2020 Critical Update to Caltrans Wildfire Vulnerability Analysis

July 2021

A Technical Report from the National Center for Sustainable Transportation

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16. Abstract

Catastrophic wildfires over the past five years (2015-2020) have caused damage to the Caltrans road network in 81 separate wildfire events, leading to expenditures of over $590,000,000 to repair highway assets. To reduce the risk of further wildfire damage and to improve public safety, particularly for disadvantaged communities, Caltrans has engaged in assessing the priority locations for vegetation treatment within the lands it owns called the Right of Way (ROW). A 2019 analysis provided a map showing the top 17% of vulnerabilities in the road network, representing both the risk of wildfire and to disadvantaged communities that might need to use the transportation network as means of evacuation. This UC Davis research project was designed to support efforts within Caltrans in conducting a wildfire vulnerability risk assessment for fuels reduction in the ROW to protect Caltrans' infrastructure and travelers. The project involved four components: 1) conducting a rigorous peer review of the 2019 GIS-based study commissioned by Caltrans; 2) collecting and assessing the outputs of several climate change, fire, and other models currently developed or under development for California, as well as future climate projections; 3) developing a framework for the use of the prioritized segment model with other data further identify priority areas for fuels and risk reduction; and 4) interviews with Caltrans staff on opportunities and obstacles to increasing the pace and scale of vegetation treatments. The results contribute to infrastructure risk assessments, can be used to prioritize areas for treatment, to create a tracking system of areas treated and risk lowered over multiple years, and to engage local governments and wildfire fighting units to coordinate landscape fire risk reductions.

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A National Center for Sustainable Transportation Technical Report

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EXECUTIVE SUMMARY

Catastrophic wildfires over the past five years (2015-2020) have caused damage to the Caltrans road network in 81 separate wildfire events, leading to expenditures of over $590,000,000 to repair highway assets. To reduce the risk of further wildfire damage and to improve public safety, particularly for disadvantaged communities, Caltrans has engaged in assessing the priority locations for vegetation treatment within the lands it owns called the Right of Way (ROW). A 2019 analysis provided a map showing the top 17% of vulnerabilities in the road network, representing both the risk of wildfire and to disadvantaged communities that might need to use the transportation network as means of evacuation.

This UC Davis research project was designed to support efforts within Caltrans in conducting a wildfire vulnerability risk assessment for fuels reduction in the ROW to protect Caltrans' infrastructure and travelers. The project involved four components: 1) conducting a rigorous peer review of the 2019 GIS-based study commissioned by Caltrans; 2) collecting and assessing the outputs of several climate change, fire, and other models currently developed or under development for California, as well as future climate projections; 3) developing a framework for the use of the prioritized segment model with other data further identify priority areas for fuels and risk reduction; and 4) interviews with Caltrans staff on opportunities and obstacles to increasing the pace and scale of vegetation treatments. The results contribute to infrastructure risk assessments, can be used to prioritize areas for treatment, to create a tracking system of areas treated and risk lowered over multiple years, and to engage local governments and wildfire fighting units to coordinate landscape fire risk reductions.

We updated the priority routes for vegetation treatment, and selected treatment needs ranking for the top scoring 10, 17, 20, and 30% of the 1500 miles of the Caltrans highway network. The top 17% is equivalent to the 2019 priority rankings. However, in the interests of creating multi-year effort, that will first bring down the wildfire risk across the entire network, and then have the possibility of being used for planning recurring treatments across the network, we identified the decile ranked approach. This allows each district to estimate how long a program to reduce risk would take in their network, based on overall statewide risk and their local capacity and funding to implement the work.

Introduction

Catastrophic wildfires over the past five years (2015-2020) have caused damage to the Caltrans road network in 81 separate wildfire events. This has led to expenditures of over $590,000,000 to replace highway assets. To reduce the risk of further wildfire damage and to improve public safety, particularly for disadvantaged communities, Caltrans has engaged in assessing the priority locations for vegetation treatment within the lands that it owns called the Right of Way (ROW). In 2019 the Davey Group provided a map showing the top 17% of vulnerabilities in the road network, representing both the risk of wildfire and to disadvantaged communities that might need to use the transportation network as means of evacuation.

This UC Davis research project was designed to support efforts within Caltrans in conducting a wildfire vulnerability risk assessment for fuels reduction in the ROW to protect Caltrans' infrastructure and travelers. The project involved four components: 1) conducting a rigorous peer review of the 2019 GIS-based study commissioned by Caltrans; 2) collecting and assessing the outputs of several climate change, fire, and other models currently developed or under development for California, as well as future climate projections; 3) developing a framework for the use of the prioritized segment model with other data further identify priority areas for fuels and risk reduction; and 4) interviews with Caltrans staff on opportunities and obstacles to increasing the pace and scale of vegetation treatments. The results contribute to infrastructure risk assessments, can be used to prioritize areas for treatment, to create a tracking system of areas treated and risk lowered over multiple years, and to engage local governments and wildfire fighting units to coordinate landscape fire risk reductions.

This project permits Caltrans to spatially evaluate risks to infrastructure and travelers from buildup of fuels within the ROW. This study spans 1 year. The project encompassed 3 Tasks, and a 4th Task was added in discussions with the sponsor.

First, we evaluated Caltrans' existing study, the data that went into it, and the methods used. The existing study, produced by the Davey Resources Group, will be referred to here as the 2019 study. The review required use of the data layers used in that analysis, the methods used, and a spatial version of the outputs.

The model developed by the Davey Resources Group weighted 21 spatial data layers in order to create a prioritization map for vegetation management within the Caltrans ROW (Table 1). Caltrans undertook the work following Executive Order N-05-19, which directed the California Department of Forestry and Fire Protection (CAL FIRE) to, in consultation with other state agencies and departments, to recommend immediate, medium, and long-term actions to help prevent destructive wildfires. With assistance from the Governor's office of Emergency Services and other agencies, CAL FIRE produced the *Community Wildfire Prevention and Mitigation Report*, also known as the 45 Day Report.

Among the criteria for identifying areas for priority fuels reductions, CAL FIRE identified the following criteria that can be used as maps in creating a priority landscape for vegetation management. Note that social equity and safety for disadvantaged communities is critical and has its own section, in order to try and map communities that are at risk.

Table 1. The 21 data layers that were used in the original fire-risk ranking in the 2019 spatial model of the Caltrans road network. The agency that produced the data is shown in the left-hand column.

Source	Map Type
Caltrans	Average Daily Traffic Count
	Highway Class
	Emergency Evacuation Routes
CAL FIRE	Fire Threat
	SRA / FHSZ
	Fire History
	Large Trees
US Census Bureau	Families in Poverty
	People with Disabilities
	People that have Difficulty Speaking English
	People over 65
	People Under 5
	Households without a Car
	Housing Density
USDA Forest Service	WUI
	FRID
	Carbon Storage
	Wildfire Threat to Water
	Surface Waters
	Site Quality
	Standing Timber

Because Caltrans is a land-owning agency, Caltrans responded to the statewide initiative by developing its own priority ranking of lands within its ROW for vegetation management. Caltrans added data from its own geospatial data in the form of measures of Average Daily

Traffic Numbers, Highway Class, and Emergency Evacuation Routes (called in the previous report, Lifeline Routes).

The Davey Resource Group, following guidance and with engagement from Caltrans and CAL FIRE, ranked these 21 data layers, in order to prioritize by 1-mile route segments all the ~1500 miles road network under Caltrans management (Appendix 1). Their map, here titled the 2019 Wildfire Vulnerability Map, has been in use by Caltrans in order to prioritize additional vegetation management procedures. These procedures are undertaken by the Caltrans Maintenance Division, with typically each of the 12 Caltrans Districts responsible for their own roads.

The UC Davis obligation is presented here as four tasks:

Task 1

First, UC Davis reviewed the input data from the 2019 Wildfire Vulnerability Map, find updated data layers, replicate the original analysis, update the analysis using new edition spatial data, and evaluate the overall model.

Task 2

Second, we reviewed climate change projections and the current wildfire data for California. Dr Thorne recently served as a science reviewer and content editor for California's 4th climate vulnerability assessment. He used the climate projections from that exercise and compared their predicted future annual minimum temperature and precipitation to a contemporary baseline. He selected an emissions scenario and general circulation model (GCM) to use for climate risk assessment for this project. Similarly, he reviewed recent publications from the wildfire modeling community. The results are presented below.

Task 3

Third, we overlaid newly acquired spatial data (for forest/vegetation structure or fuel density and future climate stress for existing vegetation, as well as recent wildfire footprints) with our updated version of the 2019 model, here called the 2020 model. We note that fire risk from Cal Fire was already embedded in the 2019 and 2020 models. We used the outputs to evaluate risk factors along the State and Interstate highway network, and to create a framework for engaging local governments and fire officials in discussions of priority areas for vegetation management to reduce wildfire risk.

