Appendix “G”

Fire Behavior Report Tentative Tract 38605

Fire Behavior Report
Greentree Ranch
Tentative Tract 38605

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Purpose of Report

Firesafe Planning Solutions performed an assessment of the risks related wildland fire and to establish the appropriate criteria for a defensible space installation and maintenance program that will reduce the intensity of a wildfire approaching the Greentree Ranch residential community. This report will provide the results of the assessment and provide objective support of the defensible space installation and maintenance program for this community that is equal to or greater than the risk which would be encountered in a worst-case scenario. The study takes into consideration existing/future vegetative interface fuels, topography, and weather conditions during a fire. The report provides results of computer calculations that measured the fire intensity from a worst-case scenario wildfire in both the extreme (Santa Ana- NE wind) and the predominant (Onshore – SW wind) conditions. The results of fire behavior calculations will be incorporated into the fire protection design built into the Greentree Ranch development.

Geographic Description

The proposed project (outline) is located north of Lake Mathews within the northwestern portion of Western Riverside County, California. The Project site is within the Gavilan Hills, and is generally located south of the 91 Freeway, east of La Sierra Road, north of El Sobrante Road, and west of Van Buren Boulevard. The site is bounded by undeveloped land and rural development to the north (currently in planning phase for development), east, and west.

Figure 1 – Vicinity Map

CAL FIRE State Responsibility Area Very High Fire Hazard Severity Zone Map

State law requires development in State Responsibility Area (SRA) within any fire hazard zone to comply with the WUI (Wildland Urban Interface) codes contained in the California Residential Code (Chapter 3, Section R337) , California Building Code (Chapter 7A) and California Fire Code (Chapter 49). The currently adopted Fire Hazard Severity Map for this area (adopted in 2007) places the entire project in a Moderate hazard zone as shown below in Figure 2. As required by statute, the zones are periodically updated. The state of California is currently (as of the writing of this report) updating the SRA area first and will follow that effort with the Local Responsibility Area (LRA) updates. Initial updates were completed in 2023, circulated for public comment and have made several specific area changes as requested by local jurisdictions and landowners based on updated inputs to the algorithm and data which produces the recommended zones. Once the SRA process has been completed, the LRA process will be undertaken.

The Greentree Ranch site is located completely in a Moderate Fire Hazard Severity Zone in the currently map and mostly in Moderate for the proposed hazard map (Figure 2 - Current map and Figure 3 - Proposed map). All portions of the project site are within a hazards zone and will be required to comply with the WUI codes cited above.

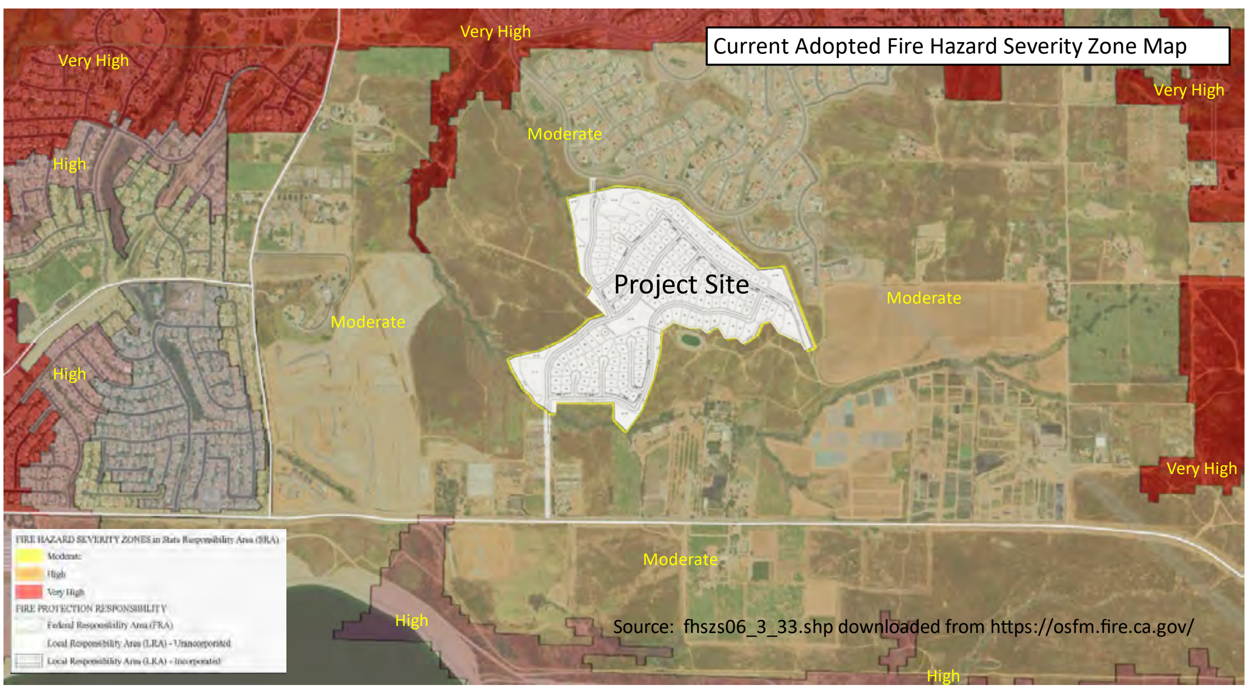

Figure 2 – Current Fire Hazard Severity Zone Map

Much of the Moderate hazard area to the north of the project site has been reclassified to Very High hazard and unlike the previous map where zone transitioned from very high to moderate in a single cell, the updated maps step the hazard down to high and then to moderate. The net effect on the project site is minimal as all of the building sites have remained in Moderate hazard zones.

