	Monthly list of streets to chip	Reduce fire hazard to a community	TBD	Very High
Mill Valley Fire	Hazard Tree Removal	High	Remove dead/dying haz. trees	Reduce fire hazard to a community	TBD	Very High
Mill Valley Fire	Semi Annual clearing of SLPs	High	Emergency egress/evac	Improve evacuation route	TBD	
Mill Valley Fire	Fuel Breaks	High	Fuel break	Reduce fire hazard to a community	TBD	Very High
Mill Valley Fire	Euc Removal	High	Euc removal	Reduce fire hazard to a community	TBD	High
Muir Beach VFD/CSD	Hazard Tree Removal	High	Dead tree removal	Community risk reduction	$150,000	Moderate
Muir Beach VFD/CSD	Vacant lot veg removal	High	Fuel reduction	Community risk reduction	$30,000	Very high
Muir Beach VFD/CSD	Hwy1 fuel break	High	Fuel break/Defensible space	Community risk reduction	TBD	Very High
Muir Beach VFD/CSD	Pacific way fuel reduction	High	Fuel break/Defensible space	Community risk reduction	$20,000	Very High
Navoto fire District	Marin Valley Shahed Fuel Break	High	Shaded fuel break	Reduce fire hazard to a neighborhood		Very High
Novato Fire District	Marin Valley Evacuation Route	High	Roadside evac. route	Improve evacuation route		Very High
Novato Fire District	Kathleen/Michelle Circle Wildfire Mitigation Home Assessments	High	Defensible space	Reduce fire hazard to a neighborhood	$6,000	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Novato Fire District	Wood Hollow	High	Defensible space	Improve or create defensible space	$100,000	Very High
Novato Fire District	Kathleen/Michelle Circle shaded fuel break	High	Shaded fuel break	Reduce fire hazard to a neighborhood	$6,000	High
Novato Fire District	Marin Highland Park	High	Shaded fuel break	Reduce fire hazard to a neighborhood	$36,000	Very High
Novato Fire District	Marin Highland Park	High	Defensible space	Improve or create defensible space		Very High
Novato Fire District	Marin Highland Park Chipper Days	Moderate	Fuel reduction	Reduce fire hazard to a neighborhood		Very High
Novato Fire District	Kathleen/Michelle Circle Chipper Days	High	Fuel reduction	Reduce fire hazard to a neighborhood		Very High
Novato Fire District	Ignacio Valley Shaded Fuel Breaks	High	Shaded fuel break	Reduce fire hazard to a neighborhood		Very High
Novato Fire District	Ignacio Valley Wildfire Mitigation Home Assessments	High	Defensible space	Improve or create defensible space		High
Novato Fire District	Ignacio Valley Chipper Days	Moderate	Fuel reduction	Reduce fire hazard to a neighborhood		Moderate
Novato Fire District	Seventh St/Carmel Shaded fuel break	High	Shaded fuel break	Reduce fire hazard to a neighborhood		Very High
Novato Fire District	Seventh St/Carmel Wildfire Mitigation Home Assessments	Moderate	Defensible space	Improve or create defensible space		High
Novato Fire District	Seventh St/Carmel Chipper Days	Moderate	Fuel reduction	Reduce fire hazard to a neighborhood		Moderate
Novato Fire District	Wildfire Structure Ignitability Mitigation Initiative	High	Reduce structure ignitabilty	Reduce structure ignitability	$400,000	High
Novato Fire District	Public Evacuation Maps	High	Planning	Increase public education/information	$60,000	High
Novato Fire District	Home Hardening/D Space Evaluation Program	High	Defensible space	Reduce structure ignitability	$900,000	High
Novato Fire District	Vegetation Matching Grant Program	Moderate	Defensible space	Improve or create defensible space	$100,000	High
Novato Fire District	Parcel Level Verification	Moderate	Planning	Reduce fire hazard to a structure		N/A
Ross Valley FD Ross	Senior & AFN Dspace Assistance	High	Defensible space	Reduce structure ignitability	$20,000	N/A
Ross Valley FD Fairfax	Senior & AFN Dspace Assistance	High	Defensible space	Reduce structure ignitability	$20,000	N/A

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Ross Valley FD Fairfax	Misc/Vacant Lot Veg Removal	High	Fuel reduction	Reduce fire hazard to a neighborhood	$20,000	High
Ross Valley FD San Anselmo	Senior & AFN Dspace Assistance	High	Defensible space	Reduce structure ignitability	$20,000	N/A
Ross Valley FD San Anselmo	Sorich Park Veg Removal	High	Fuel reduction	Reduce fire hazard to a community	$30,000	High
Ross Valley FD district wide	Dspace Home Hardening Inspections	High	Defensible space	Improve or create defensible space		N/A
Ross Valley FD Fairfax	Sir Francis Drake Bvld Flammable Plant Removal	High	Flammable plant removal on evac rou	Improve evacuation route		High
Ross Valley FD Ross	Misc/Vacant Lot Veg Removal	High	Fuel reduction	Reduce fire hazard to a neighborhood	$20,000	High
Ross Valley FD Ross	Roaside Veg Removal	High	Roadside evac. route	Improve evacuation route		High
Ross Valley FD Ross	Natiel Coffin Greene Park	High	Fuel reduction	Reduce fire hazard to a neighborhood		High
Ross Valley FD Ross	Home Hardening Grant	High	Planning	Reduce structure ignitability		N/A
Ross Valley FD San Anselmo	Faud Park Veg Removal	High	Fuel reduction	Reduce fire hazard to a community	$30,000	High
Ross Valley FD San Anselmo	Misc/Vacant Lot Veg Removal	High	Fuel reduction	Reduce fire hazard to a neighborhood	$20,000	High
Ross Valley FD San Anselmo	Center Bvld Flammable Plant Removal	High	Roadside evac. route	Improve evacuation route	$50,000	High
Ross Valley FD San Anselmo	Roadside Veg Removal	High	Roadside evac. route	Improve evacuation route		High
Ross Valley FD San Anselmo	Oak Park Veg Removal	High	Fuel reduction	Reduce fire hazard to a neighborhood		High
Ross Valley FD SFPD/OSD	Freitas Ridge FB FIre Roads	High	Fire road/Ridge access	Fuel break	TBD	High
Ross Valley FD Sleepy Hollow	Oak Manor Fuelbreak	High	Fire road/Ridge access	Fuel break	$30,000	High
Ross Valley FD Sleepy Hollow	Evacuation Route improvement	High	Roadside evac. route	Improve evacuation route	TBD	High
Ross Valley FD Sleepy Hollow	Flammable Plant Removal Program	High	Flammable Plant removal	Reduce structure ignitability	$150,000	N/A
Ross Valley FD Sleepy Hollow	Hazard Tree Removal	High	Hazard Tree Removal	Reduce fire hazard to a neighborhood	TBD	High
Ross Valley FD Sleepy Hollow	Notification System Upgrades	High	Infrastructure improvements	Improve fire preparedness	TBD	High
Ross Valley FD Sleepy Hollow	Goat Grazing	High	Defensible space	Reduce fire hazard to a neighborhood	TBD	High
Ross Valley FD Sleepy Hollow	Fire Smart Demo Garden	High	Defensible space & public ed.	Increase public education/information	$150,000	N/A

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Ross Valley FD Sleepy Hollow	Emergency Communication equipment installation	High	Emergency preparedness	Improve fire preparedness	$150,000	N/A
Ross Valley FD Sleepy Hollow	CERT Equipment	High	Purchase & store eqpt.	Improve fire preparedness	$75,000	N/A
Ross Valley FD Town of Fairfax	Fairfax Evac Road Veg Removal	High	Roadside evac. route	Improve evacuation route		N/A
Ross Valley FD Town of Fairfax	Cascade Canyon Boundary	Moderate	Defensible space	Reduce fire hazard to a neighborhood		Moderate
San Rafael Fire Department	San Rafael Fire Hazardous Chipper Program	Moderate	Defensible space	Community risk reduction	$36,000 per year if 2 Chipper days per month	N/A
San Rafael Fire Department	San Rafael Fire Roads Fuel Break	High	Fire road/Ridge access	Fire road/Ridge access	$25,000	High
San Rafael Fire Department	Roadside Clearances for Evacuation Routes	High	Roadside evac. route	Improve evacuation route	$100,000	High
San Rafael Fire Department	Station 51 Response Zone Evacuation Route Clearances	High	Roadside evac. route	Improve evacuation route		High
San Rafael Fire Department	Station 52 Response Zone Evacuation Route Clearances	High	Roadside evac. route	Improve evacuation route		High
San Rafael Fire Department	Station 56 Response Zone Evacuation Route Clearances	High	Roadside evac. route	Improve evacuation route		High
San Rafael Fire Department	Station 57 Response Zone Evacuation Route Clearances	High	Roadside evac. route	Improve evacuation route		High
San Rafael Fire Department	Station 54 Response Zone Evacuation Route Clearances	High	Roadside evac. route	Improve evacuation route		High
San Rafael Fire Department	Station 55 Response Zone Evacuation Route Clearances	High	Roadside evac. route	Improve evacuation route		High
San Rafael Fire Department	Goat Grazing in San Rafael	Moderate	Fuel reduction	Reduce fire hazard to a community	$100,000	Moderate