Task 4

Fourth, we used time allotted in the grant proposal to hire a graduate student for winter quarter, 2021. The student, Jason Whitney, a Ph.D. student in the Geography Graduate Group, initiated a review of the current practices for vegetation management within Caltrans' right of way. He interviewed six people, who provided their perspectives on the current vegetation management practices in Caltrans, and the steps that might be needed to increase vegetation treatments on the landscape.

Task 1: Caltrans' Commissioned Report Review

a) UC Davis will organize agenda, announcements and meetings
b) Caltrans' Commissioned Report Review
c) GIS data used to update the model
d) 2020 Risk Model of Caltrans Road Network and Communities to Wildfire

1.a UC Davis organized and conducted meetings necessary for the project

We organized regular coordination meetings. Early topics included coordination of data for use in the modeling, a briefing from Davey Resource Group, the previous modelers, clarifying the objectives and priorities for Caltrans, and assignment of tasks to the UC Davis team members. Ongoing meetings then focused on completion of tasks, handling logistics raised by COVID, and updating the focus as new data became available. We presented final results at three meetings. Two of the final presentations were scheduled and coordinated by the UC Davis team, being to the Caltrans administrative staff and the Caltrans GIS staff. The third final presentation was organized by Caltrans, in which we presented to regional staff and stakeholders in the San Francisco Bay Area. This meeting focused on how the results of our modeling might be used for outreach to local stakeholders. In addition, UC Davis attended other meetings are requested by Caltrans during the course of the study.

1.b Caltrans' Commissioned Report Review

Caltrans commissioned a spatial analysis of fuels buildup and fire risk along its road system by the Davey Resources Group. They used 21 data layers supplied from 4 sources to build the assessment (Table 2). As mentioned, 18 of these are data also used by CAL FIRE has used in its "45 Day Report" for assessing wildfire risk at landscape levels, and were authorized by the governor's office to include metrics that permit an assessment of the vulnerability of communities to wildfire as well. Because Caltrans is a land-owning agency, it also added three metrics relevant specifically to the road network.

We reviewed the data inputs and the spatial methods used to create the 2019 risk map. Because the model is using a state-wide framework also in use by other agencies, and because the methods were transparent and replicable, we accepted the methodology used in the 2019 report. We note that in some districts, additional priorities could be added. We recommend retaining the original model, and incorporating either district or more localized considerations afterwards. If those are available in map form, they can be overlaid in a GIS. If they are in the form of verbal suggestions, named areas can be inspected using the GIS and additional contextual data such as high-resolution aerial imagery.

We replicated the model outputs from the 2019 effort, despite somewhat limited methods being available. We then updated the input data, such as the census elements used, and updated the risk model for 2020. Note that because the Davey Resource Group Executive Report (2019) contains additional methods as to the weightings assigned to the 21 data layers, we include that report here for reference as Appendix 1. The intent of including it is to retain all the information associated with the creation of the spatial model in a recoverable format.

1.c GIS data used to update the model

There were 21 data layers used in the Davey group's model (Table 1). We obtained the data and reconstructed the model outputs. We used the following steps to review the previous model and to build the updated 2020 spatial model and maps:

1. Evaluate 2019 assessment data layers and bring them up-to-date with most current data
   a) Updated layers included fire history data, fire return interval, wildfire threat to water, surface waters drinking water, and all socioeconomic data from the US Census American Community Survey
2. Create priority index raster layer by combining stack of 21 updated layers using weightings from 2019 analysis
3. Buffer state highway vector layer by 1/10th mile
4. Use state highway buffer as mask on raster priority index layer
5. Buffer 1-mile interval postmile points to create half-mile radius circles covering state highway network
6. Overlay circular point buffers on priority index layer to extract index values for 1-mile segments along highway network
7. Import data table of values along segments into R for analysis
8. Calculate breakpoints for priority index using percentile ranges of values
   a) 0-17% range to give corresponding mileage to 2019 analysis
   b) Breakpoints of 0-10%, 10-20%, 20-30%,30-60%, 60-100% for alternative presentation
   c) Focus on 0-10%, 10-20%, 20-30% classes
9. Assign circular point buffers to these range classes
10. Map the highway network to these index classes using postmile ranges corresponding to these circular point buffers

To join the circular point buffers to the post mile and road segments used by Caltrans for mapping its road network, we:

1. Segmented state highway network by 1/10 mile postmiles
2. Spatially joined the ½ mile circles (above) with the 2020 priority index value to the highway segments (using the road segment's centroid).
3. Assigned each segment in the highway network to the range classes (based on the breakpoints: the top 10%, 17%, 20%, & 30%).

These steps permitted Selection of ranking criteria, in order to identify the segments of roads that have the highest level of risk, according to the model. In discussions with Caltrans, we identified two levels of ranking. We used the top 17% of the ranked state highway ROWs as the first cutoff, because that was also used in the 2019 report (Appendix 1). We also used the top 10%, the next 10-20%, and the 20-30% rankings, to show what a program of 3 years might look like with vegetation treatments for fire risk reduction within the ROW.

The data review examined the suitability of a variety of spatial data for use in creating a baseline inventory of vegetation type, density and size within Caltrans Right of Ways. We considered the date of publication, spatial extent, the mapping grain size, level of processing, difficulty with which the data could be used to accomplish the inventory, and other aspects of the data.

We identified several modes of analysis. For rapid regional screening, the use of our 2020 version of the risk abatement priority model provides the lowest cost method to identify candidate roads for fuels reduction. However, these results need to be provided to Caltrans region personnel, and to local firefighting groups, in order to ensure that actions they have already prioritized are supported, or extended through the use of the 2020 model.

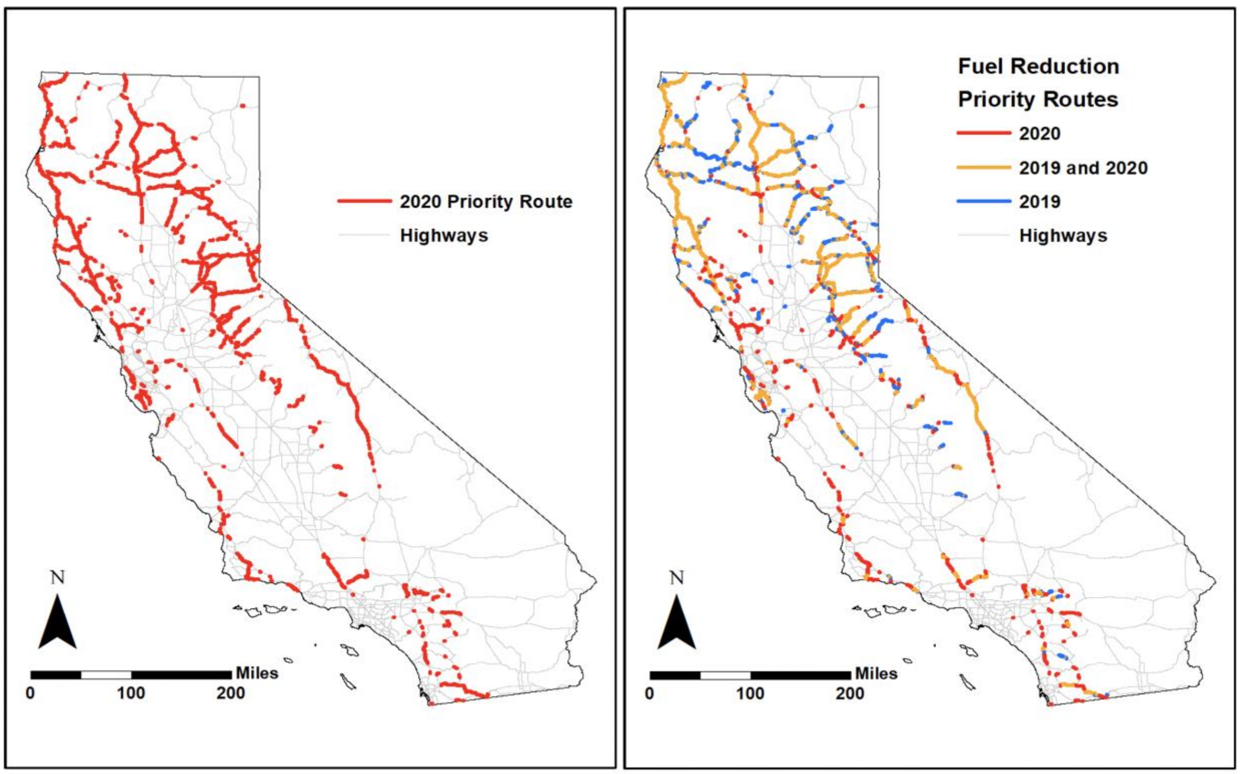

Figure 1. Selected road segments using (left) the 17% extent of the Caltrans road network also identified in the 2019 report. Right shows prioritized segments in the top 30%, by decile.