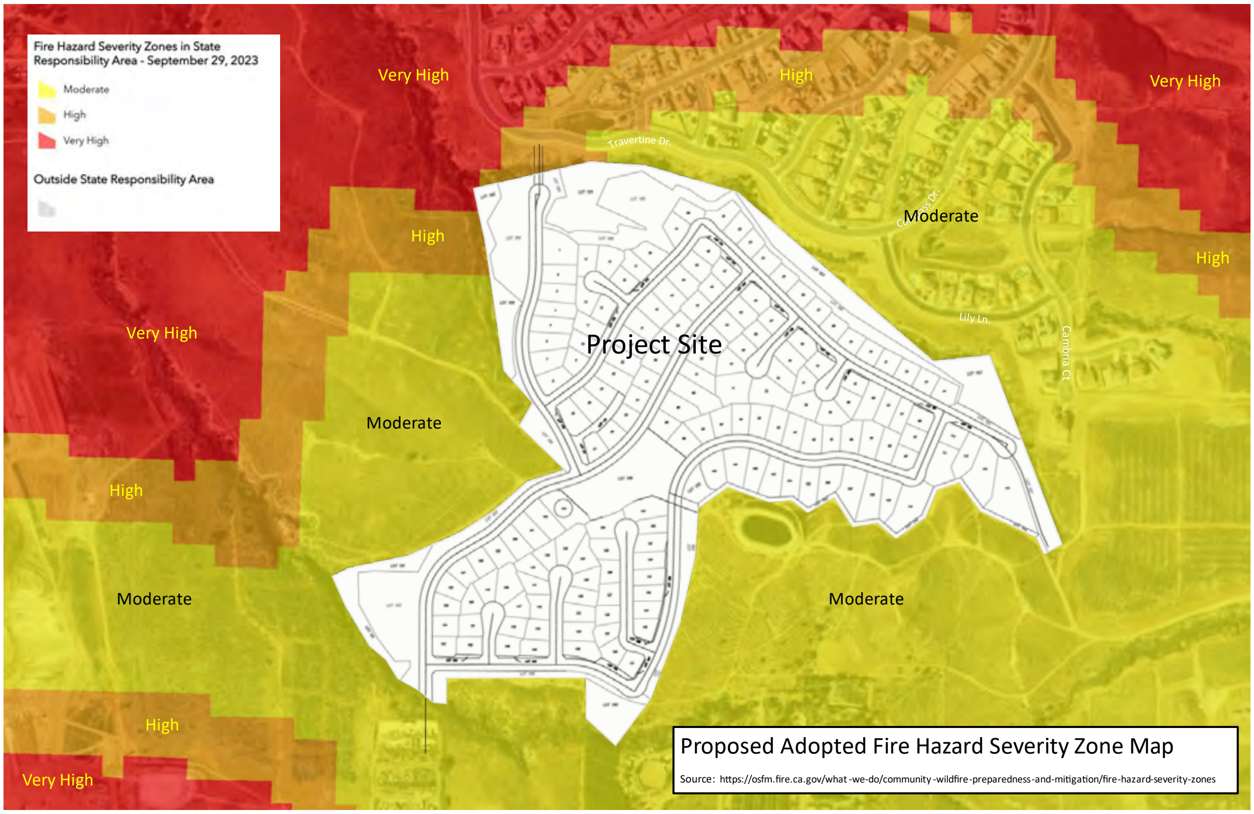

Figure 3 – Proposed Fire Hazard Severity Zone Map

<u>Fire History</u>

A review of the CalFire database (FRAP) which compiled this statewide spatial database of fire perimeters from BLM, NPS, and USFS fires 10 acres and greater in size and CAL FIRE fires 300 acres and greater in size shows a picture of the project site and the adjacent historic fire corridor. It is depicted on the next page in Figure 3.

The project site development area has no recorded fire history in the CALFIRE database (Figure 4). In 1978 a non-named fire burned through a small area southeast of the project site but not over any of the proposed development areas. None of the fires adjacent to the project site have come within ¼ of a mile of the project site development envelopes with the exception of the 1978 fire. Of particular note is that none of these fires are northeast or southwest of the project site (strongest wind directions).

All but three of the adjacent fires occurred over 30 years ago. In 1978, two fires (without names) occurred. The first burned 2,157.16 acres and the second 507.21 acres. The next year (1979) the Steele Fire started on July 9th and burned 107.41 acres. The following year (1980) the Quail Fire started on July 6th and burned 200.85 acres and the Pierce Fire started on July 9th of this same year and burned 985.28 acres. There is not another fire adjacent to the projects site for 11 years until June 28th of 2001 with the Cajalco Fire burned 224.96 acres. In 2005, the Knoll Fire which started on April 20th burned 19.57 acres and finally the Lakepointe Fire, which was over 1.5 miles away at its closed point (burned 256 acres in May of 2012). There have been no large fires near the project site since 2001 (over twenty years). Clearly historic fire corridors exist to the southeast and southwest of the project site, but none have impacted the project site during the time covered by the CALFIRE database.