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
San Rafael Fire Department	B Street Demo Garden	Moderate	Defensible space	Increase public education/information	$25,000	Low
San Rafael Fire Department	San Rafael Vegetation Management Assistance Program	Low	Defensible space	Improve or create defensible space		Low
San Rafael Fire Department	Seasonal Defensible Space Inspector Program	Moderate	Defensible space	Increase public education/information	$223,500	N/A
San Rafael Fire Department	FireClear Evacuation Maps	High	Planning	Increase public education/information	$65,000	N/A
San Rafael Fire Department	D Street Roadside Clearance	High	Roadside evac. route	Improve evacuation route	$25,000	N/A
San Rafael Fire Department	Parking Box Program	High	Roadside evac. route	Improve evacuation route	$75,000	N/A
San Rafael Fire Department	Enhanced Vegetation Standards	High	Defensible space	Improve or create defensible space		High
Southern Marin Fire	Wolfback Ridge - Fuel Break	High	Fuel break/Defensible space	Improve or create defensible space	$125,000	Very High
Southern Marin Fire	Live Oak - Fuel Break	High	Fuel break/Defensible space	Fuel break	$20,000	Very High
Southern Marin Fire	Shoreline Hwy - Fuel Break	High	Fuel break/Defensible space	Improve or create defensible space	$20,000	High
Southern Marin Fire	Autumn Ln/Cabin	High	Fuel break/Defensible space	Improve or create defensible space	$15,000	Very High
Southern Marin Fire	Ring Mtn. Area	High	Fire road/Ridge access	Fire road/Ridge access	$10,000	Very High
Southern Marin Fire	Rodeo Water Tank	High	Fuel break	Reduce fire hazard to a community	$15,000	High
Southern Marin Fire	Meda Project	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$30,000	High
Southern Marin Fire	Milland	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$10,000	High
Southern Marin Fire	Seminary	High	Fuel reduction	Reduce fire hazard to a community	$75,000	High
Southern Marin Fire	Hawkhill	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$5,000	High
Southern Marin Fire	Laguna/Forest	High	Fuel break/Defensible space	Improve or create defensible space	$25,000	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Southern Marin Fire	Lattie Lane/Hwy 1	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$30,000	Very High
Southern Marin Fire	Hwy 1 - Erica/Friars	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$25,000	Very High
Southern Marin Fire	So. Morning Sun/Tennessee	High	Roadside evac. route	Improve evacuation route	$7,500	High
Southern Marin Fire	Blackfield	Moderate	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$20,000	High
Southern Marin Fire	Edwards/Marion	High	Fuel break	Reduce fire hazard to a neighborhood	$35,000	Very High
Southern Marin Fire	Cabin Drive	High	Tree removal	Reduce fire hazard to a community	$50,000	Very High
Southern Marin Fire	Fairview	Moderate	Roadside evac. route	Improve evacuation route	TBD	High
Southern Marin Fire	Homestead Valley Land Trust	High	Fuel break/Defensible space	Improve or create defensible space	TBD	High
Stinson Beach	Chipper days	High	Fuel reduction	Reduce fire Hazards in Neighborhoods	$9,000	
Stinson Beach	Mowing Highlands	High	Fuel Break	Reduce fuel hazards		High
Stinson Beach	Evacuation Route improvement	Moderate	Roadside improvements	improve roadside hazards	TBD	Moderate
Tiburon FPD	Ring Mountain	Moderate	Fire road/Ridge access	Fire road/Ridge access	$0	Moderate
Tiburon FPD	Old St, Hilary's Open Space	Moderate	Fuel reduction	Reduce fire hazard to a neighborhood		Moderate
Tiburon FPD	Old St. Hilary's Open Space	Moderate	Defensible space	Reduce structure ignitability	$250	Moderate
Tiburon FPD	Middle Ridge Open Space	High	Fuel reduction	Improve or create defensible space	$4,000	High
Tiburon FPD	Middle Ridge Open Space	High	Fuel reduction	Improve or create defensible space	$4,000	High
Tiburon FPD	Blackies Pasture	High	Fuel reduction	Community risk reduction		High
Tiburon FPD	Chipper/Veg Removal Events	High	Fuel reduction	Community risk reduction	$3,000	High
Tiburon FPD	Chipper/Veg Removal Events	High	Fuel reduction	Community risk reduction		High
Nicasio Fire	Chipper/Veg Removal Events	High	Fuel break/Defensible space	Improve or create defensible space	$6,000	Moderate/High/Very High
Nicasio Fire	Dixon Ridge Road to Devil's Gulch	High	Fire road/Ridge access	Fire road/Ridge access	$50,000	High
Nicasio Fire	Fernwood Ln Fire Road	High	Fire road/Ridge access	Fire road/Ridge access	$40,000	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Nicasio Fire	Smith Ridge (Gunsight) and Los Pinos Ridge Roads	High	Fire road/Ridge access	Fire road/Ridge access	$50,000	High
Nicasio Fire	Lucas Valley Roadside fuels treatment East of Camino Margarita	Moderate	Roadside evac. route	Improve evacuation route	$10,000	CASIO/I
Nicasio Fire	Chipper/ coyote brush removal	High	Fuel break/Defensible space	Reduce fire hazard to a neighborhood	$10,000	High
Marin County Fire	Mapping and printing FireClear	High	Public Prepardness	Improve public prepardness	$20,000	RIN/A
Kentfield Fire District	Dspace Home/Hardening Evaluations	High	Defensible space	Reduce structure ignitability	$75,000	High
Kentfield Fire District	From King Mountain Loop project (Larkspur) to 76 Ridgecrest Rd.	High	Fire road/Ridge access	Fire road/Ridge access	$50,000	High
Kentfield Fire District	From 123 Crown Rd, including the area of Harry Allen Trail to area of Goodhill Rd and Crown Rd.	High	Fire road/Ridge access	Fire road/Ridge access	$7,500	High
Kentfield Fire District	From 123 Crown Rd, to Phoenix Rd and continuing on the Indian Fire Rd stopping at Blithedale Ridge/Eldridge Grade intersection.	High	Fire road/Ridge access	Fire road/Ridge access	$7,500	High
Kentfield Fire District	From 351 Evergreen Rd to 414 Crown Rd to 12 Ridgecrest Rd. South and Southeast facing slope.	High	Fire road/Ridge access	Fire road/Ridge access	$7,500	High
Kentfield Fire District	From 12 Ridgecrest Rd to 76 Ridgecrest Rd. Including all of BlueRidge Rd. Southwest facing slope.	High	Fuel break/Defensible space	Reduce fire hazard to a community	$35,000	High
Kentfield Fire District	From 296 Crown road to 8 Woodland Place	High	Fuel break/Defensible space	Reduce fire hazard to a community	$7,500	High

Agency/Entity	Project Name/Title	Project Priority	Project Type	Primary Mitigation Objective	Estimated Cost ($)	County-level Fire Hazard Ranking
Kentfield Fire District	From 147 Crown road to Coronet Way	High	Fire road/Ridge access	Fire road/Ridge access	$10,000	High
Kentfield Fire District	From 390 Evergreen Drive to Indian fire Rd	High	Fire road/Ridge access	Fire road/Ridge access	$5,000	High
Kentfield Fire District	From 161 Rancheria Rd connection to 144 Rancheria Rd	High	Fire road/Ridge access	Fire road/Ridge access	$5,000	High
Kentfield Fire District	From 530 Woodland Rd to 503 Goodhill Rd	High	Fire road/Ridge access	Fire road/Ridge access	$2,500	Moderate
Kentfield Fire District	Brushwood Lane/ Tamal Vista Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a community	$45,000	High
Kentfield Fire District	Brushwood Lane/ Vista Grande Fuel Reduction	High	Fuel break/Defensible space	Reduce fire hazard to a community	$40,000	High
Kentfield Fire District	Hazard Tree Mitigation Program	High	Dead tree removal	Reduce fire hazard to a community	$205,000	High

FireDistrict	AreaName	Map
Central Marin	Baltimore Canyon	Map
Central Marin	Chapman Park	Map
Central Marin	Christmas Tree Hill	Map
Central Marin	East Corte Madera	Map
Central Marin	Marina Vista	Map
Central Marin	Meadowsweet	Map
Central Marin	Palm Hill	Map
Central Marin	Skylark	Map
Central Marin	Sycamore Canyon	Map
Kentfield	Goodhill	Map
Kentfield	Kent	Map
Kentfield	Murray	Map
Kentfield	Woodland	Map
Marin County	Drakes View	Map
Marin County	Dreamfarm	Map
Marin County	Forest Knolls	Map
Marin County	Inverness	Map
Marin County	Inverness Park	Map
Marin County	Lagunitas	Map
Marin County	Panoramic	Map
Marin County	Point Reyes	Map
Marin County	Rancho Santa Margarita East	Map
Marin County	Rancho Santa Margarita West	Map
Marin County	San Geronimo	Map
Marin County	Silverhills	Map
Marin County	Woodacre	Map
Mill Valley	Blithedale	Map
Mill Valley	Cascade	Map
Mill Valley	Edgewood	Map
Mill Valley	Flatts	Map
Mill Valley	Hillside	Map
Mill Valley	Mill Vallley spz_Bolsa	Map
Mill Valley	Scott Valley	Map
Mill Valley	Summit	Map
Novato	7th Street	Map
Novato	Bahia	Map
Novato	Black Point	Map
Novato	Cherry Hill	Map
Novato	College	Map
Novato	Fairway	Map
Novato	Green Point	Map
Novato	Hamilton	Map
Novato	Highland	Map
Novato	Ignacio	Map
Novato	Indian Valley	Map
Novato	Little Mountain	Map
Novato	Marin Valley	Map
Novato	Pacheco Valley	Map
Novato	Presidents	Map

FireDistrict	AreaName	Map
Novato	Saddlewood	Map
Novato	San Marin	Map
Novato	Wild Horse Valley	Map
Novato	Wilson	Map
Novato	Wood Hollow	Map
Ross	Ross	Map
Ross	Ross East	Map
Ross Valley	Cascade	Map
Ross Valley	Deerpark	Map
Ross Valley	Frustruck	Map
Ross Valley	Laurel Canyon	Map
Ross Valley	Manorhill	Map
Ross Valley	Oak	Map
Ross Valley	Redwood	Map
Ross Valley	Scenic	Map
San Rafael	Big Rock	Map
San Rafael	Black Canyon	Map
San Rafael	Blackstone	Map
San Rafael	Bret Harte	Map
San Rafael	Country Club	Map
San Rafael	Dominican	Map
San Rafael	Fairhills	Map
San Rafael	Freitas Ridge North	Map
San Rafael	Freitas Ridge South	Map
San Rafael	Glenwood	Map
San Rafael	Greenbrae	Map
San Rafael	Kentfield	Map
San Rafael	Loch Lomond	Map
San Rafael	Los Ranchitos	Map
San Rafael	Lucas Valley	Map
San Rafael	Marinwood	Map
San Rafael	Peacock	Map
San Rafael	San Pablo	Map
San Rafael	San Rafael Hill	Map
San Rafael	Santa Venetia	Map
San Rafael	Sleepy Hollow	Map
San Rafael	Sorich Ranch Park	Map
San Rafael	Southern Heights	Map
San Rafael	Sun Valley	Map
San Rafael	Terra Linda Ridge	Map
San Rafael	Toyon_Gerstle	Map
Southern Marin	Erica Chamberlain	Map
Southern Marin	Greenhill	Map
Southern Marin	Hawk Hill	Map
Southern Marin	Homestead Valley	Map
Southern Marin	Marin Drive	Map
Southern Marin	Marinview	Map
Southern Marin	Northern	Map
Southern Marin	Sausalito (NEW)	Map
Southern Marin	Tennessee	Map
	Unlisted/Other	

Appendix C: Surface Fuel Models Report

CATEGORIZING SURFACE FUEL MODELS IN MARIN COUNTY, CALIFORNIA

Christopher A. Dicus, PhD

2020-August-31

INTRODUCTION

This report details the assignment of surface fuel models (Scott & Burgan 2005) throughout Marin County, California, and the reasoning behind assigning specific break points (based on remotely-sensed spatial data) for their designation. These fuel model designations, which will be mapped across the county, will subsequently be used to help predict wildland fire behavior there and prioritize areas to mitigate against wildfire risk.