1.d 2020 Risk Model of Caltrans Road Network and Communities to Wildfire

The Risk model is a spatial product. The input data layers and the final GIS maps are included in the GIS deliverables. These data have been provided to Caltrans and are posted on Dryad (https://doi.org/10.5061/dryad.sj3tx964v).

Table 2. The 21 data elements used in the 2019 edition of the model.

Group	Criteria	Raster Name	Last Update	Source	Link	Weighting
Caltrans	Average Daily Traffic Numbers (AADT)	AADT.tif	2018	Caltrans, created from 2017 AADT GIS data maintained by Caltrans, Division of Traffic Operations -provided by Andrew Lozano	Contact Andrew Lozano (Caltrans)	0.07
	Highway Class	HighwayClass.tif	2018	Maintained by Caltrans -provided by Andrew Lozano "HighwayClassification_MetaData.docx"	Contact Andrew Lozano (Caltrans)	0.07
	Lifeline Routes	EmergencyLifeRoute.tif	2018	Maintained by Caltrans -provided by Andrew Lozano "HighwayClassification_MetaData.docx"	Contact Andrew Lozano (Caltrans)	0.14
Calfire	Fire Threat	Threat.tif	2013	CalFire (FRAP)	https://frap.fire.ca.gov/mapping/gis-data/	0.08
	SRA / FHSZ	SRA_FHSZ.tif	2018	CalFire (FRAP)	https://hub.arcgis.com/datasets/MontereyCo::sra-fire-haz-zones-1	0.05
	Fire History	FireHistory.tif	2018	CalFire (FRAP)	https://frap.fire.ca.gov/mapping/gis-data/	0.05
	Large Trees	LargeTrees.tif	2015	CalFire (FRAP)	https://frap.fire.ca.gov/mapping/gis-data/	0.05
Census	Families in Poverty	FamiliesInPoverty.tif	5-year American Community Survey 2013-2017	US Census Bureau - Poverty Status of Families by Family Type in Last 12 Months: Census Data Table: B17010	https://www.nhgis.org/documentation/tabular-data	0.03
	People with Disabilities	PeopleWithDisabilities.tif	5-year American Community Survey 2013-2017	US Census Bureau - Sex by Disability Age: Census Data Table B18101	https://www.nhgis.org/documentation/tabular-data	0.03
	People that have Difficulty Speaking English	DifficultySpeakingEnglish.tif	5-year American Community Survey 2013-2017	US Census Bureau - Language Spoken at Home for the Population 5 years and Over: Census Data Table C16001	https://www.nhgis.org/documentation/tabular-data	0.03
	People over 65	PeopleOver65.tif	5-year American Community Survey 2013-2017	US Census Bureau - Sex by Age: Census Data Table B01001	https://www.nhgis.org/documentation/tabular-data	0.03
	People Under 5	PeopleUnder5.tif	5-year American Community Survey 2013-2017	US Census Bureau - Sex by Age: Census Data Table B01001	https://www.nhgis.org/documentation/tabular-data	0.03
	Households without a Car	NoTransportation.tif	5-year American Community Survey 2013-2017	US Census Bureau - Means of Transportation to Work by Vehicles Available: Census Data Table B08141	https://www.nhgis.org/documentation/tabular-data	0.03
	Housing Density	HousingDenisty.tif	5-year American Community Survey 2013-2017	US Census Bureau - Housing Units: Census Data Table B25001	https://www.nhgis.org/documentation/tabular-data	0.04
USDA	WUI	WUI.tif	2015	USFS - 2010 Wildland Urban Interface of the Conterminous United States	https://data.nal.usda.gov/search/type/dataset	0.06
	FRID	FRID.tif	2017	USFS - Region 5, Land & Resource Management	https://www.fs.usda.gov/detail/r5/landmanagement/gis/?cid=STELPRDB5327836	0.06
	Carbon Storage	CarbonStorage.tif	2013	USDA - Forest carbon stocks of the contiguous United States (2000-2009)	https://www.fs.usda.gov/rds/archive/catalog/RDS-2013-0004	0.03
	Wildfire Threat to Water	FireThreatToWater.tif	2010	USDA - Forest2Faucets	https://www.fs.fed.us/ecosystemservices/FS_Efforts/GetF2FData/index.php	0.03
	Surface Waters	SurfaceDrinkingWater.tif	2010	USDA - Forest2Faucets	https://www.fs.fed.us/ecosystemservices/FS_Efforts/GetF2FData/index.php	0.03
	Site Quality	SiteQuality.tif	2019	USDA - FIA (Forest Inventory Analysis) County Estimates 2017	https://data.fs.usda.gov/geodata/edw/datasets.php?xmlKeyword=FIA+Landcover+County+Estimates	0.03
	Standing Timber	StandingTimber.tif	2014	Oregon State University (LEMMA) - Uses FIA Data from USDA	https://lemma.forestry.oregonstate.edu/data/structure-maps	0.03

Task 2: Collect and Assess Fire and Climate Model Outputs

Deliverables:

a) Assessment – Review of Climate and Fire Models
b) Selected data layers for use as context in prioritizing road segments for vegetation treatment

2.a Assessment - Review of Climate and Fire Models (Called 2A & 2B in contract).

Research in the fields of climate change and wildfire is fast-moving. The most recent benchmark for the state was California's 4th Climate Vulnerability Assessment (4th CCCVA; https://www.climateassessment.ca.gov/). We used the assessment as basis for considering data layers to include as contextual information in screening the California highway network. Confidence in projections of increasing temperatures is very high, as with predictions of declining snowpack, and frequency of drought. Confidence in increasing acreage burned by wildlife is medium-high. Projections to mid-century under RCP8.5 show an increase in annual average maximum daily temperatures of +5.8°F. As has been observed since the assessment, climate projections suggest seasonal summer dryness in California will become prolonged due to "earlier spring soil drying that lasts longer into the fall and winter rainy season (e.g., Pierce et al., 2014; Swain et al., 2018)" (Bedsworth et al. 2018).

The primary statewide report (Bedsworth et al. 2018). The overall finding for the state was that, under current emission levels, the area per year burned would increase by 77% by the end of century, and that insurance costs would rise and become harder to obtain. The statewide report suggests research that management is a way to lower wildfire risk, by reducing density of trees. Increased fire risk correlates to increasing temperatures. The statewide report (Bedsworth et al. 2018) discusses the increase in Santa Ana winds in southern California, and Nausler et al 2019, shows similarities of winds in the 2017 Tubbs fire to wind events that increased the burn severity to those from southern California. However, spatially explicit models of where higher severity fires due to increasing wind speeds have not been published.

We reviewed the models used in the CA climate assessments, and selected MIROC ESM RCP8.5 emissions scenario as suitable for use by Caltrans vegetation management planning. The RCP4.5 emissions scenario is closest to the Paris Accord-level of emissions, but achieving this level of reductions is not under the control of the Caltrans Maintenance, and the time table to actually "bend the curve" of global emissions is such that it is an unsafe assumption that these lowered emission levels will be achieved with the next 30 years.

Generally, wildfire models that predict increases in area burned are statistical (e.g., Westerling et al. 2018). While the outputs are spatial (e.g., Figure 2Figure 2), they typically are either too far into the future and possibly too generalized to inform vegetation treatment in the ROW, at least in the short term. Not surprisingly, the areas that are wooded appear with higher risk. Converging lines of evidence, including the CCCVA and CAL FIRE fire risk maps suggest that Caltrans has adopted an appropriate response in seeking to reduce risk of wildfire within its

ROW. Instead, we identified the use of fine scale (10 m), remotely-sensed measures of vegetation density such as Surface fuels and Bulk Density to identify where fires could be more impacting, and wildfire perimeters to provide a view of where fuel loads may have been decreased in the near term along state highways.

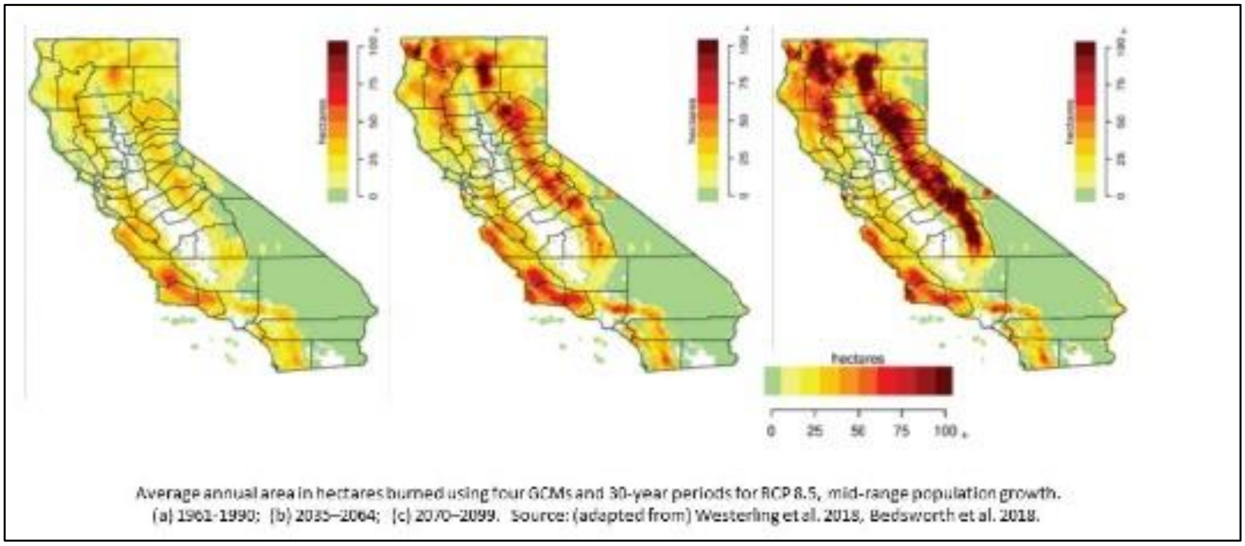

Figure 2. Graphics from 4th CCCVA showing the annual area burned using an ensemble of 4 GCMs, and for 3 periods (left to right): 1961-1990, 2035-2055, and 2070-2099.