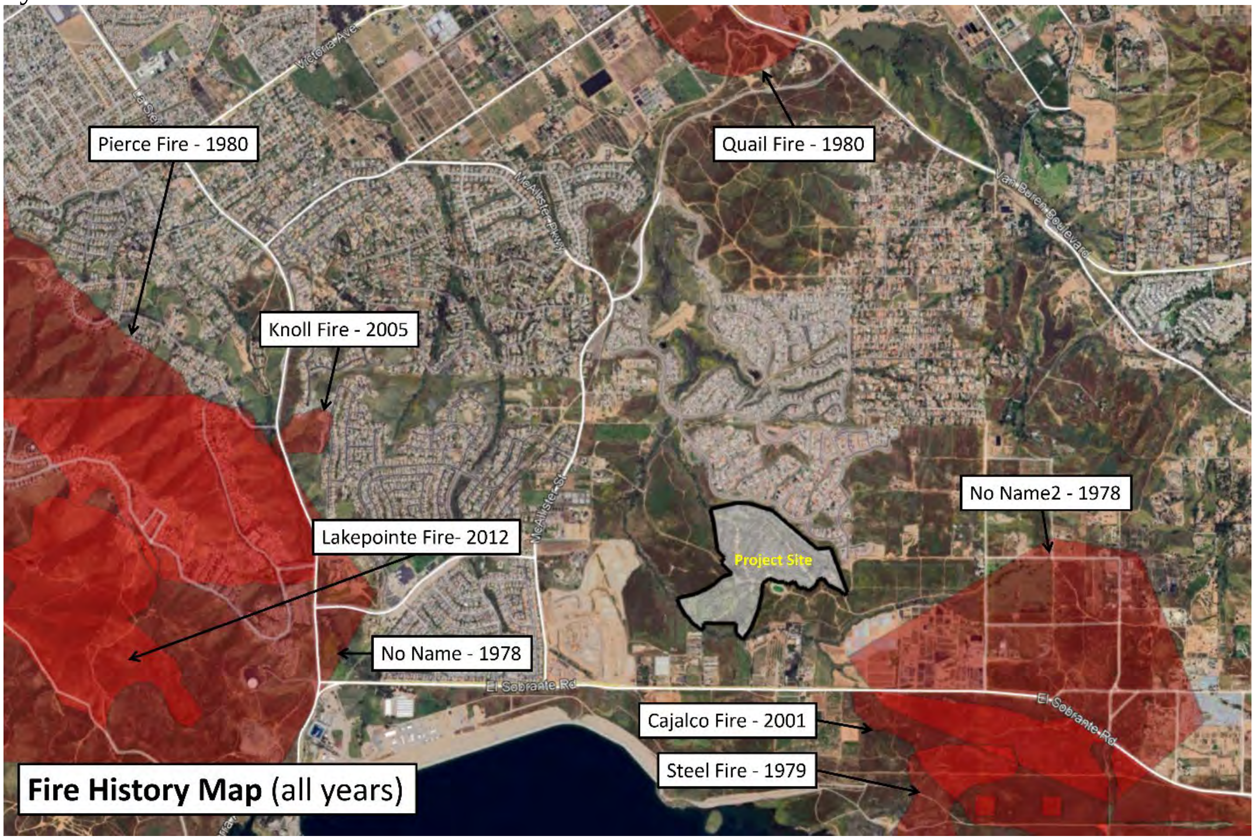

Figure 4 – Fire History Map

Note: Collection criteria for CAL FIRE fires changed in 2002 to include timber fires greater than 10 acres, brush fires greater than 50 acres, grass fires greater than 300 acres, fires destroying three or more structures, and fires causing $300,000 or more damage. In 2008 collection criteria for CAL FIRE fires eliminated the monetary criterion and redefined the definition of structures.

Fire Behavior

Firesafe Planning Solutions used a computer software program titled, "BehavePlus Fire Modeling System 6.0.0" to predict the level of wildfire intensity for a fire approaching the Greentree Ranch project site . BehavePlus, is a fire behavior prediction and fuel modeling system and is one of the most accurate methods for predicting wildland fire behavior. The BehavePlus fire behavior computer modeling system is utilized by wildland fire experts nationwide. Vegetative fuels are recognized as fuel models within the BehavePlus program. The fuel models in the computer program, are also referenced from the book titled, "*Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model*". The fuel models were designed to aid in determining fuel types and are used in calculating and estimating fire behavior. We used BehavePlus to measure the intensity of a fire moving towards this development.

The fire model describes the fire behavior only within the flaming front of the fire. The primary moving force in the fire is dead fuel less than ¼" in diameter. These are the finest fuels that carry the fire. Fuels larger than ¼" contribute to fire intensity, but not necessarily to fire spread as much as the fine fuels. The BehavePlus fire model describes a wildfire spreading through surface fuels, which are the burnable materials within 6' of the ground and contiguous to the ground.

BehavePlus Related References:

1. Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model, Joe H. Scott and Robert E. Burgan, United States Department of Agriculture - Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-153, June 2005

2. BehavePlus: Fire Behavior Prediction and Fuel Modeling System - BURN Subsystem. General Technical Report INT-194. Patricia L. Andrews, United States Department of Agriculture - Forest Service, Intermountain Station, Ogden, Utah 84401

Wildland Interface Fuel Types

For the purposes of modeling in the plan, the following fuel models were used:

Model GR1 (101) Dry Climate Grass is short, patchy, and possibly heavily grazed. Spread rate moderate; flame length low. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 0.4 feet.

Model GR2 (102) Dry Climate - Moderately coarse continuous grass, average depth about 1 foot. Spread rate high; flame length moderate. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 1.0 feet.

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Model GS1 (121) Dry Climate - Shrubs are about 1-foot high, low grass load. Spread rate moderate; flame length low. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 0.9 feet.

Model GS2 (122) Dry Climate - Shrubs are 1 to 3 feet high, moderate grass load. Spread rate high; flame length moderate. Dynamic. Moisture of extinction is 15%. Fuel bed depth is 1.5 feet.

Model SH2 (142) Dry Climate - Moderate fuel load (higher than SH1), depth about 1 foot, no grass fuel present. Spread rate low; flame length low. Moisture of extinction is 15%. Fuel bed depth is 1.0 feet.

Model SH7 (147) Dry Climate - Very heavy shrub load, depth 4-6 feet. Spread rate lower than SH5, but flame length similar. Spread rate high; flame length very high. Moisture of extinction is 15%. Fuel bed depth is 6.0 feet.

Model TL6 (186) Fuelbed not recently burned. Fuelbed composed of broadleaf (hardwood) litter. Moderate load, less compact. Spread rate moderate; flame length low. Moisture of extinction is 25%. Fuel bed depth is 0.3 feet.

Fuel **Model TU5** (165) Dry Climate - Fuelbed is high load conifer litter with shrub understory. Spread rate moderate; flame length moderate. Moisture of extinction is 25%. Fuel bed depth is 1.0 feet.

In addition to the models from the Landfire database, one custom southern California fuel model will also be considered in the modeling:

Model SCAL18 is a southern California specific model for coastal sage scrub and northern mixed chaparral with an average fuel depth of 3 feet. This has been used in place of the SH7 (147) as a more specific model in the worst-case scenario

The graphic below (Figure 5) shows the fuels as recorded in the Landfire database for wildland fuel using the Scott and Bergan 40 fuel classifications.