Previously, Huang et al. (2016) utilized a crosswalk methodology to assign specific surface fuel models across Marin County based upon 2010 LiDAR data and other remotely-sensed spatial data from various sources. These fuel model designations were based upon the (1) designated CalVeg vegetation type (Meyer & Laudenslayer 1988), (2) topographic aspect in which the vegetation resided, (3) height of the vegetation, and (4) density of the vegetation.

In 2019, Marin County utilized an improved LiDAR methodology to reassess the area. The spatial data collected was at a higher resolution than the previous 2010 sampling, and included designations at every raster for 22 lifeform classes (which replace the previous CalVeg designation), percent area covered by vegetation, vegetative height, a ladder fuel proxy, topographic aspect, and others.

The objective of the present study is to utilize the 2019 LiDAR data to develop new fuel model designations for vegetation across Marin County, which are based upon specific biophysical breakpoints for a given fuel type. These fuel model designations will then be used, in part, to model wildland fire behavior and subsequently prioritize areas to modify so as to reduce the risk of loss during a wildfire.

METHODOLOGY

Guiding Principles

Twenty-two "Lifeform" classes (Table 1), which were assigned following 2019 LiDAR data collection, form the basis for designating surface fuel models at a given location. These Lifeform classes were initially assigned a general surface fuel "Type" (i.e., nonburnable, grass, shrub, timber, etc.). Within each surface fuel type, specific breakpoints, based upon vegetative cover and vegetative height, were then utilized to designate a specific fuel model.

It is critical to recognize that fuel models apply only to *SURFACE* fuels, regardless of the overall lifeform class at a given site. That is, fuel models apply to the live and dead vegetative fuels that would carry a surface fire and do not consider any canopy cover above those surface fuels, even if that canopy cover would likely contribute to a high-intensity crown fire.

For example, grass is common under oak stands in coastal California (Figure 1). While the designated lifeform for an oak stand would be "Forest & Woodland", it is actually the grass that would carry a surface fire there and not the tree canopies. Thus, a grass fuel model would be designated, even if the lifeform was classified as a forest. This distinction only applies to forested areas because shrubs and grass are considered to be surface fuels (even if they are 20+ feet tall) in Rothermel's (1972) surface fire spread model, which forms the basis for wildland fire behavior simulations in commonly-used software such as FlamMap (Finney 2006) and BehavePlus (Andrews 2014).

Table 1. Crosswalk of Lifeform Classes to general Fuel Types. Specific surface fuel models are provided for select Lifeform Classe,s while others are diffentiated by breakpoints that vary by Fuel Type.

Acres	Lifeform Class	Description	Fuel Type	Fuel-Model
26024	Developed	Manmade developed areas greater than 0.2 acres	Nonburnable	NB1
1550	Major Roads	Area is a major road	Nonburnable	NB1
26599	Water	Water covers the area	Nonburnable	NB8
5787	Freshwater Wetland	Areas that are depressional, wet all year long, and exhibit obvious herbaceous wetland vegetation	Nonburnable	NB8
5594	Tidal Marsh	Area that has salt-water tolerant wetland species within the tidal zone	Nonburnable	NB8
3614	Tidal Mud Flat	Areas in the intertidal zone that are unvegetated and exposed during low tide	Nonburnable	NB8
1545	Eel Grass	Areas where eel grass is dominant	Nonburnable	NB8
80	Aquaculture	Area where aquaculture is present (e.g., oyster beds)	Nonburnable	NB8
2898	Bare Soil	Areas where shrub, forest, and herbaceous cover are each less than 10% absolute cover and the area is best characterized as bare land	Nonburnable	NB9
188	Vineyard	Area is a vineyard	Agriculture	GR1
142	Annual Cropland	Area is an irrigated annual cropland (e.g., vegetable crops)	Agriculture	GR1
107	Orchard or Grove	Area is an orchard or grove of fruit or nut trees	Agriculture	GR1
10	Nursery or Ornamental Horticulture Area	Nursery or horticultural area	Agriculture	GR1
107846	Upland Forb & Grass	Area where herbaceous vegetation is at least 10% absolute cover and is not overtopped by woody vegetation of equal or higher cover	Grass	Varies by breakpoints
1987	Intensively Managed Hayfield	Area is an intensively managed hayfield that is mechanically turned over every year	Grass	Varies by breakpoints
1722	Non-native Herbaceous	Area where non-native herbaceous vegetation is at least 10% absolute cover and is not overtopped by woody vegetation of equal or higher cover	Grass	Varies by breakpoints
228	Irrigated Pasture	Area is an irrigated pasture	Grass	Varies by breakpoints
52802	Shrub	Area where native woody shrubs are at least 10% absolute cover	Shrub	Varies by breakpoints
820	Non-native Shrub	Area where non-native, ornamental, or landscaping woody shrubs are at least 10% absolute cover	Shrub	Varies by breakpoints
1	Perennial Cropland	Area is a perennial cropland (e.g., lavender, berries, Christmas trees, rhododendron)	Shrub	Varies by breakpoints
122767	Forest & Woodland	Areas where native woody vegetation >15 feet is at least 10% absolute cover	Forest	Varies by breakpoints
3998	Non-native Forest & Woodland	Area where non-native, ornamental, or landscaping trees dominate the tree stratum	Forest	Varies by breakpoints

Figure 1. Grasses under an oak forest, which would carry a surface fire. Thus, the area should be classified as a Grass Fuel Type even if the Lifeform is categorized as "Forest and Woodland". Photo: US Forest Service Digital Photo Series.

Therefore, the ladder fuel proxy that was developed during the 2019 LiDAR data collection was not used here in designating surface fuel models. Ladder fuels in forests are incredibly important to calculating the transition from a lower-intensity surface fire to a high-intensity crown fire (Scott & Reinhardt 2001), but do not influence designation of surface fuel models.

While not utilized here, the ladder fuel proxy should greatly aid in more accurately simulating wildland fire behavior in Marin County, which is to follow categorization of surface fuel models. The LiDAR-derived ladder fuel proxy is incredibly beneficial in accurately quantifying canopy fuels (Kramer et al. 2014, 2016) and should be utilized in any future fire behavior predictions in Marin County.

For example, Figure 2 illustrates how ladder fuels can influence wildland fire behavior. Potential fire behavior was simulated in 2 coniferous stands utilizing Nexus software (Scott 1999), with the only differentiation between the two stands being that Canopy Base Height (i.e., the height at which forest canopy initiates) was 3 feet in one scenario and 10 feet in another. As shown, a stand with a Canopy Base Height of 3' (easily attainable in the presence of ladder fuels) almost immediately transitions to a crown fire even without wind. The stand with a canopy base height of 10', however, required a windspeed of ~12 mph before it began to transition to crown fire and subsequently experience an exponentially more intense fire.

Thus, while the ladder fuel proxy was not utilized here to designate a surface fuel model, it will be incredibly helpful in future fire behavior simulations because ladder fuels influence the transition from a surface fire to a crown fire, even though they do not impact the actual surface fire itself.

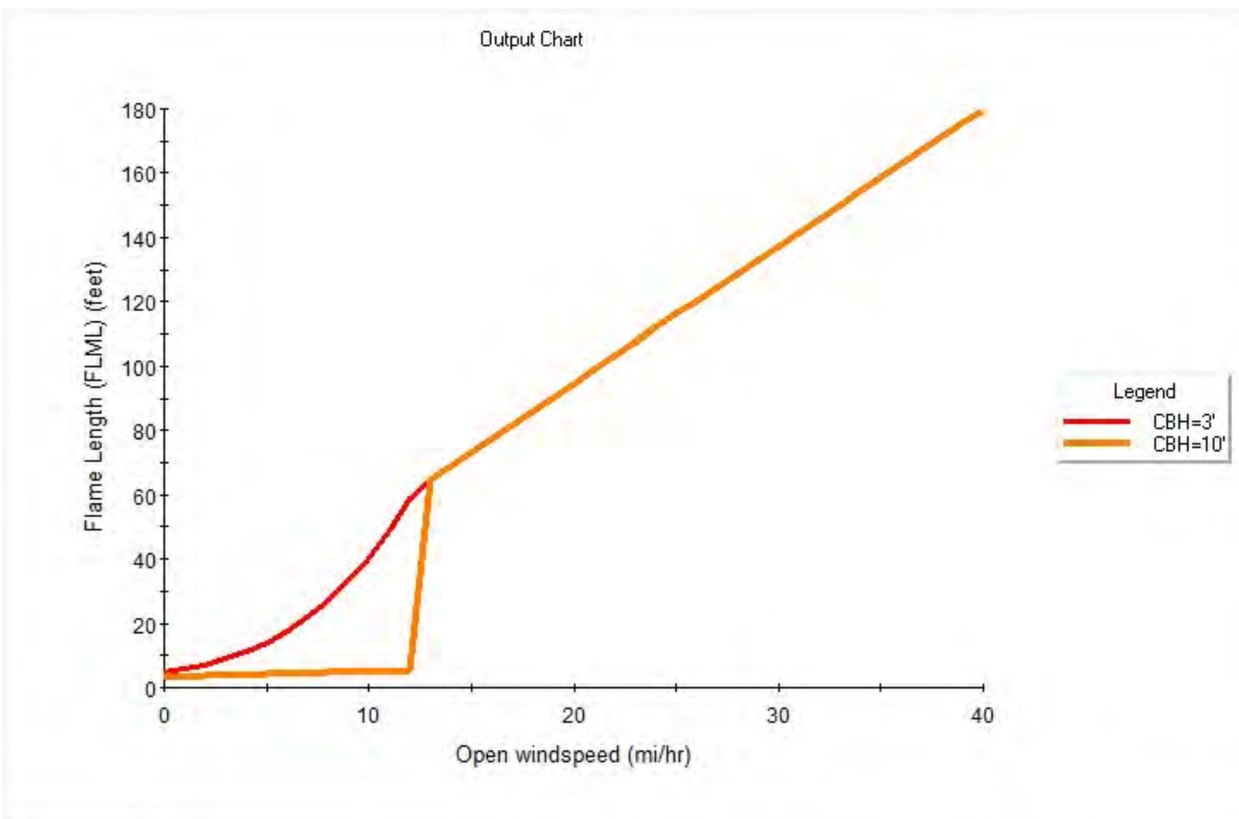


Figure 2. Fire behavior simulation in two coniferous stands, which vary only in Canopy Base Height (CBH). Stand with CBH=3' immediately transitions from a surface fire to a crown fire, while the stand with CBH=10' requires an ~12 mph wind to transition to a crown fire.