Current efforts to better model the behavior of future wildfire are funded and underway at the present time, including a project the California Energy Commission, a project funded by the University of California, and one funded by the CA Department of Conservation.

To further evaluate the ROWs we added three sources of data to use as context in addition to the 2020 update of the ROW wildfire risk map.

First, the California Forest Observatory (https://forestobservatory.com/), produced annually by Salo Sciences, provides 10m-resolution maps of a variety of forest structure for all of California. Their vegetation bulk density and surface fuels measures (30m or finer spatial resolution, statewide coverage) from this site can be used to identify areas within and adjacent to the ROW that have high fuel loads, and therefore are at risk of more severe wildfire.

Second, we used climate change projections that were also included in the 3rd and 4th California Climate Vulnerability Assessments (https://www.climateassessment.ca.gov/) and a climate risk model developed by the Thorne group (Thorne et al. 2016; 2017; 2020; Choe & Thorne 2019; Williams et al. 2018). This model identifies the areas for each major vegetation type (WHR types as used by CDFW) that are the most likely to remain in climatically suitable locations, therefore more climate-secure; and those areas most likely to be highly climatically stressed, therefore more at risk from stand-replacing wildfires. We suggest using the MIROC ESM RCP8.5 climate exposure data from our 2020 publication (Thorne et al. 2020) as a suitable spatial model for use in exploring the risks to existing vegetation types within Caltrans ROW.

Third, we evaluated the use of fire perimeter maps as provided by CAL FIRE and the USFS. These show areas that, if recently burned, may require a lower level of vegetation management within the ROW, even while in many cases other costs are incurred by Caltrans due to passage of wildfire across a road.

2.b Selected data layers for use as context in prioritizing road segments for vegetation treatment

The California Forest Observatory data, the climate exposure data are provided as additional GIS data in the GIS deliverables (Table 3). The fire perimeters data is also included, but it was additionally part of the 2020 Wildfire Risk update.

Table 3. Additional data provided for context evaluation.

New data				
Group	**Description (Criteria)**	**New Updates**	**Source**	**Location**
Salo Sciences	Surface Fuels	2020	California Forest Observatory	https://forestobservatory.com/
	Bulk Density	2020	California Forest Observatory	https://forestobservatory.com/
	Canopy cover	2020	California Forest Observatory	https://forestobservatory.com/
	Canopy height	2020	California Forest Observatory	https://forestobservatory.com/
	Ladder fuel density	2020	California Forest Observatory	https://forestobservatory.com/
UC Davis	Vegetative Climate Exposure	2019	UC Davis - Information Center for the Environment (Thorne et al. 2020)	
Calfire	Fire Perimeters 2016-2019	2019	CalFire (FRAP)	
NIFS	Fire Perimeters 2020	2020	National Interagency Fire Cen	downloaded Dec 7, 2020; https://data-nifc.opendata.arcgis.com/datasets/5da472c6d27b4b67970acc7b5044c862_0

Task 3: Compilation

Deliverables:

a) Data framework for selection of road segments for the entire state, by district, or for visualizing local areas for engagement of stakeholders
b) Final graphics in the form of the final presentation to Caltrans and associated tabular data.
c) Final presentation of findings; provide data and graphics to Caltrans

We combined the updated data layers to develop the 2020 fuels risk maps, with additional data possible to add representing the fire perimeters, climate risk and fuels within the ROW. In discussion with the sponsor, we identified a framework for considering how the outputs could be incorporated into ongoing-decision support for Caltrans operations and management.

3.a Data framework for selection of road segments for the entire state, by district, or for visualizing local areas for engagement of stakeholders

The UCD Davis team has provided all documents and project coordination. Due to the varying local conditions and the need to engage local governments and stakeholders in the process of selecting areas in the Caltrans ROW (and beyond the ROW) for vegetation management, we recommend the use of the 2020 updated wildfire risk maps as a starting point for visualization and prioritization exercises that also incorporate regional data identified here (vegetation structure, future climate risk, and fire perimeter data) as well as district- and stakeholder-provided data and observations when making the final yearly determination of vegetation treatment segments in the ROW.

3.b Final graphics in the form of the final presentation to Caltrans and associated tabular data

This report is the deliverable to 3B. This report established the data, protocols and rankings for the Caltrans ROW with regards to identifying priority fuels reduction areas. The report also makes recommendations on how to provide the spatial results for ongoing Caltrans operations. The report further provides feedback from Caltrans staff about how to navigate the increased pace and scale of vegetation treatments that are anticipated. The final graphics are available as a PowerPoint presentation, submitted with this report as an accompanying document.

3.c Final presentation of findings; provide data and graphics to Caltrans

The UCD Team and the sponsor agreed to present the final results at zoom meetings at the request of the sponsor. Three final presentations to Caltrans Staff were presented on April 23, May 7, and May 14, 2021. The first presentation was to Caltrans Sacramento and District staff; the second was with the GIS staff in the maintenance division, in order to relay the organization of the GIS data; and the third presentation focused on an application of the analysis for District 4 staff. There was no in-person meeting, due to COVID.

Task 4: Interviews with Caltrans vegetation management experts

Deliverables:

a) Written summary and report from the interviews.

4.a Written summary and report from the interviews

Mr. Jason Whitney, graduate student at UC Davis conducted a series of interviews at the request of the sponsor. The intent was to find out Caltrans staff members' thoughts about how vegetation management in the ROW is typically conducted, and what are the current challenges for increasing the pace and scale of management in order to reduce risk of wildfire.

Six employees, including 2 from headquarters and four from district offices were interviewed. Their perspectives and responses are compiled here.

Interview Results from Caltrans Staff

Jason Whitney, UC Davis

ABSTRACT

Caltrans faces significant challenges as California experiences another year of severe drought. As of April 2021, several California counties have already been declared as drought emergency areas. This paper provides a critical evaluation of Caltrans' vegetation management program with a lens on climate change adaptation and resilience based largely on consultation with representatives across relevant Caltrans programs.

Introduction

As extended drought continues to create dangerous fire conditions in California, new efforts are being made to ensure that management activities focus on appropriate mitigation strategies to combat this threat. The Governor's Forest Management Task Force recently established California's Wildfire and Forest Resilience Action Plan, which is a comprehensive strategy to reduce wildfire risk and improve health of forests and wildlands (Forest Management Task Force, 2020). To help ensure that state agencies have appropriate resources to work together and meet these challenges, the Wildfire and Forest Resilience Action Plan has been followed by a proposed one-billion-dollar investment in the 2021-2022 state budget. More specifically it provides:

- "$512 million to increase landscape scale resilience in our forests and natural landscapes, including through increased use of prescribed fire and funding for tribes and small landowners.
- $335 million to complete at least 45-60 strategic fuel break projects each year over the next several years and grants to support local wildfire plans and projects.
- $38 million to harden and protect fire-vulnerable communities.

- $39 million to ensure our predictive models and investments in wildfire resilience are based on the best available science.
- $76 million to expand economic and job opportunities through the Climate Catalyst Fund's low-interest lending program, the California Conservation Corps workforce programs, and forest management job training." (CalEPA, 2021)

Caltrans has also been working to meet the fire risk challenges posed by climate change, in an effort documented in published reports ranging from late 2017 to late 2019. These Climate Change Vulnerability Assessments Summary Reports and associated Technical Reports describe a suite of climate change effects in each of Caltrans' 12 districts (Caltrans, 2019). In addition to the district level analysis of climate change issues, Caltrans contracted with Davey Resources Group to produce the 2019 Caltrans Wildfire Vulnerability Assessment. This assessment which combined multiple geographic map layers in a geographic information system (GIS) model to create a map that identified and prioritized 2,600 centerline miles of roadway with significant fire risk.