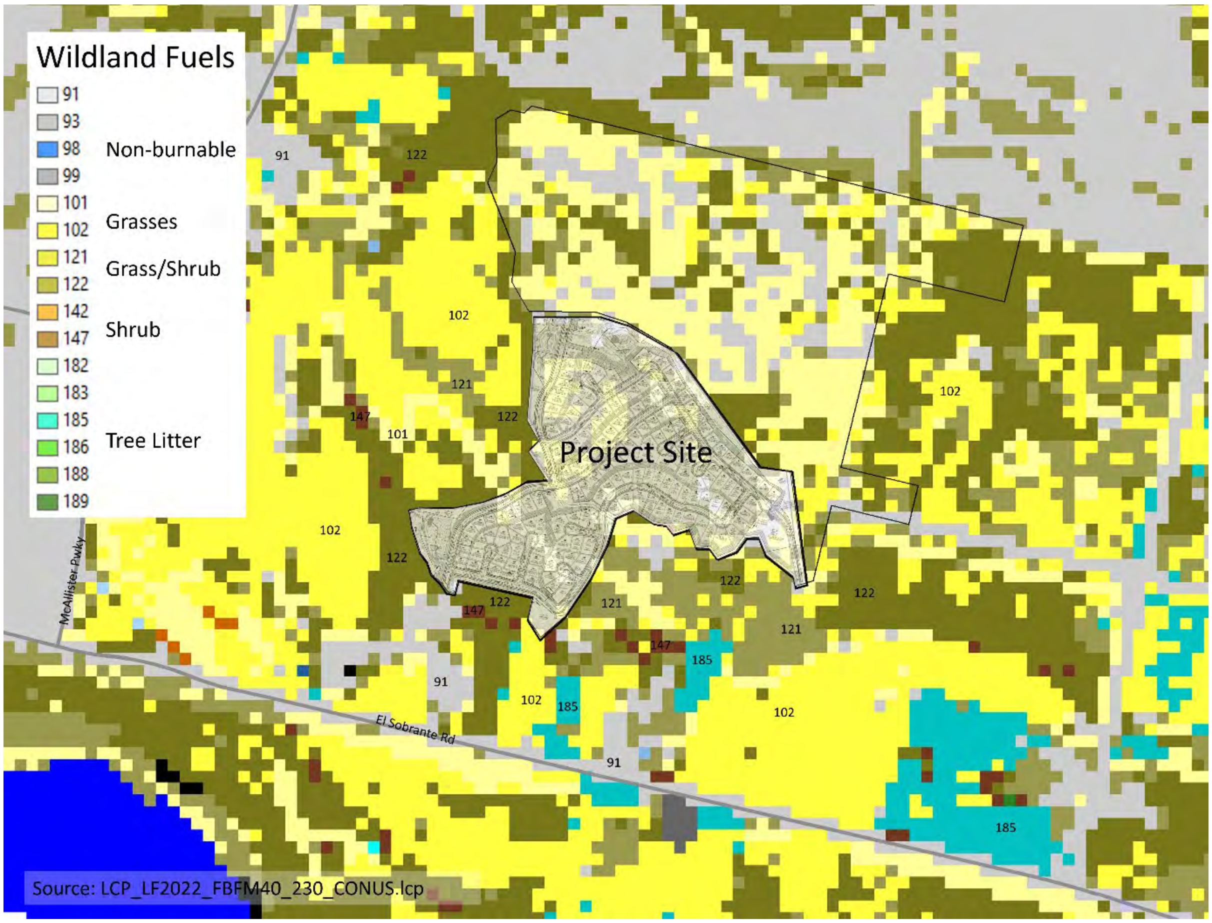


Figure 5 – Wildland Fuels Map – Landfire database

In Figure 5 (Wildland Fuels Map), the yellows are grasses (GR), the army green are grass /scrub mixes (GS), the orange and brown are the scrub fuels (SH), and the blue/greens are the tree litter fuels (TL).

Figure 6 indicates the existing vegetation class of wildland fuels as delineated by the Landfire database. In this graphic it is easier to see the difference between the grasslands, shrublands and tree canopy fuels. Figure 7, on the next page, provides the Existing Vegetation Types (EVT) as determined in the Landfire database for the EVT file.