Designating General Fuel Types

As noted previously, the 22 Lifeform classes were initially classified into 1 of 5 general surface fuel types (Table 1), including

- Non-burnable
  - Insufficient wildland fuel to carry wildland fire under any condition
- Agriculture
  - Vegetation can ignite and burn, but fire intensity is minimal
- Grass
  - Nearly pure grass and/or forbs, or
  - A mixture of grass and shrub, up to about 50% shrub coverage
- Shrub
  - Shrubs cover at least 50% of the site and grass is sparse to nonexistent
- Timber
  - Dead and down woody fuel beneath a forest canopy, or
  - Grass or shrubs are mixed with litter from a forest canopy

Several of the designated life forms do not readily ignite and were thus easily designated as either a non-burnable NB-8 (open water) or NB-9 (bare ground) surface fuel model (Table 1). Of note, Scott & Burgan (2005) classify urban development as non-burnable, but recent history has readily shown that homes can ignite and contribute to fire spread, especially during extreme weather events. Buildings are regularly mapped as unburnable, which effectively halts fire spread across a given landscape during a fire behavior computer simulation. Quantifying urban fuels (i.e., buildings) has proved elusive in North America and, thus, the "Developed" Lifeform class was grudgingly classified here as unburnable. As new fire behavior modeling techniques and methodologies evolve, these areas should be re-classified.

Similarly, while they don't normally contribute to active fire spread, vineyards (Figure 3), orchards (Figure 4), and other agricultural uses can ignite during a wildfire. That said, fires occurring in these types regularly burn with low intensity and a significantly reduced rate of spread. Thus, all Lifeforms that were classified as "Agriculture" Fuel Type were designated as a GR1 fuel model (short, sparse dry climate grass), which will ignite, but burns in an extremely benign manner.

While some agricultural uses can slow fire spread, other agricultural uses (e.g., pastures, hayfields, perennial croplands) can burn with great intensity and rapid rates of spread. These agricultural uses were therefore classified into surface fuel models per the same protocol as grasses and shrubs, described hereafter.


Figure 3. Vineyards scorched in the 2017 Tubbs Fire near Santa Rosa, California. Photo: C.A. Dicus


Figure 4. Orchards scorched during the 2018 Woolsey Fire near Malibu, California. Photo: C.A. Dicus

Designating Specific Surface Fuel Models

As noted, some Lifeform Classes were easily classified into a surface fuel model. The Lifeforms do not normally ignite were classified as either NB-8 (Open Water) or NB-9 (Bare Ground), dependent on the specific nature of the Lifeform class. Other agricultural uses were classified as GR-1 (Short, Sparse Dry Climate Grass) because while they will indeed ignite, they do not normally burn with great intensity or actively contribute to fire spread, much like the GR-1 fuel model. Other Lifeform classes proved to be more challenging and, thus, a protocol was created to designate specific fuel models for those Lifeform classes.

Surface fuel models are a means to more easily convey the numeric values for various fuel parameters that drive Rothermel's (1982) fire spread equation, which forms the basis of fire behavior modeling in the United States. Thus, instead of a user having to know the specific fuel loadings for each of the dead and down fuels in a dense, closed canopy oak stand, they can instead simply designate the fuel configuration as a "TL6" fuel model (Moderate Load Broadleaf Litter). Anderson (1982) first developed 13 fuel models, which were differentiated simply by fuel loading (tons/acre) in various size classes and by fuelbed "depth".

Scott & Burgan (2005) recognized multiple limitations of the original 13 fuel models and subsequently developed their 45 "new" fuel models, which provided more flexibility for users. Their fuel models are differentiated by differing values for various parameters that drive Rothemel's (1972) fire spread equation (Table 2).

While Scott & Burgan (2005) fuel models are the standard means in the United States to classify surface fuels for fire behavior simulations, they were not developed with actual lab or field testing. Instead, they were developed in such a way as to simply provide reasonable values for the various parameters that drive Rothermel's (1972) spread equation in differing fuel types and fuel structures. Thus, even though Scott and Burgan (2005) provide photograph examples to assist users in designating a fuel model, they are artificial in nature. Therefore, user flexibility in designating fuel models is critical.

Given this caveat, I designated fuel models for each of the Lifeform classes based first on Fuel Type (i.e., grass, shrub, timber, etc.), and then differentiated the fuel types into specific surface fuel models (i.e., GR1, SH5, TL6, etc.) based upon breakpoints in vegetative cover and in vegetative height, both of which were measured during the 2019 LiDAR data collection for Marin County.

As earlier noted, a given Lifeform class does not necessarily address the surface fuels that would burn underneath them (e.g., the aforementioned grass fuels that would fuel a fire underneath an oak stand). Thus, I attempted to provide reasonable breakpoints of vegetative height and cover to classify surface fuel models based upon values in Scott & Burgan's (2005) fuel parameters (Table 2).

Table 2. Values for various parameters that distinguish Scott & Burgan (2005) surface fuel models.

				Fuel load (t/ac)						SAV ratio (1/ft)b					
FUEL TYPE	Fuel Model #	Fuel Model Code	Description	1-hr	10-hr	100-hr	Live herb	Live woody	Fuel Model type	Dead 1-hr	Live herb	Live woody	Fuelbed depth (ft)	Dead fuel extinction (percent)	Heat content (BTU/lb)
GRASS	101	GR1	Short, Sparse Dry Climate Grass	0.1	0	0	0.3	0	dynamic	2200	2000	9999	0.4	15	8000
	102	GR2	Low Load, Dry Climate Grass	0.1	0	0	1	0	dynamic	2000	1800	9999	1	15	8000
	104	GR4	Moderate Load, Dry Climate Grass	0.25	0	0	1.9	0	dynamic	2000	1800	9999	2	15	8000
	107	GR7	High Load, Dry Climate Grass	1	0	0	5.4	0	dynamic	2000	1800	9999	3	15	8000
GRASS-SHRUB	121	GS1	Low Load, Dry Climate Grass-Shrub	0.2	0	0	0.5	0.65	dynamic	2000	1800	1800	0.9	15	8000
	122	GS2	Moderate Load, Dry Climate Grass-Shrub	0.5	0.5	0	0.6	1	dynamic	2000	1800	1800	1.5	15	8000
SHRUB	141	SH1	Low Load Dry Climate Shrub	0.25	0.25	0	0.15	1.3	dynamic	2000	1800	1600	1	15	8000
	142	SH2	Moderate Load Dry Climate Shrub	1.35	2.4	0.75	0	3.85	N/A	2000	9999	1600	1	15	8000
	145	SH5	High Load, Dry Climate Shrub	3.6	2.1	0	0	2.9	N/A	750	9999	1600	6	15	8000
	147	SH7	Very High Load, Dry Climate Shrub	3.5	5.3	2.2	0	3.4	N/A	750	9999	1600	6	15	8000
TIMBER-UNDERSTORY	161	TU1	Low Load Dry Climate Timber-Grass-Shrub	0.2	0.9	1.5	0.2	0.9	dynamic	2000	1800	1600	0.6	20	8000
	165	TU5	Very High Load, Dry Climate Timber-Shrub	4	4	3	0	3	N/A	1500	9999	750	1	25	8000
TIMBER-LITTER	181	TL1	Low Load Compact Conifer Litter	1	2.2	3.6	0	0	N/A	2000	9999	9999	0.2	30	8000
	182	TL2	Low Load Broadleaf Litter	1.4	2.3	2.2	0	0	N/A	2000	9999	9999	0.2	25	8000
	183	TL3	Moderate Load Conifer Litter	0.5	2.2	2.8	0	0	N/A	2000	9999	9999	0.3	20	8000
	184	TL4	Small downed logs	0.5	1.5	4.2	0	0	N/A	2000	9999	9999	0.4	25	8000
	185	TL5	High Load Conifer Litter	1.15	2.5	4.4	0	0	N/A	2000	9999	1600	0.6	25	8000
	186	TL6	Moderate Load Broadleaf Litter	2.4	1.2	1.2	0	0	N/A	2000	9999	9999	0.3	25	8000
	187	TL7	Large Downed Logs	0.3	1.4	8.1	0	0	N/A	2000	9999	9999	0.4	25	8000
	188	TL8	Long-Needle Litter	5.8	1.4	1.1	0	0	N/A	1800	9999	9999	0.3	35	8000
	189	TL9	Very High Load Broadleaf Litter	6.65	3.3	4.15	0	0	N/A	1800	9999	1600	0.6	35	8000

Four specific breakpoints of vegetative COVER were designated that were applicable to all fuel types (Figure 5), which were based upon standard classifications developed by the National Wildfire Coordinating Group (2019). However, breakpoints for vegetative HEIGHT varied by specific fuel type (TABLE 3) and were meant to reflect the distinct values in fuel parameters that differentiate the Scott & Burgan (2005) fuel models.