The 2019 Caltrans Wildfire Vulnerability Assessment has subsequently been updated and verified by UC Davis Transportation Institute researchers with 2020 data to enable the operationalization for prioritization of vegetation management efforts in Caltrans managed state responsibility areas (SRA). The responsibility of Caltrans to create fire-safe roadways is highlighted in sections 2.24 – 2.29 of California's Wildfire and Forest Resilience Action Plan (Forest Management Task Force, 2020). This research effort directly addresses aspects of action item 2.25:

> "Develop Framework for Safe Road Corridors: Through workshops with key agencies and stakeholders, Caltrans is establishing a framework for collaborative fuels reduction projects to protect roadway travelers, communities along highways and to reduce roadside ignitions along primary and secondary emergency evacuation routes. Caltrans will **identify highway corridors most in need of defensible space** and develop a strategy in the spring of 2021 while seeking to align funding and crew resources."

Caltrans Integrated Vegetation Management Program

The environmental impacts of Caltrans vegetation management activities are addressed by a 1992 programmatic environmental impact report (PEIR) entitled "Environmental Impact Report on Caltrans' Vegetation Control Program". The PEIR was prepared to address public concerns about the health risks of chemical control methods. For clarity, the "vegetation control program" the PEIR addresses is the entirety of all Caltrans activities directed at management of non-cultivated vegetation occurring along the state highway system. The PEIR analyzed six options, including the current program at that time, the "Chemical-Preferred" program and a "No Control" option. The alternative which had the least significant impacts, and which Caltrans has been implementing since that time, is the "Integrated Vegetation Management Program" or IVM. In the IVM, all methods are available (mechanical (i.e., mowing), chemical (i.e., herbicide spraying), manual, cultural, thermal, and biological techniques) to establish preferred roadside vegetation wherever feasible.

The PEIR identified the project area as approximately 230,000 acres of right-of-way (ROW) of California's 15,000 miles of highways and or about ¼ of 1 percent of California. Caltrans divides California into 12 districts many of which span multiple ecoprovinces with a diverse range of vegetation in each. Caltrans vegetation management activities are also affected by the broad range of stakeholders which create additional zones of differing management complexity. These range from limited vegetation control activities on highways crossing federal lands to a requirement that non-chemical methods of control be used in some counties and municipal jurisdictions. Within the PEIR the stated objectives of vegetation control are to:

- protect roadbed and pavement integrity;
- preserve visibility of traffic, highway facilities, and wildlife;
- promote road system drainage;
- inhibit ignition and spread of fire;
- maintain designed vehicle recovery areas;
- allow large vehicle and snowplow clearance;
- promote melting of ice and snow;
- minimize soil erosion and slope instability;
- suppress noxious weeds;
- eliminate damaged vegetation that may fall or spread plant disease;
- maintain an attractive roadside appearance; and
- protect landscape plantings

Caltrans has operationalized the IVM in the Maintenance Manual, specifically chapter C2 where it identifies IVM methods to create a 4-8 ft "narrow clear strip" as including: chemical, thermal, biological, cultural, mechanical, structural, and manual control with stated Department objectives to achieve the goal of a 50% reduction in herbicide use from 1992 levels to an 80% reduction by 2012 (Caltrans Maintenance Division, 2014). The methods used to create the "narrow clear strip" are identified in vegetation control plans (veg con) by Landscape Specialists in each District who prepare veg con plans each year. These plans are finalized in April of each year and identify vegetation management activities for every segment of the roadway. These veg con plans are then used by maintenance crews from Caltrans yards to coordinate vegetation control activities. Landscape Specialists generally have a Pest Control Advisors license and sometimes are certified arborists and critically are in advisory roles only.

Vegetation management challenges identified by interviews

What follows is a summary of the challenges identified through conversations with representatives across relevant Caltrans programs. These serve to highlight some of the common as well as unique challenges and opportunities facing vegetation management efforts on the district and statewide level. Effort was made to obtain a representative sample of districts across the state. Four employees from three districts and two from the Caltrans Office of Roadside Management at headquarters (HQ) in Sacramento were interviewed. This portion of the study was constrained by time challenges, willingness to participate, and difficulty contacting relevant individuals. The employees from the districts consisted of three landscape specialists (who write vegetation control plans) and an environmental planner. The views expressed herein are a synthesis and interpretation of those interviews by the author. The list of challenges below is unlikely to be complete, but the intention is to provide a window into the unique challenges faced by Caltrans with the objective of a helping to create a more adaptable and resilient California.

1. Dangerous roadways
    a. All interviewees identified the risk that roadside work creates and emphasized that this creates additional challenges in any vegetation management activities. Concerns mentioned were that cars pass at high rates of speed and often do not slow down for road workers.
    b. Some counties or cities do not allow herbicide use and instead rely on manual control methods causing employees to be along the roadside for longer periods of time compared to herbicide application which is done primarily from spray vehicles.
2. Hiring challenges and impacts
    a. Landscape Specialists with a Pest Control Advisors license can make significantly more money working in private industry.
    b. There is no cost-of-living adjustment for Caltrans employees.
    c. This causes some districts which when fully staffed would have 3 or 4 Landscape Specialists creating the veg con plan to only have 1 or 2. In addition this creates a situation where a single Landscape specialist can be advising the activities of over 30 maintenance crews.
3. ROW mapping and prioritization
    a. A GIS layer of the Caltrans ROW is not available. Some districts have created a ROW map layer to help guide management efforts.
    b. While maps of priority areas of high fire have recently become available there is not a standard approach for how to incorporate these maps into the existing vegetation control workflow.
4. Communication and accountability
    a. Some interviewees expressed frustration with what they see as a lack of communication between the Office of Roadside Management (ORM) and the Office of Emergency Management (OEM) which have both overlapping and independent directives regarding vegetation management.
    b. Landscape Specialists operate in advisory roles only, and as such do not have the direct authority to tell Maintenance Crews to go out at specific times to take specific management actions. This has led in some cases to the hiring of third-party contractors to manage certain areas when there is a breakdown of the teamwork between Landscape Specialists and Crew Supervisors. In other cases, the reliance on third parties has caused issues where trees which had been marked for removal were not removed and subsequently fell onto the roadway leading to injury or death.

c. Communication with external partners also varies on a district-by-district basis. Some districts are more engaged with outreach to local fire, county pest management, and other agencies with similar vegetation management objectives and knowledge.
d. Despite the PEIR stating that "annual district vegetation control plan and report, would be available to the public and public agencies each year before Caltrans takes actions to control vegetation" the process by which these are made available is unknown. Upon viewing feedback from some local fire chiefs, this is not occurring in all cases.
e. While initial efforts to use alternative vegetation control techniques were made immediately after the PEIR, these have been severely limited due to logistical constraints. Constraints include the previously mentioned lack of resources (herbicide application is the cheapest method) and a desire to limit exposure to roadway conditions.

5. Multiple Roles of ORM
    a. Vegetation management is a small part of the ORM which has a wide range of responsibility. This creates internal competition for scarce resources.
    b. Vegetation control is a small fraction of the ORM budget, for illustration in 2020 the proposed budget for ORM was $2.4 billion while in 2018 the cost for non-landscaped weed control was $36.9 million. This contrasts with the $115.2 million in litter in and debris removal in 2018 (Caltrans, 2020) and the nearly $150 million in damages to state highway property and infrastructure in 2018 (Herby Lissade et al., 2019).
6. Climate Change/Drought/Invasive Species
    a. While the PEIR states that "new information or changed circumstances would warrant an additional environmental review" and that each district "document annually whether each year's program continues to be consistent with the selected program alternative" little incentive exists for such a determination.
    b. There is no invasive species tracking and species-specific removal instructions based on best available science.
    c. Drought creates situations where herbicides are either not applied, as they need a certain amount of rain after application to be effective or need to be applied in all target areas in an extremely short window of time. This is critically important to help reduce the risk of roadside ignition and spread, as happened in the Carr fire of 2018.

Recommendations

As climate impacts are resulting in more severe fire conditions more resources are required to ensure greater climate adaptation and resilience. Essential to these actions are improved coordination between relevant stakeholders. Critically important is to include local fire agencies input into the vegetation control plans. The annual district vegetation control plan and report should be available to the public and public agencies each year before Caltrans takes actions to control vegetation". Also, of utmost importance is to have an adaptive management plan which incorporates past actions with a fire risk model to focus limited resources into targeted management efforts. This would allow greater ability to track and monitor the effectiveness of various vegetation control methods and inform further activities as well as preventing spread of invasive species, many of which can serve increase fire risk. It is also clear that Caltrans needs to have a full GIS model of the highway ROW so that proper geospatial analysis of land cover characteristics can be undertaken to help guide management efforts in SRAs. Greater coordination between the ORM and OEM would also go a long way to facilitate effective management. More specifically, there should be explicit guidance on the process to unify vegetation control plans and fire management plans. It is also recommended that alternative vegetation control plans and resources are made available if herbicide applications are prohibited by lack of precipitation. Another recommendation is to have a GIS where maintenance crews can provide feedback of current roadside conditions, this could be combined with a data driven prioritization model of high-risk fire areas to guide and evaluate existing vegetation control methods. It is also recommended that significant fire risk reduction activities take place in the ROW outside of the clear strip. Such fire risk reduction activities could potentially be funded by grants made available through the California Climate Investments (CCI) Fire Prevention Grant Program or through advanced mitigation requirements.