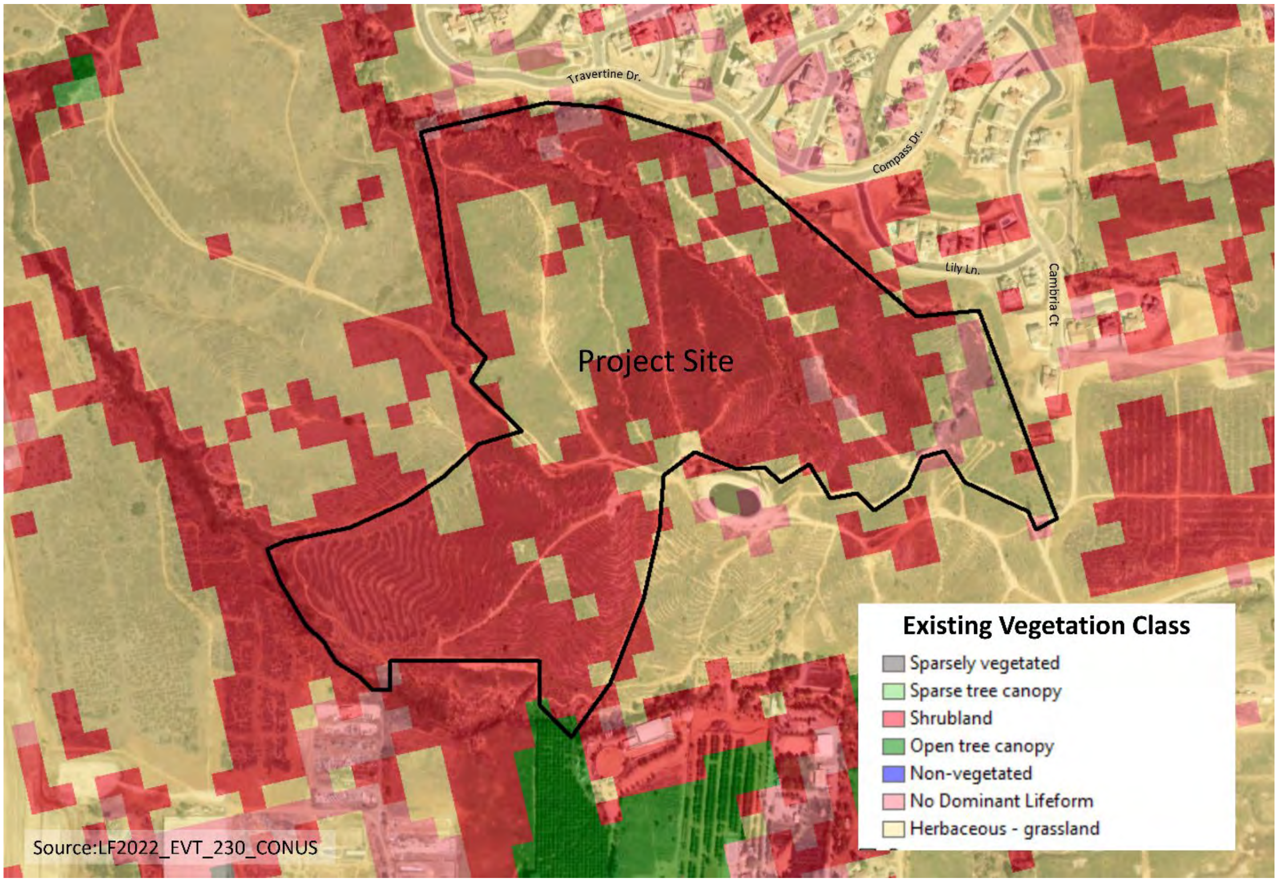


Figure 6 – Existing Vegetation Class – Landfire database

It should be noted that the areas to the northeast and southwest of the project site were and continue to be developed prior to the project site being developed. These adjacent developments have been superimposed on this area for reference (Figure 8). Citrus Heights (Northeast of Project Site) is completed, and Lake Ranch has been graded, streets are in, and homes are being constructed.

The development of the area to the northeast has reduced the wildland interface between the two projects to a thin strip of riparian drainage that bisects the two projects. This is true to a lesser degree for the southwest project area; although a similar drainage exists to the west, southwest and south of the project site development area (mixed interface but still fragmented from a wildland fuel perspective).

The new developments, El Sobrante road and the location of Lake Mathews combine to create a mosaic of fuel beds to the S, SW, and W of the Project Site. Large expansive runs of fuels are not as common and will continue to decline as more of the area is ultimately developed. The current conditions represent the worst-case scenario.