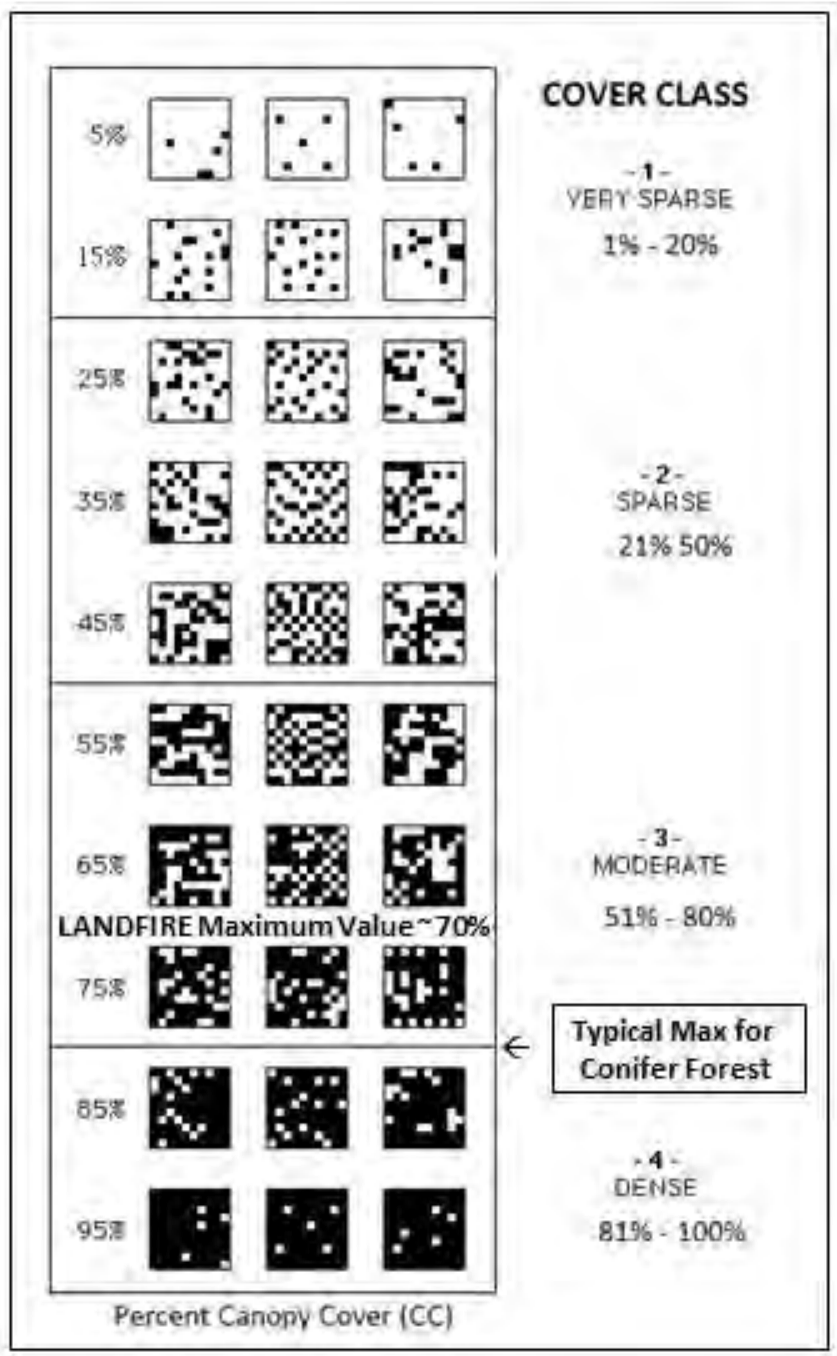


Figure 5. Cover classes utilized in assigning breakpoints for vegetative cover (National Wildfire Coordinating Group 2019).

Table 3. Breakpoints of vegetative cover and height, which then translate into specific surface fuel models.

	Cover	Height	Fuel Model
Grass	<20%	<1'	GR1
		1'	GR1
		2'	GR1
		3'+	GR1
	21%-50%	<1'	GR1
		1'	GR2
		2'	GR2
		3'+	GR4
	51%-80%	<1'	GR1
		1'	GR2
		2'	GR4
		3'+	GR7
	81%-100%	<1'	GR1
		1'	GR4
		2'	GR7
		3'+	GR7

	Cover	Height	Fuel Model
Shrubs	<20%	<1	GR1
		1-5	GS1
		>5	GS1
	21%-50%	<1	GS1
		1-5	GS2
		>5	SH5
	51%-80%	<1	SH1
		1-5	SH5
		>5	SH7
	81%-100%	<1	SH2
		1-5	SH5
		>5	SH7

	Cover	Height	Fuel Model
Timber (Broadleaf)	<20%	<25'	GR4
		25'-50'	GR4
		>50'	GR4
	21%-50%	<25'	GR4
		25'-50'	TU4
		>50'	TU5
	51%-80%	<25'	TU5
		25'-50'	TU5
		>50'	TL9
	81%-100%	<25'	TL2
		25'-50'	TL6
		>50'	TL9

	Cover	Height	Fuel Model
Timber (Conifer)	<20%	<25'	GR4
		25'-50'	GR4
		>50'	GR4
	21%-50%	<25'	GR4
		25'-50'	TU4
		>50'	TU5
	51%-80%	<25'	TL3
		25'-50'	TL5
		>50'	TL5
	81%-100%	<25'	TL5
		25'-50'	TL5
		>50'	TL5

Thus, specific fuel models were designated based upon the following:

- Fuel type
    - Non-burnable
    - Agriculture
    - Grass
    - Shrub
    - Forest
        - Separated into Broadleaf and Conifer sub-types

- Vegetative cover class (identical for all fuel types)
    - 1%-20%
    - 21%-50%
    - 51%-80%
    - 81%-100%

- Vegetative Height (varies by fuel type)
    - Grass
        - <1'
        - 1'-2'
        - 2'-3'
        - >3'
    - Shrub
        - <1'
        - 1'-5'
        - >5'
    - Timber litter (applicable to both broadleaf and coniferous forests)
        - <25'
        - 25'-50'
        - >50'

Given these breakpoints, I then used my knowledge and experience of wildland fire behavior and of vegetative stand development to develop specific fuel models that seemed to reasonably characterize the Lifeforms and their variance between the breakpoints above. Representative photographs for each of the fuel models were then acquired from the national Digital Photo Series (Wright & Vihnanek 2014), the photographs of which were chosen based in part on how the reported stand characteristics compared to fuel parameter values for the specific fuel models (Table 2).

After designating specific fuel models for each of the general fuel types, I then simulated surface fire behavior for each of the fuel models to ensure that fire intensity and spread rate seemed reasonable for a fuel model and its associated photograph. Only surface fire behavior was simulated (i.e., crown fires were not enabled). To best quantify surface fire behavior during extreme fire weather events, simulations were based upon a "Very low" moisture scenario (Scott & Burgan 2005), which included the following fuel moistures:

- 1-hr dead fuels (<1/4"): 3%
- 10-hr dead fuels (1/4"-1"): 4%
- 100-hr dead fuels (1"-3"): 5%
- Live herbaceous fuels: 30%
- Live woody fuels: 60%

RESULTS

Fuel model designations for the Non-burnable and Agriculture Fuel Types are shown in Table 1. Fuel model designations for grass, shrub, and timber fuel types (both broadleaf and coniferous) are shown in Table 3, and are differentiated by breakpoints that vary by fuel type. As noted, these fuel model designations are meant to reflect reasonable differences between fuel type and loading that would naturally occur during stand development.

Representative photos for each the fuel models are illustrated in Figures 6-18.

Surface fire behavior for each of the fuel models are illustrated in Figures 19-31.

Photo Examples of Surface Fuel Models

Figure 6. Example of GR1 surface fuel model (short, sparse dry climate grass), which resulted following grazing of grass. Photo: Marin County Parks.

Figure 7. Example of GR2 surface fuel model (Low load dry climate grass). Photo: US Forest Service Digital Photo Series.

Figure 8. Example of GR4 surface fuel model (Moderate load dry climate grass). Photo: US Forest Service Digital Photo Series.

Figure 9. Example of GR7 surface fuel model (High load dry climate grass). Photo: US Forest Service Digital Photo Series.

Figure 10. Example of SH2 surface fuel model (Moderate load dry climate shrub). Photo: US Forest Service Digital Photo Series.

Figure 11. Example of SH5 surface fuel model (High load dry climate shrub). Photo: US Forest Service Digital Photo Series.

Figure 12. Example of SH7 surface fuel model (Very high load dry climate shrub). Photo: US Forest Service Digital Photo Series.

Figure 13. Example of TU1 surface fuel model (Low load dry climate timber-grass-shrub). Photo: US Forest Service Digital Photo Series.