Acknowledgements

Thanks goes out to the individuals who were willing to participate and discuss the challenges faced at individual districts and at headquarters, regarding Caltrans vegetation management efforts.

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Data Management

Products of Research

The research team used a combination of the previously assembled spatial data sources, some of which we updated and the collection of new data. We used these to build a model that ranks the relative risk of Caltrans' ROW segments to more intense wildfire for the ~15,000 miles of the highway network. See the methods section and Appendix A for a description of each variable, how it was used in the modeling and the relevant citation. Additionally, see more information, including tables, variable descriptions, and the spatial data at the DRYAD link below.

Data Format and Content

The final data are in GIS format, with each post mile and route scored. They include a ranking system in the attributes that permits setting a threshold according to rank-priority, to find corresponding areas in the ROW for priority fuels reduction/wildfire risk mitigation. All public data is posted. One spatial data layer used was not considered the authoritative layer by Caltrans. That layer is excluded, but contact Caltrans to request the data from the agency is provided

Data Access and Sharing

The data have been posted to Dryad at the following address:
https://doi.org/10.5061/dryad.sj3tx964v

Reuse and Redistribution

There are no restrictions on reuse and re-distribution by the general public. The citation for the dataset is:

Boynton, Ryan; Thorne, James; Hollander, Allan (2021), 2020 Critical update to Caltrans wildfire vulnerability analysis, Dryad, Dataset, https://doi.org/10.5061/dryad.sj3tx964v.

Appendix A

Davey Resource Group Executive Summary – Caltrans Methods for Prioritizing Fuel Load Reduction Projects (2019). We include the summary provided by the previous modelers regarding wildfire risk to the Caltrans Road Network here, to retain the methods for weighting the spatial data used in the 2019 edition. The data presented below were updated as stated in the main report. The weightings were retained for each spatial data layer that went into the model because those were: a) previously determined by a roundtable of California State Agencies as appropriate and are being used in a variety of other agency applications; and b) the weightings were found to be acceptable in our review.

Summary

This project was conducted to assess the vulnerability and risk of wildfire to Caltrans-owned state highways. Data sources were sought across the board to analyze a variety of factors that contribute to wildfire and its spread. Analysis included data sets from CAL FIRE, US Department of Agriculture, US Census Bureau, and Caltrans. The resulting analysis found segments along Caltrans state highways that could benefit from fuel load reduction in order to create defensible space along the rights-of-way.

This project was made possible by a partnership between Caltrans and Davey Resource Group, Inc. Caltrans provided guidance throughout the project to ensure Davey Resource Group, Inc. had ample data and information to complete a thorough study of Caltrans state highways.

Description

Through advanced geospatial analysis, Caltrans and Davey Resource Group completed a priority-based risk assessment of Caltrans state highways to model the risk and vulnerability of road segments that fall within Caltrans jurisdiction. Data used in the model varied in their temporal resolution as well as spatial resolution. To normalize the spatial resolution, Davey Resource Group, Inc. converted all data to raster formats and set the resolution at 30m with a projection of NAD 1983 Albers. The data sets were created state-wide for this analysis.

Each data source utilized the most current version. US Census data was taken from the 5-year American Community Survey (ACS) estimates ranging from 2013-2017. US Department of Agriculture data ranged from 2010-2018. CAL FIRE datasets were downloaded from their website with dates spanning from 2010-2019. Caltrans data included current data from 2018-2019. A description of the data sources can be found in the methodology (lineage) section of the metadata.

Methodology

Using the CAL FIRE 45-day Report as a guide, Caltrans and Davey Resource Group, Inc. sought to create a similar priority guideline for Caltrans-owned rights-of-way. Data sources used in this assessment mirror those in the CAL FIRE 45-day report with the addition of Caltrans internal data for traffic volumes, highway classes, and emergency routes. This project took the principles of socio-economic analysis and vulnerable communities to complete a thorough assessment of the Caltrans rights-of-way going through these communities while also factoring in environmental risks of wildfire to natural resources (i.e. loss of trees, carbon storage, negatively impacting water supplies, etc.). However, instead of having a community-based focus, the goal of this analysis was to prioritize Caltrans highways that serve those communities in order to address fuel loading concerns. By prioritizing routes, Caltrans can work with other stakeholder groups to reduce fuels in and around these critical communities. By keeping evacuation routes clear, Caltrans can create defensible space and possibly save lives in the event of wildfire outbreaks.

To address route prioritization, a geospatial risk-based model was constructed by Davey Resource Group, Inc. during Summer/Fall 2019. Datasets were collected and assessed through a variety of sources (listed below). Davey Resource Group, Inc., in conjunction with Caltrans, deliberated each potential data source to determine which pieces of information would be most beneficial to the model. Construction of the risk-based model was intended to identify priority routes or segments along Caltrans operated highways that could benefit from fuel load reductions in order to create defensible space along the rights-of-way.

All data was converted to 30m raster datasets to complete the analysis. An intra-dataset ranking was constructed for each variable in the model using values ranging from 0-7 (see Data Descriptions Section). A value of zero (0) was indicative of No Data. Lower values were reasoned by carrying less risk. A weighted overlay analysis was implemented to determine risk throughout the state. Data were summarized using a 1/10-mile buffer and calculating the average risk value within the buffer around all Caltrans operated state highways.

Each road segment was summarized for its average risk value within the buffered zone. The scores were then normalized by dividing the score by the highest score and multiplying by 100. This puts the scale in an easy 0-100 scale, where 100 is the highest priority. The normalized values were statistically binned into seven (7) classes within ArcGIS using Natural Breaks classification. The top 3 classes were deemed as the priority range for this analysis. With the priority segments identified, additional GIS analysis was performed to assign each segment a Caltrans District, Cal Fire Unit, California State Park, National Forest, BLM Unit, Tribal Land, and County, if applicable.

Data was also processed to include post mile markers for the closest ranges to give a better understanding of the location for each potential fuel reduction project.

Table 4. The source and date of production for the 21 data layers used in the updated model.

Group	Criteria	Raster Name	Last Update	Weighting
Caltrans	Average Daily Traffic Numbers (AADT)	AADT.tif	2018	0.07
	Highway Class	HighwayClass.tif	2018	0.07
	Lifeline Routes	EmergencyLifeRoute.tif	2018	0.14
Calfire	Fire Threat	Threat.tif	2013	0.08
	SRA / FHSZ	SRA_FHSZ.tif	2018	0.05
	Fire History	FireHistory.tif	2018	0.05
	Large Trees	LargeTrees.tif	2015	0.05
Census	Families in Poverty	FamiliesInPoverty.tif	5-year American Community Survey 2013-2017	0.03
	People with Disabilities	PeopleWithDisabilities.tif	5-year American Community Survey 2013-2017	0.03
	People that have Difficulty Speaking English	DifficultySpeakingEnglish.tif	5-year American Community Survey 2013-2017	0.03
	People over 65	PeopleOver65.tif	5-year American Community Survey 2013-2017	0.03
	People Under 5	PeopleUnder5.tif	5-year American Community Survey 2013-2017	0.03
	Households without a Car	NoTransportation.tif	5-year American Community Survey 2013-2017	0.03
	Housing Density	HousingDenisty.tif	5-year American Community Survey 2013-2017	0.04
USDA	WUI	WUI.tif	2015	0.06
	FRID	FRID.tif	2017	0.06
	Carbon Storage	CarbonStorage.tif	2013	0.03
	Wildfire Threat to Water	FireThreatToWater.tif	2010	0.03
	Surface Waters	SurfaceDrinkingWater.tif	2010	0.03
	Site Quality	SiteQuality.tif	2019	0.03
	Standing Timber	StandingTimber.tif	2014	0.03

Weighted Overlay Equation (output created a statewide risk layer used in prioritization):

(0.07*"AADT.tif")+(0.07*"HighwayClass.tif")+(0.14*"EmergencyLifeRoute.tif")+(0.06*"WUI.tif")+(0.06*"FRID.tif")+(0.03*"FamiliesInPoverty.tif")+(0.03*"PeoplewithDisabilties.tif")+(0.03*"DifficultySpeakingEnglish.tif")+(0.03*"PeopleOver65.tif")+(0.03*"PeopleUnder5.tif")+(0.03*"NoTran sportation.tif")+(0.04*"HousingDensity.tif")+(0.08*"Threat.tif")+(0.05*"SRA_FHSZ.tif")+(0.05*"FireHistory.tif")+(0.05*"LargeTrees.tif")+(0.03*"CarbonStorage.tif")+(0.03*"FireThreatToWater.tif")+(0.03*"SurfaceDrinkingWater.tif")+(0.03*"SiteQuality.tif")+(0.03*"StandingTimber.tif")

Data Details

Caltrans

Average Daily Traffic Numbers (AADT)

Source: Caltrans, created from 2017 AADT GIS data maintained by Caltrans, Division of Traffic Operations - provided by Andrew Lozano

Link: Contact Andrew Lozano (Caltrans)

Data Field: AvgAADT

This layer provided average road usage as of 2017, aggregated between “Ahead” and “Back” average daily traffic numbers (ex. Northbound vs. Southbound). We separated the AvgAADT into seven (7) equal ranks, and those with higher AADT were assigned higher ranks.