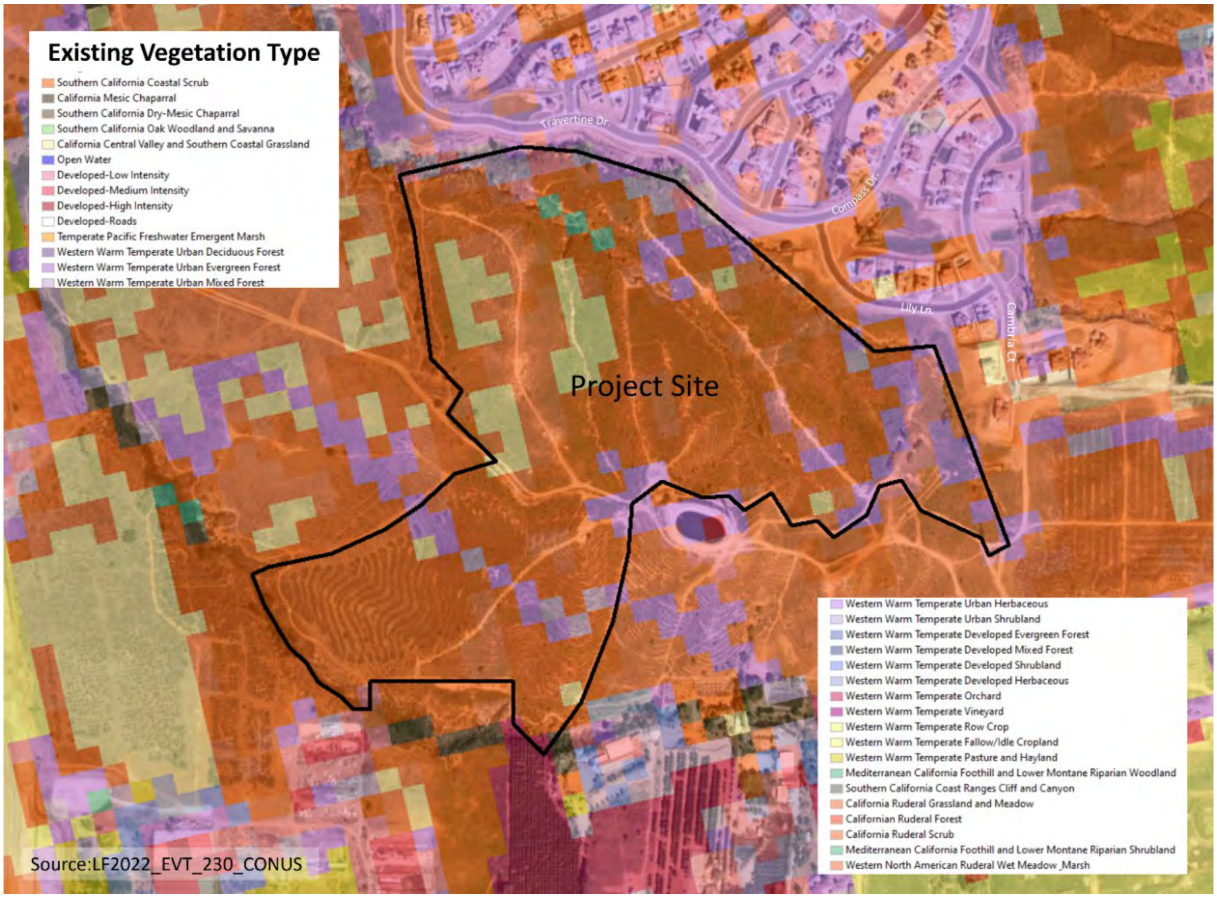


Figure 7 – Existing Vegetation Type– Landfire database

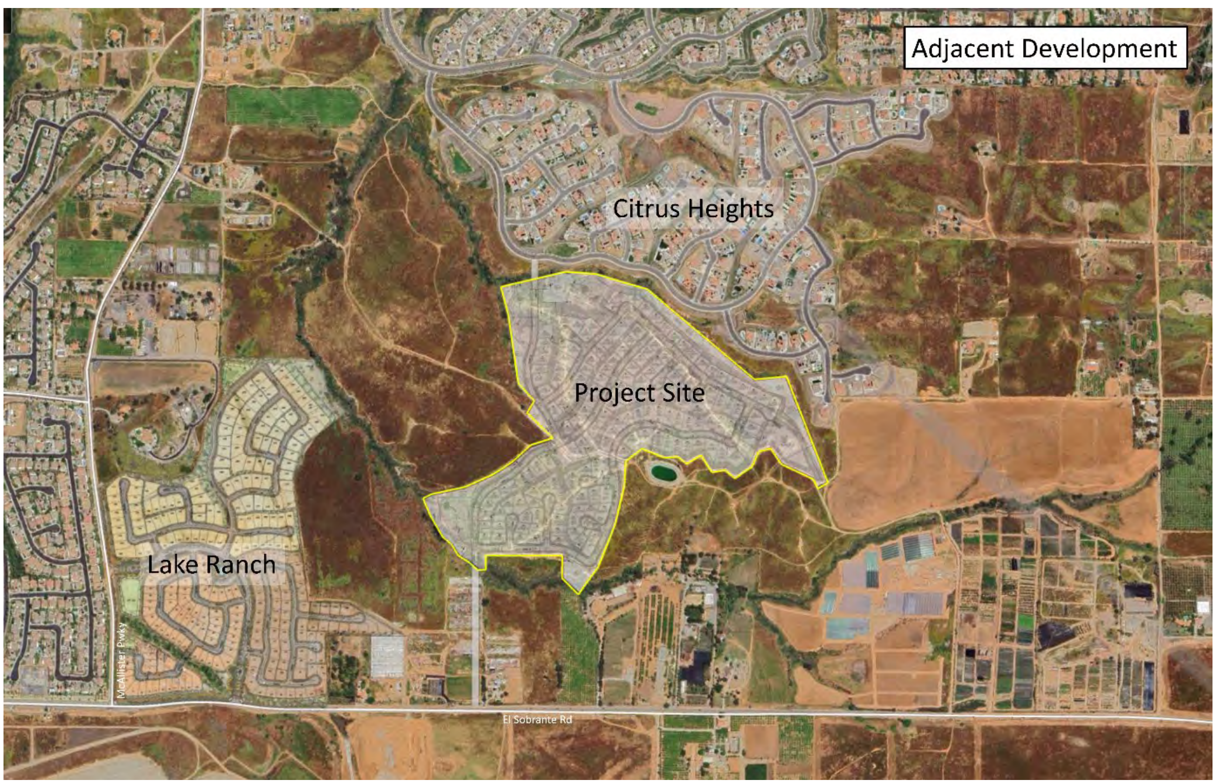


Figure 8 – Adjacent Communities Map

Fuels Summary

The predominant fuels in or near the project site are grasses, grass/scrub mixtures and shrubs. At the bottom of each of the main drainages are willow trees, scrub and nonnative vegetation such as palm trees/ornamentals. Below and on the following pages, a series of photos are used to show the predominant vegetation on the site. More detailed photos are contained in Appendix B of this report. While all of the existing vegetation will be removed in the development areas, the drainages and areas adjacent to the project site to the north and east will be maintained as habitat/open space areas with little to no management of these areas other than the possible removal of nonnative species.

Photo 1 shows the typical interface with shrub fuels. Mostly shrub fuels in this small pocket near the riparian to the south. This fuel type is limited to a few small areas on the perimeter of the project site.

Photo 1 – Shrub Fuels

Fuels within the projects site and adjacent to the project site are relatively sparse in most areas. Grasses will grow between the scrubs on wet years, but most years will have limited fine fuels to carry the fire from one group of scrubs to the next. Since the area has had no large fire history and little evidence is shown onsite of fire activity, it is safe to assume that this is the fuel configuration that will be present on the site.

Photo 2 shows the interface of the vast majority of the area around the project site. The area has been disked over time and maintained free of shrubs in most areas for some time. Currently this area is moderate grass and other herbaceous fuels. Much of the area is classified as either seasonal grasses or Southern California Coastal Scrub with the possible development of full SCAL18 fuel bed in periods where there is more rainfall.


Photo 2 – Grass and Grass/Shrub Fuels

Photo 3 (below) shows an example of the interface with the riparian open space and the existing fuel modification zones to the northeast. Note that most of the fuels within the riparian are recessed into the drainage.


Photo 3 – Existing Fuel Modification Zones (adjacent development)

Photo 4 (below) shows an example of an area of fuel on site where the bottom of the drainages can have moderate to significant growth. These areas maintain their live fuel moistures year-round with urban runoff and other water sources. Exotic and invasive plants which are not native species will be removed from these areas.

Photo 4 – Drainage Fuels

Slope

Slope can influence the direction of travel, intensity, and rate of spread of a fire more than anything other than wind (within a given fuel type). The majority of the site interface with moderate fuel loading is the riparian drainage that runs on both sides (north and south) of the project site development area. For fire modeling purposes, the slope is averaged over 30-meter grids. Figure 9, on the next page, provides a graphic of the slope averages from the Landfire database. It should be noted that no areas within the graphic exceed 16% slope, when average over the 30-meter grid. For the worst-case scenario, a slope of 50% will be used. Small areas of slope greater than 50% do exist on the banks of the riparian drainage but not in amount sufficient enough to greatly impact fire behavior above the 50% impact being used for the modeling. Photo 4 above is a good example of this condition.

Aspect

Aspect is important, especially when it aligns with the fuel, wind and slope. Figure 10 on the next page provides the slope aspects for the same 30-meter grids used in the slope and vegetation graphics. While there are areas where the aspect aligns with the wind, these areas are within the fuel modification zones and as shown earlier in Slope Map (Figure 9), lack significant slope in the interface areas beyond the fuel modification zones, expect in the riparian drainages. The limited slope (15%) reduces the overall impact of aspect, as shaded areas on the northern faces are not created and this does not produce conditions which increase fuel moisture due to aspect.