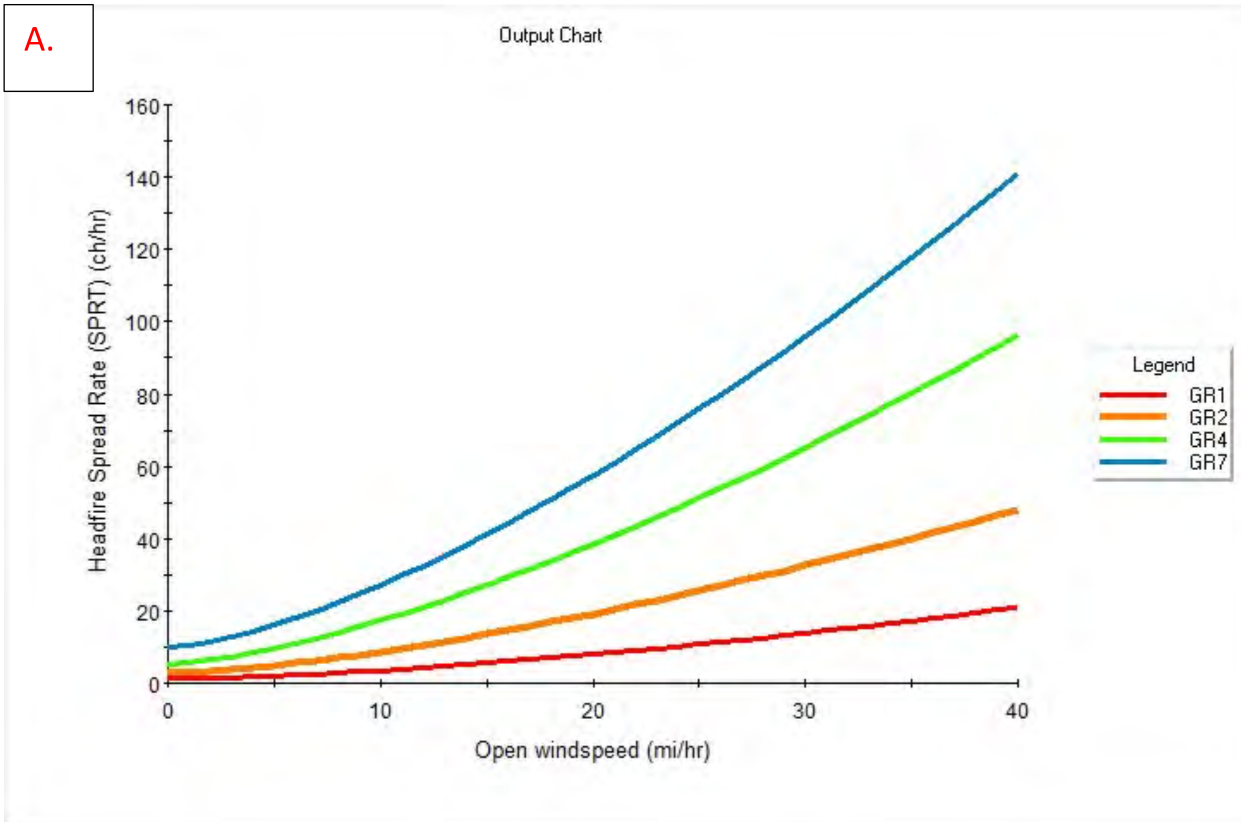
Figure 14. Example of TU5 surface fuel model (Very high load dry climate timber- shrub). Photo: US Forest Service Digital Photo Series.

Figure 15. Example of TL6 surface fuel model (Moderate load broadleaf litter). Photo: US Forest Service Digital Photo Series.

Figure 16. Example of TL9 surface fuel model (Very high load broadleaf litter). Photo: US Forest Service Digital Photo Series.

Figure 17. Example of TL3 surface fuel model (Moderate load conifer litter). Photo: US Forest Service Digital Photo Series.

Figure 18. Example of TL5 surface fuel model (High load conifer litter). Photo: US Forest Service Digital Photo Series.



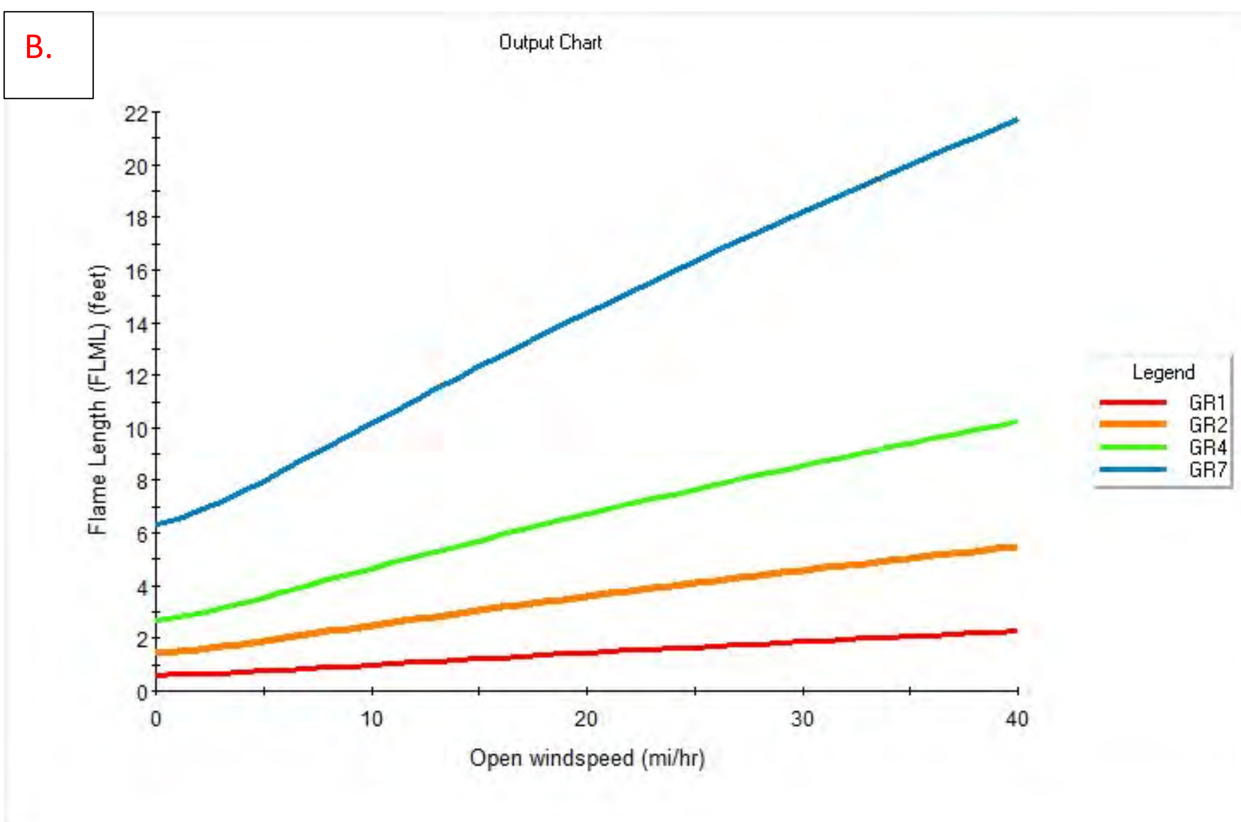


Figure 19. Simulated Rate of Spread (A) and Flame Length (B) for Grass surface fuel models.

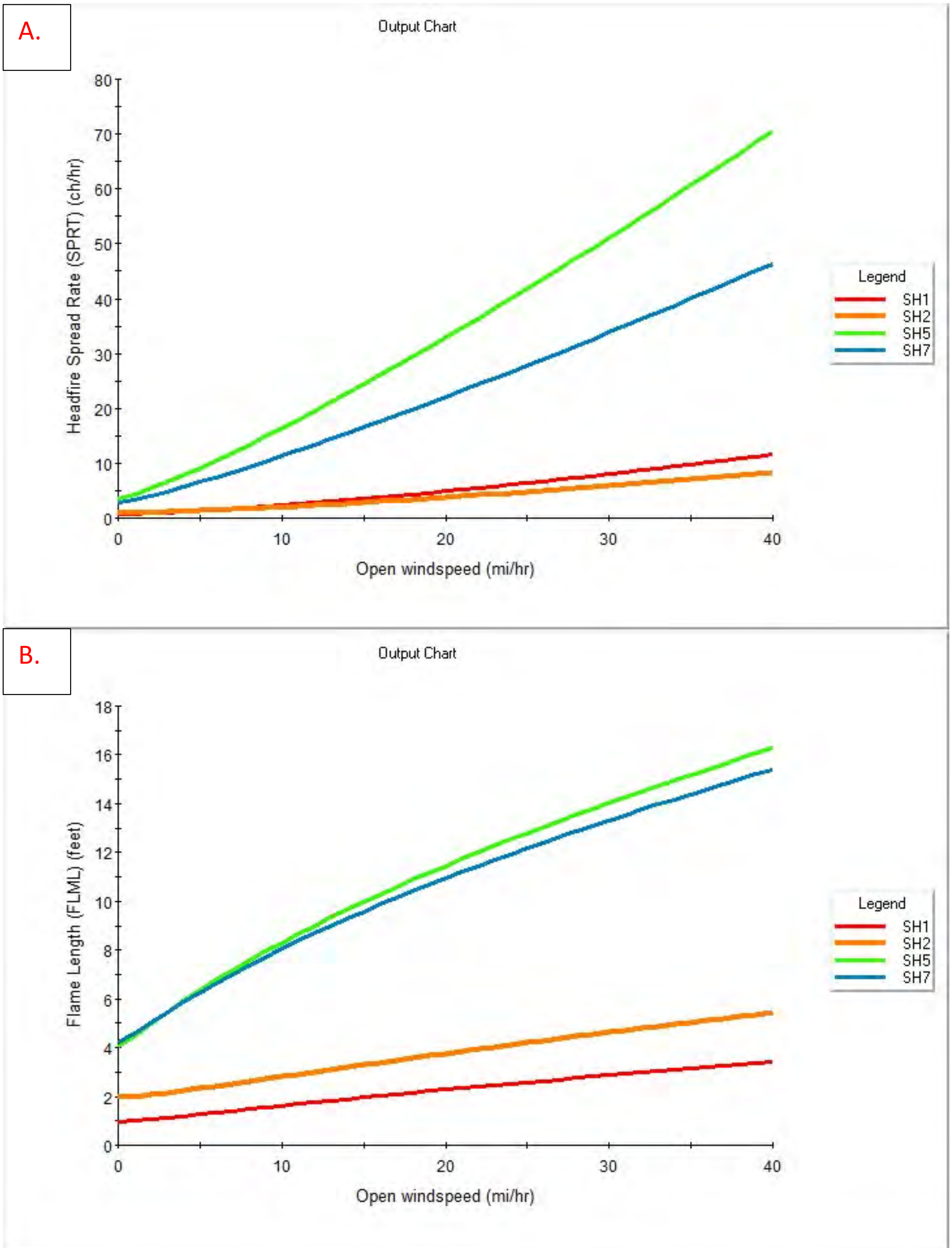
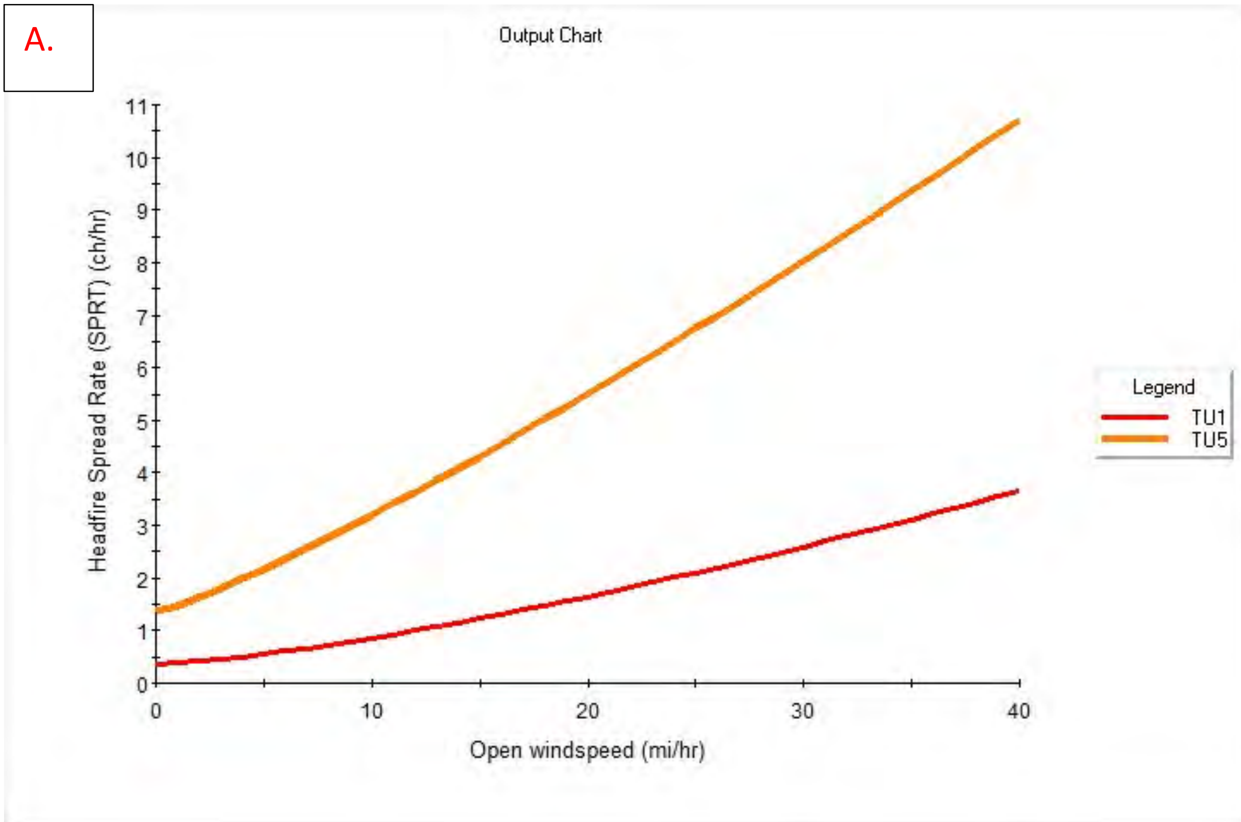