Table 5. Caltrans - Average Daily Traffic Numbers (AADT)

Rank	Avg ADT Count
1	0-55,000
2	55,001-110,000
3	110,001-160,000
4	160,001-220,000
5	220,001-265,000
6	265,001-325,000
7	325,001+

Highway Class

Source: Maintained by Caltrans - provided by Andrew Lozano

“HighwayClassification_MetaData.docx”

Link: Contact Andrew Lozano (Caltrans)

Data Field: FUNCCL

FUNCCL listed in Caltrans Metadata as "Item used to describe functional classification system" and is broken down into 17 different road classifications from unclassified, to rural road types, to urban types. These 17 classifications were concatenated and grouped into 7 classes in order to align with the scoring range. Higher rankings were given to Rural routes as opposed to interstates because interstates and other urban routes receive more attention due to higher volumes of daily traffic. Rural routes are often the only way in and out of small communities, making them paramount to the safe evacuation of those living in the areas, but due to lower volumes of traffic they are infrequently maintained.

Table 6. Caltrans - Highway Class

Rank	Description
1	Urban Principal Arterial/Other Hwys or Expwys, Urban Principal
2	Urban Other Principal Arterial
3	Urban Collector
4	Urban Minor Arterial
5	Rural Principal Arterial-Interstate
6	Rural Minor Arterial, Rural Other Principal Arterial
7	Rural Major Collector, Rural Minor Collector

Lifeline Routes

Source: Maintained by Caltrans - provided by Andrew Lozano "HighwayClassification_MetaData.docx"

Link: Contact Andrew Lozano (Caltrans)

Data Field: LIFE

In 1998, the Federal Emergency Management Agency (FEMA) and the American Society of Civil Engineers entered into a cooperative agreement to establish the American Lifelines Alliance (ALA) to facilitate the "creation, adoption and implementation of design and retrofit guidelines and other national consensus documents that, when implemented by lifeline owners and operators, will systematically improve the performance of utility and transportation systems to acceptable levels in natural hazard events, including earthquakes.

LIFE listed in Caltrans Metadata as "Item used to define Lifeline Routes on the State Highway System" assigned a 0 or 1 (Non-Lifeline vs. Lifeline). According to Caltrans Strategic Plan, Oct. 1994 - A Lifeline route is a route on the state highway system that is deemed so critical to emergency response/lifesaving activities of a region or state that is must remain open immediately following a major earthquake or for which preplanning for detour and/or expeditions repair and reopening can guarantee movement. The focus is on highly critical routes that allow for the immediate movement of emergency equipment and supplies into a region or through a region.

Table 7. Caltrans - Lifeline Routes

Rank	Emergency Route
1	No
7	Yes

CAL FIRE

Fire Threat

Source: CalFire (FRAP)

Link: https://frap.fire.ca.gov/mapping/gis-data/

Data Field: Threat, Count

CalFire metadata describes this layer as a "Statewide GIS layer in raster format of fire threat, which combines expected fire frequency with potential fire behavior to create four (4) threat classes". Data was expanded into six (6) rankings spanning from No Data to Very High threat levels by using the count field to break the data into equal classes. The higher the count/threat level, the higher ranking that was assigned.

Table 8. CalFire - Fire Threat

Rank	Threat
1	No Data
2	Very Low
3	Low
4	Moderate
5	High
6	Very High

SRA (State Responsibility Areas) / FHSZ (Fire Hazard Severity Zones)

Source: CalFire (FRAP)

Link: https://hub.arcgis.com/datasets/MontereyCo::sra-fire-haz-zones-1

Data Field: Hazard Class

Data shows state responsibility areas that are the highest fire hazards. Within the data, there are four classes of hazards, ranging from No Data, Very Low to Very High. The highest ranking was assigned a seven (7) to keep consistent with the scoring ranks assigned throughout the project.

Table 9. CalFire - SRA/FHSZ

Rank	Hazard Class
1	No Data - Very Low
4	Moderate
6	High
7	Very High

Fire History (Fire Perimeters)

Source: CalFire (FRAP)

Link: https://frap.fire.ca.gov/mapping/gis-data/

Data Field: Cause

This layer shows the spatial distribution of historical large fires, last updated May 1, 2019. From CalFire's project website: "The Fire and Resource Assessment Program (FRAP) compiles fire perimeters and has established an on-going fire perimeter data capture process. CAL FIRE, the United States Forest Service Region 5, the Bureau of Land Management, and the National Park Service jointly develop the fire perimeter GIS layer for public and private lands throughout California at the end of the calendar year. Upon release, the data is current as of the last calendar year". Data was concatenated into seven (7) cause classes, grouped by similarities to bring the count of classes down from 14. By looking at the frequency of each cause code, ranks were assigned from highest to lowest in terms of frequency as well to the circumstance of ignition.

Table 10. CalFire - Fire History

Rank	Hazard Class
1	Firefighter & Non-Firefighter Training, Structure, Aircraft, Illegal
2	Escaped Prescribed Burn, Railroad
3	Playing with Fire
4	Unknown/Unidentified
5	Equipment Use, Arson
6	Lightning, Miscellaneous
7	Smoking, Campfire, Debris, Vehicle, Power Line

Large Trees

Source: CalFire (FRAP)

Link: https://frap.fire.ca.gov/mapping/gis-data/

Data Field: WHRSIZE - Wildlife Habitat Relationship Size Class (tree types only)

From metadata: “An accurate depiction of the spatial distribution of habitat types within California is required for a variety of legislatively-mandated government functions. The California Department of Forestry and Fire Protection's CALFIRE Fire and Resource Assessment Program (FRAP), in cooperation with the California Department of Fish and Wildlife Veg Camp program and extensive use of USDA Forest Service Region 5 Remote Sensing Laboratory (RSL) data, has compiled the "best available" land cover data available for California into a single comprehensive statewide data set. The data span a period from approximately 1990 to 2014. Typically, the most current, detailed and consistent data were collected for various regions of the state. Decision rules were developed that controlled which layers were given priority in areas of overlap. Cross-walks were used to compile the various sources into the common classification scheme, the California Wildlife Habitat Relationships (CWHR) system.”. Size classes were broken down into seven (7) classes by DBH, starting with No Data areas, to Seedlings <1”, and continuing up to Multi Layered: Size 5 with a Total Tree Crown > 60%.

Table 11. CalFire - Large Trees

Rank	Size Class
1	Not Forest (urban, marsh, pastures,barren, etc)
2	Seedling: <1" dbh
3	Sapling: 1-6" dbh
4	Pole: 6-11" dbh
5	Small Tree: 11-24" dbh
6	Medium/Large Tree: >24" dbh
7	Multi Layered: Size 5 over Size 4 or 3: Total Tree Crown >

US Census

Families in Poverty

Source: US Census Bureau - Poverty Status of Families by Family Type in Last 12 Months: Census Data Table: B17010

Link: https://www.nhgis.org/documentation/tabular-data

Data Field: AH1KE002 - Income in the past 12 months below poverty level

Data shows the percentage of families in the census tract living below the poverty line in the past twelve months.

Table 12. US Census - Families in Poverty

Rank	Percent of Census Tract
1	0-5%
2	5.01-15%
3	15.01-30
4	30.01-45%
5	45.01-60%
6	60.01-75%
7	75.01% +

People with Disabilities

Source: US Census Bureau - Sex by Disability Age: Census Data Table B18101

Link: https://www.nhgis.org/documentation/tabular-data

Data Field: AIG0E001: Total with disability

Data shows the Percentage of population in census tract estimated to have a disability; based on self-reporting.

Table 13. US Census - People with Disabilities

Rank	Percent of Census Tract
1	0-5%
2	5.01-15%
3	15.01-30%
4	30.01-45%
5	45.01-60%
6	60.01-75%
7	75.01% +

People that have Difficulty Speaking English

Source: US Census Bureau - Language Spoken at Home for the Population 5 years and Over: Census Data Table C16001

Link: *https://www.nhgis.org/documentation/tabular-data*

Data Field: *AIE7 - Speak English less than 'very well' fields*

Data shows percentage of population in the census tract estimates to have difficulty speaking English.