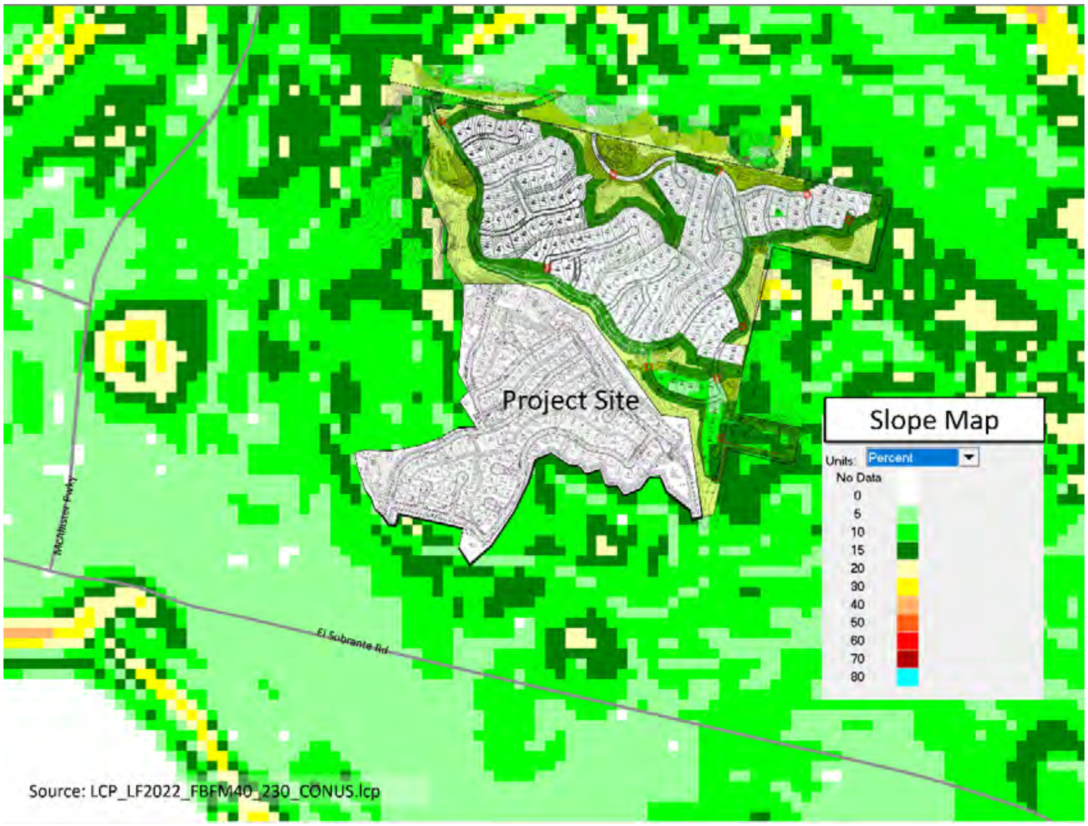


Figure 9 – Slope Map – Landfire database

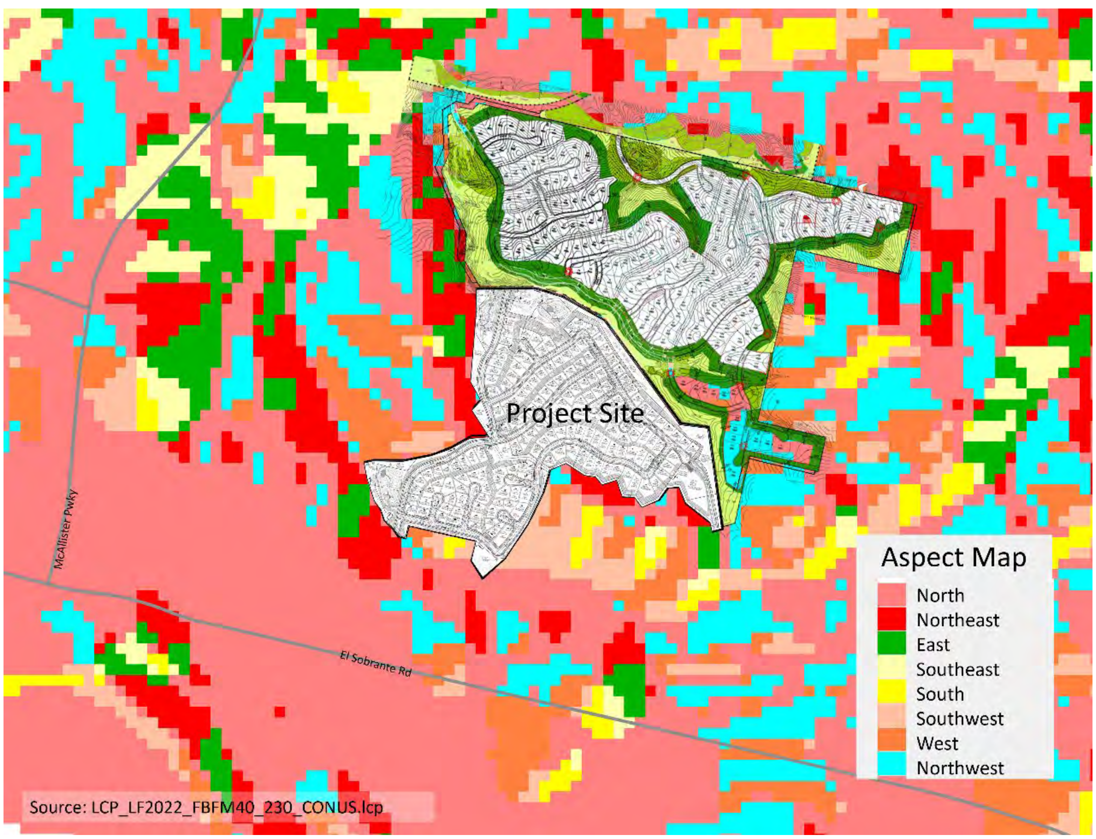


Figure 10 – Aspect Map - Landfire database

Wind Patterns and Weather Inputs

After a review of the local PWS (Private Weather Station) and RAWS (Remote Automated Weather Station) data, the most extreme wind patterns and speeds relating to wildfires were entered into the modeling programs (Behave and Wind Ninja). Lesser wind patterns and wind speeds normally produce less fire intensity based on a fire in wildland fuels and as such are not considered in the worst-case calculations. Several PWS are available in the area of the project, but most have limited data. The closest PWS, with reliable data, is directly above the project site to the N of the project site (KCRIVER18). The site is 2.8 miles to the north. The location is shown in Figure11. KCARIVER18 is actually not currently in service at the time of this report but historical data was available and has been used to illustrate some of the historical weather observations which are relevant to this analysis.

A summary graph (Figure 12 on next page) shows the predominant wind direction is from the west at that location. The occasional Santa Ana Wind event brings a north or northeast wind. Note the higher wind gusts are associated with the east and northeast wind events. The maximum wind for the 7+year period shown was 27 mph with a 31-mph wind gust.