Figure 20. Simulated Rate of Spread (A) and Flame Length (B) for Shrub surface fuel models.



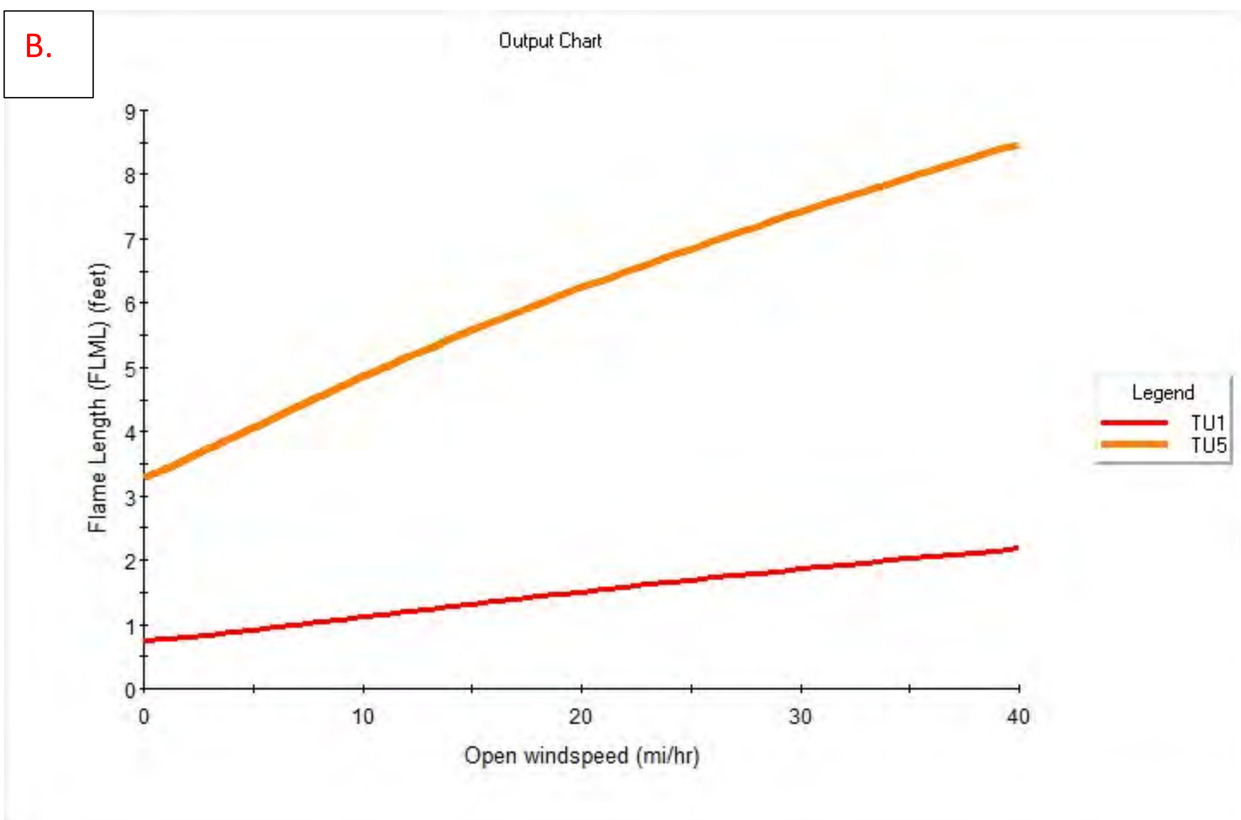


Figure 21. Simulated Rate of Spread (A) and Flame Length (B) for Timber Understory surface fuel models.

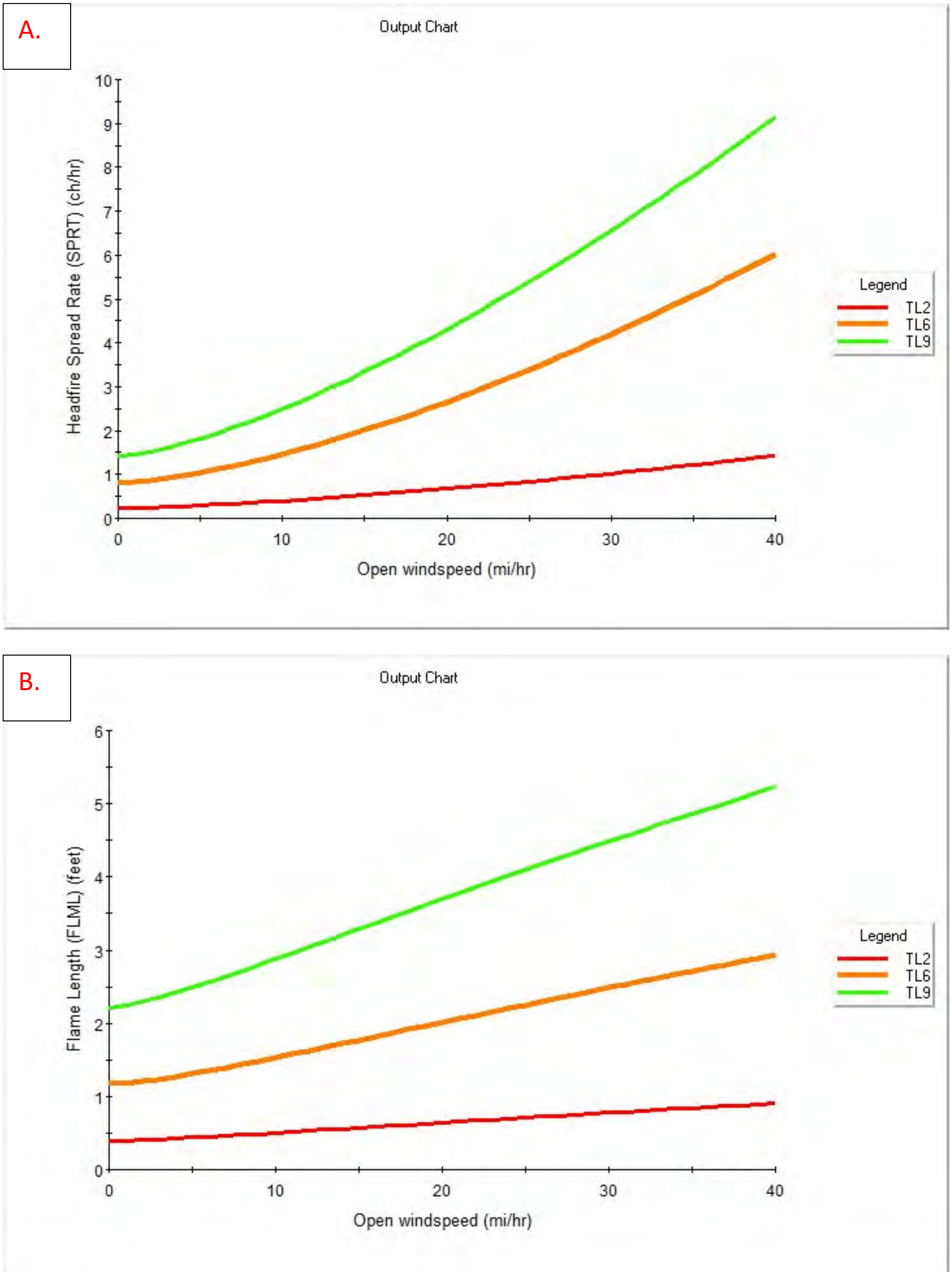
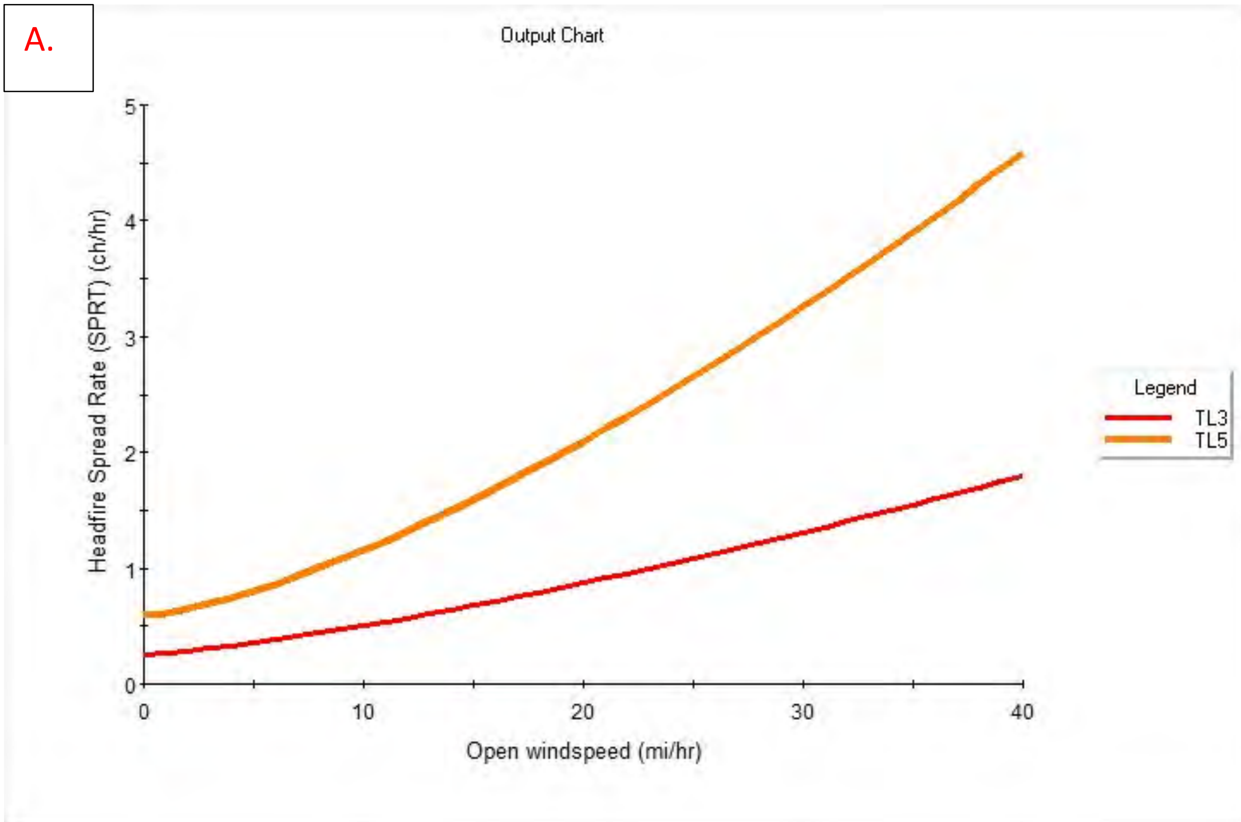