Table 14. US Census - People that have difficulty speaking

Rank	Percent of Census Tract
1	0-10%
2	10.01-20%
3	20.01-30%
4	30.01-40%
5	40.01-50%
6	50.01-60%
7	60.01% +

People Over 65

Source: *US Census Bureau - Sex by Age: Census Data Table B01001*

Link: *https://www.nhgis.org/documentation/tabular-data*

Data Field: *AHYQM020-25 Males 65+, AHYQM044-49 Females, 65+*

Data shows percentage of population in the census tract over the age of 65; indicates elderly.

Table 15. US Census - People over 65

Rank	Percent of Census Tract
1	0-5%
2	5.01-15%
3	15.01-30
4	30.01-45%
5	45.01-60%
6	60.01-75%
7	75.01% +

People Under 5

Source: US Census Bureau - Sex by Age: Census Data Table B01001

Link: https://www.nhgis.org/documentation/tabular-data

Data Field: AHYQM003: Male: Under 5 years, AHYQM027: Female Under 5 years

Data shows percentage of population in the census tract under the age of 5; indicates young children.

Table 16. US Census - People Under 5

Rank	Percent of Census Tract
1	0-1%
2	1.01-5%
3	5.01-10%
4	10.01-15%
5	15.01-20%
6	20.01-25%
7	25% +

Households without a Car

Source: US Census Bureau - Means of Transportation to Work by Vehicles Available: Census Data Table B08141

Link: https://www.nhgis.org/documentation/tabular-data

Data Field: AICLE002: No vehicle available

Data shows percentage of population in the census tract without a car.

Table 17. US Census - Households without a Car

Rank	Percent of Census
1	0-5%
2	5.01-15%
3	15.01-30
4	30.01-45%
5	45.01-60%
6	60.01-75%
7	75.01% +

Housing Density

<u>Source</u>: *US Census Bureau - Housing Units: Census Data Table B25001*

<u>Link</u>: *https://www.nhgis.org/documentation/tabular-data*

<u>Data Field</u>: *AH35M001: Total*

Data shows total housing units per acre.

Table 18. US Census - Housing Density

Rank	Housing Units per Acre
1	0-1
2	1.01-5
3	5.01-10
4	10.01-25
5	25.01-50
6	50.01-100
7	100.01-153

USDA

WUI - Wildland Urban Interface

<u>Source</u>: *USFS - 2010 Wildland Urban Interface of the Conterminous United States*

<u>Link</u>: *https://data.nal.usda.gov/search/type/dataset*

<u>Data Field</u>: WUICLASS10

WUICLASS10 listed in metadata as Wildland-Urban Interface class: Classified by housing density. From USDA: "The wildland-urban interface (WUI) is the area where houses meet or intermingle with undeveloped wildland vegetation. This makes the WUI a focal area for human-environment conflicts such as wildland fires, habitat fragmentation, invasive species, and biodiversity decline. Using geographic information systems (GIS), we integrated U.S. Census (2010) and USGS National Land Cover Data (2006), to map the Federal Register definition of WUI (Federal Register 66:751, 2001) for the conterminous United States. These data are useful within a GIS for mapping and analysis at national, state, and local levels." Ranks were assigned from 1-7 to match the scoring schema, and those with higher vegetation classifications were assigned a higher score.

Table 19. USDA - WUI

Rank	WUI Classification
1	No Veg/Water
2	Uninhabited Veg
3	Very Low Veg Density
4	Low Veg Density
5	Low/Medium Veg Density
6	Medium Veg Density Interface
7	High Veg Density

FRID - Fire Return Interval Departure

<u>Source</u>: USFS - Region 5, Land & Resource Management

<u>Link</u>: https://www.fs.usda.gov/detail/r5/landmanagement/gis/?cid=STELPRDB5327836

<u>Data Field</u>: NPS_FRID_Index

This data layer shows the Fire Return Interval Departure signaling times since the last fire occurred and an expected recurrence in an area. From USFS - "This polygon layer consists of information compiled about fire return intervals for major vegetation types on the 18 National Forests in California and adjacent land jurisdiction. Comparisons are made between pre-Euro American settlement and contemporary fire return intervals (FRIs). Current departures from the pre-Euro American settlement FRIs are calculated based on mean, median, minimum, and maximum FRI values. This map is from a project of the USFS Pacific Southwest Region Ecology Program." Ranks were assigned from 1-7, with higher rankings assigned to areas with a higher FRID Index, or higher frequency of recurring fires per area.

Table 20. USDA - FRID

Rank	FRID Index
1	No Data
2	0.33+
3	-0.74 - 0.32
4	-2.20 - -0.75
5	-4.15 - -2.21
6	-6.72 - -4.16
7	-8.91 - -6.73

Carbon Storage (of Living Trees Above Ground)

Source: USDA - Forest carbon stocks of the contiguous United States (2000-2009)

Link: https://www.fs.usda.gov/rds/archive/catalog/RDS-2013-0004

Data Field: Above Ground Forest Biomass (Megagrams/Hectare (mg/ha))

From publication Abstract: "Through application of a nearest-neighbor imputation approach, mapped estimates of forest carbon density were developed for the contiguous United States using the annual forest inventory conducted by the USDA Forest Service Forest Inventory and Analysis (FIA) program, MODIS satellite imagery, and ancillary geospatial datasets." Data was broken down into seven (7) categories and has also been converted into tons/acre for ease of understanding and can be implemented into analysis should this be the chosen route.

Table 21. USDA - Carbon Storage

Rank	Above Ground Forest Biomass
1	0-15
2	15-50
3	50-100
4	100-150
5	150-200
6	200-600
7	600+

Wildfire Threat to Water

<u>Source:</u> USDA - Forest2Faucets

<u>Link</u>: https://www.fs.fed.us/ecosystemservices/FS_Efforts/GetF2FData/index.php

<u>Data Field</u>: 3_FIR_FOR in F2F_outputs.dbf

From the USDA: “For this analysis, areas were included that ranked as having high or very high wildland fire potential. Fire affects watershed stability and water quality differently depending on many factors including geographic region, distance of fire to water source, local topography, soil type, slope, and weather patterns. In addition, forest fire is a natural process and is critically important to the natural functioning of many forests. When interpreting the output map, it is important to consider this.”

Table 22. USDA - Wildfire Threat to Water

Rank	Percentage
1	0-10%
2	10.01-20%
3	20.01-30%
4	30.01-40%
5	40.01-50%
6	50.01-60%
7	60.01% +

Surface Waters

<u>Source</u>: USDA - Forest2Faucets

<u>Link</u>: https://www.fs.fed.us/ecosystemservices/FS_Efforts/GetF2FData/index.php

<u>Data Field</u>: 1IMP in F2F_outputs.dbf

From the USDA: “The USDA Forest Service Forests to Faucets project uses GIS to model and map the continental United States land areas most important to surface drinking water, the role forests play in protecting these areas, and the extent to which these forests are threatened by development, insects and disease, and wildland fire.”

Table 23. USDA - Surface Waters

Rank	Percentage
1	0-15%
2	15.01-30%
3	30.01-45%
4	45.01-60%
5	60.01-75%
6	75.01-90%
7	90.01% +

Site Quality

Source: USDA - FIA (Forest Inventory Analysis) County Estimates 2017

Link: https://data.fs.usda.gov/geodata/edw/datasets.php?xmlKeyword=FIA+Landcover+County+Estimates

Data Field: Average Annual Net Growth (in cubic feet)

"This feature class represents forest area estimates (and percent sampling error) by county for the year 2017. Features and attributes of the county layer were adapted to match attributes within the FIA database (FIADB) and features have been generalized by removing vertices to enhance performance. Future iterations of this dataset will be produced using refined methods and higher resolution spatial data. Productivity of forestland based on potential volume of wood that can be produced per acre in a year." Data was broken into seven (7) equal categories by quantities of cubic feet. Those with higher average annual net growth were given higher rankings.

Table 24. USDA - Site Quality

Rank	Average Annual Net Growth (in cubic feet)
1	All Negative Values
2	0-1,000,000
3	1,000,000-5,000,000
4	5,000,000-15,000,000
5	15,000,000-30,000,000
6	30,000,000-70,000,00
7	70,000,000+

Standing Timber

<u>Source</u>: Oregon State University (LEMMA) - Uses FIA Data from USDA

<u>Link</u>: https://lemma.forestry.oregonstate.edu/data/structure-maps

<u>Data Field</u>: BA_G3

From metadata: "Digital Gradient Nearest Neighbor (GNN) imputation maps are provided as 30m-resolution ArcGIS grids, where the grid value is a unique plot number that links to the plot database. Selected vegetation variables from the plot database are joined as items in the grid to facilitate viewing and exploratory spatial analysis. Metadata for the vegetation variables are included with the grids and in the plot database. Dates for maps developed from GNN species-size models are determined by the vintage of the satellite imagery used in their development.". Data was categorized by Basal Area and split into seven (7) equal categories.

Table 25. Oregon State University (LEMMA) - Standing

Rank	Basal Area
1	0-6
2	6-17
3	17-30
4	30-43
5	43-60
6	60-83
7	83+