Figure 22. Simulated Rate of Spread (A) and Flame Length (B) for broadleaf Timber Litter surface fuel models.



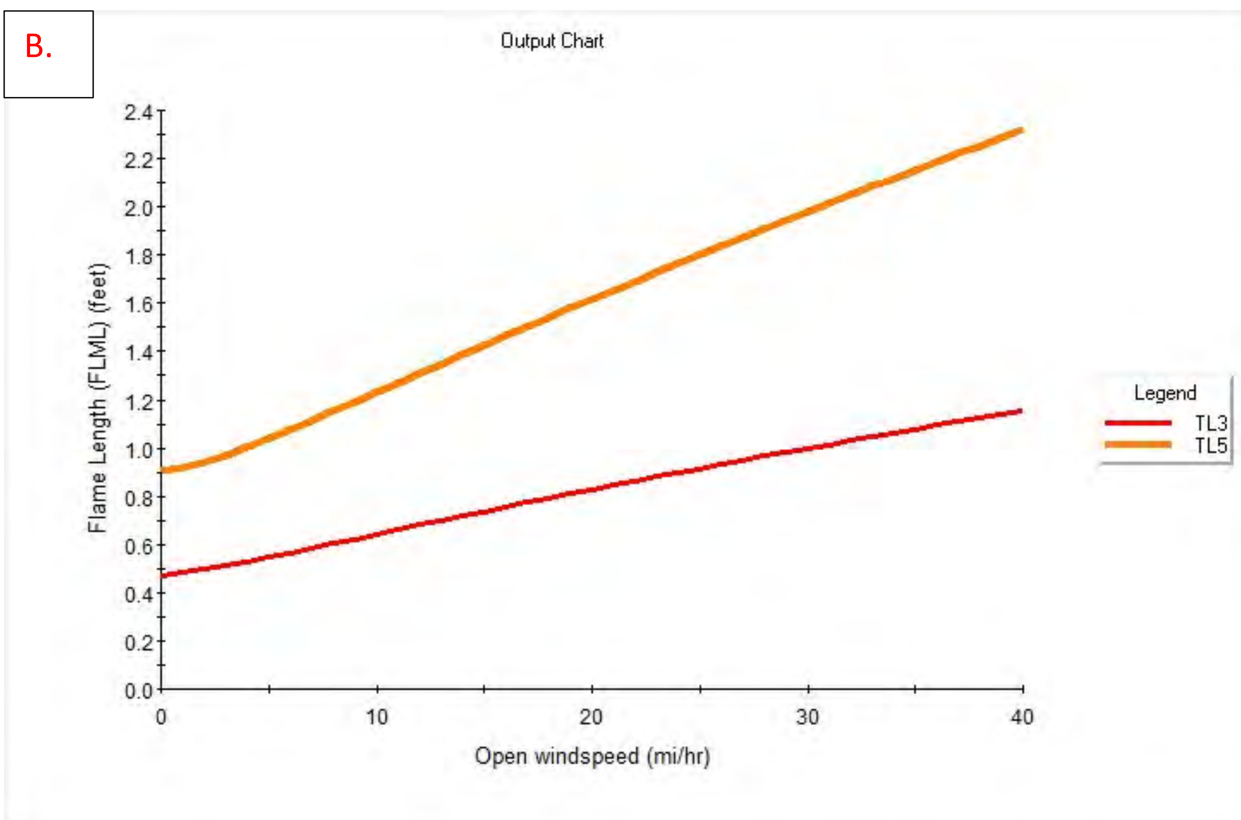


Figure 23. Simulated Rate of Spread (A) and Flame Length (B) for conifer Timber Litter surface fuel models.

Discussion

These fuel model designations seem to reflect reasonable differences between Lifeform classes and the stand structure within a given Lifeform class. The methodology here varies somewhat from that employed by Huang et al. (2016), who designated fuel models based upon CalVeg vegetation classifications, aspect, size, and density.

While these fuel model designations seem reasonable, there are some considerations that could cause unrealistic fire behavior simulation results. First, compared with the previously used CalVeg vegetation classes, the present Lifeform classes are extremely broad in nature and, thus, it is somewhat difficult to assign specific fuel models over such broad classes, even when utilizing breakpoints. For example, the current Lifeform designations only designates forests and woodlands as either Native or Non-Native, which can easily provide a vast myriad of species/forest structure combinations that are not readily captured here. Compare that with the CalVeg classifications, which categorized forests into multiple types, including Bishop pine, black oak, canyon live oak, interior live oak, interior mixed hardwood, Douglas-fir, riparian mixed hardwood, and many others. The separation of broadleaf vs. conifer forests hopefully capture some of the differences between forest and woodland vegetation types.

Second, I was unable to physically view or measure fuel traits for each of the fuel type/structure combinations. While designation of fuel models in themselves are subjective in nature (and yet has profound impacts on simulated fire behavior), it helps to "walk the ground" before designating fuel models. That said, I believe that these designations are a thoughtful characterization of fuels in Marin County, especially given the aforementioned broad nature of Lifeforms on which the fuel model designations are based.

Third, I was unable to calibrate my models against observed fire behavior. Fire behavior modeling is certainly based on science, but there is also an art in accurately simulating realistic fire behavior. It is not uncommon for a fire behavior analyst to purposefully provide unrealistic inputs so as to obtain realistic outputs. For example, when serving as a Fire Behavior Technical Specialist on a wildfire in chaparral and oak savannah fuel types, I intentionally changed the LandFire-designated fuel models to Boreal Forest fuel models so that my simulations matched actual observed fire behavior. Thus, it imperative that future users of these fuel models (or any fuel models, for that matter) ensure that outputs seem realistic based upon observed fire behavior in similar conditions. Further, it is critical to understand the assumptions and limitations of the Rothermel (1972) spread equations so as to best provide outputs that are realistic in nature. Some of these assumptions include that a given fire is free-burning (i.e., there are no suppression activities to modify fire behavior), fuels are contiguous (i.e., rocks, streams, or other non-burnable features don't exist within a fuel model), and others.

Finally, fuel model designations are intended for surface fire behavior and do not reflect crown fires or the canopy fuels through which they burn. Therefore, the LiDAR ladder fuel proxy was purposefully ignored here. That said, this data (which accurately characterizes canopy fuels in forests and woodlands) are a boon to any who seek to accurately simulate landscape fire behavior, which includes the presence of crown fires and long-range spotting.

CONCLUSIONS

The fuel model designations here are intended to reasonably characterize vegetative fuels in Marin County. They are based upon Lifeform designations, which are subsequently divided by specific breakpoints for vegetative cover and for vegetative size (the latter of which varies between grass, shrubs, and forests).

These designations are based upon my knowledge and experience in wildland fire behavior and in vegetive stand development. However, it is critical that users of these fuel models calibrate any fire behavior simulations based upon actual observed fire behavior in similar settings and weather conditions.

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