Figure 11 – Weather Data Location Map

The Lake Mathews RAWS is located 3.5 miles to the Southwest of the Project Site and has a large database. An 11-year period was used for the data analysis (Jan 2013 to Dec 2023). The results of that data analysis are provided in Figure 13, on the next page. While the dataset shows a wind gust of 84 mph, it occurred only once in 11 years. Wind gusts greater than 50 mph occurred only seven times in this same period which represents over 0.001% of the data points in the dataset.

Sustained wind (Wind in this dataset) is the average wind speed of over two minutes, whereas wind gusts are a burst in wind that lasts less than 20 seconds.

Figure 12 – PWS Data

Lake Mathews RAWS

	1/1/13 4:16	**Start**	
STATION: MHEC1	12/31/23 3:16	**End**	
STATION NAME: LAKE MATHEWS	4,016	**Days**	
LATITUDE: 33.816940	11.0	**Years**	
LONGITUDE: -117.463610			
ELEVATION [ft]: 1516.0	96,096	**Data Points**	

	Temp	**RH**	**Wind**	**Dir**	**Gust**
Min	33	1	0.0	0.0	0.0
Max	114	100	50.0	360.0	84.0
Avg	66	53.4	6.1		11.0
99th	97	100.0	22.0		34.0
1st	42	7.0	0.0		3.0

Greater than	**Wind**		**Gust**	
90			-	
80			1	0.001%
70			1	0.001%
60			5	0.01%
50			33	0.03%
45	1	0.001%	94	0.1%
40	6	0.01%	319	0.3%
30	138	0.2%	1,762	1.8%
20	1,542	1.7%	11,250	11.8%
10	20,074	22.5%	44,425	46.4%
0	89,221		95,704	

Figure 13 - - Lake Mathews RAWS Data Summary

When the wind data is analyzed by direction, it is clear to see that the stronger winds are from the N, NNE, and NE, as shown below in Figure 14 and Figure 15. In Figure 14, the offshore wind is highlighted in light red, and the onshore flow is highlighted in yellow. The predominant wind is from the NNW and NW (green highlight in Figure 14). This is likely due to the influence of Temescal Canyon which is west of the RAWS site.

Lake Mathews RAWS										
				Wind Speed (mph)						
			Cardinal	<20	>20	>30	>40	>50	>60	>70
N	7,184	7.5%	N	7,059	125	9	1	-	-	-
NNE	7,197	7.5%	NNE	6,474	723	77	3	1	-	-
NE	5,679	5.9%	NE	5,527	152	19	2	-	-	-
ENE	5,661	5.9%	**ENE**	5,639	22	2	-	-	-	-
E	5,347	5.6%	**E**	5,303	44	9	-	-	-	-
ESE	3,266	3.4%	**ESE**	3,253	13	2	-	-	-	-
SE	3,580	3.7%	SE	3,551	29	1	-	-	-	-
SSE	5,637	5.9%	SSE	5,591	44	7	-	-	-	-
S	5,835	6.1%	S	5,815	20	3	-	-	-	-
SSW	2,290	2.4%	SSW	2,263	26	5	-	-	-	-
SW	1,558	1.6%	SW	1,532	26	1	-	-	-	-
WSW	1,877	2.0%	WSW	1,791	86	3	-	-	-	-
W	2,656	2.8%	**W**	2,571	85	-	-	-	-	-
WNW	5,923	6.2%	**WNW**	5,876	47	-	-	-	-	-
NW	12,821	13.3%	NW	12,764	57	-	-	-	-	-
NNW	14,259	14.8%	NNW	14,216	43	-	-	-	-	-
0	5,326	5.5%	**Null**	-	-	-	-	-	-	-
Blank	-	0.0%								
	96,096	100.0%		89,225	1,542	138	6	1	-	-
				92.85%	**1.60%**	**0.14%**	**0.01%**	**0.001%**		

Figure 14 - Lake Mathews RAWS Data Summary -Directional

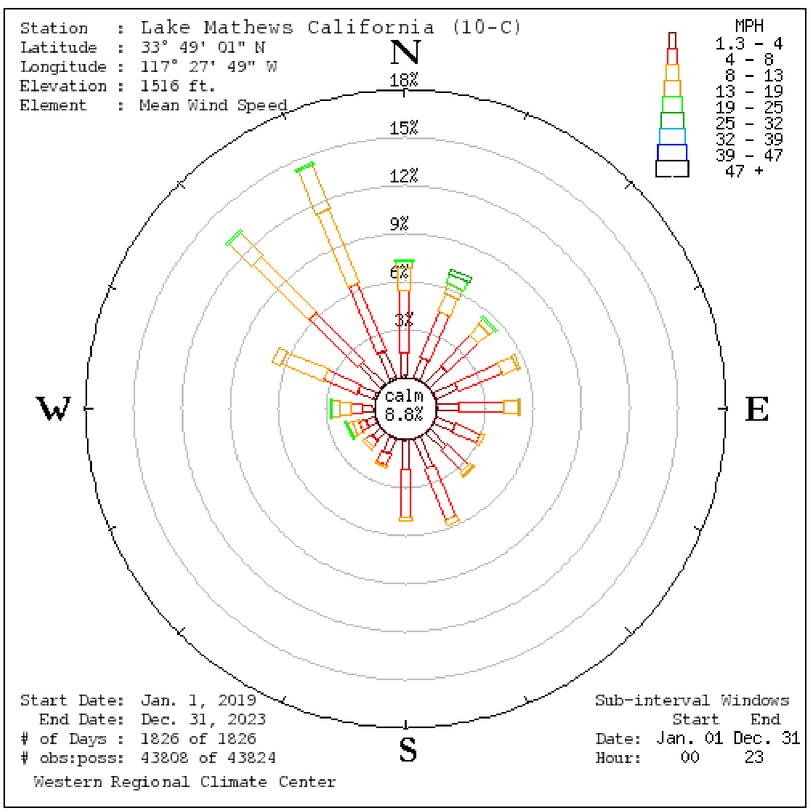


Figure 15 – Lake Mathews RAWS Wind Rose

Viewing the wind data by time of year (Figure 16), we see that the day/night patterns for the wind in the area of the project site are different in the fall. Wind from the NE increases, especially during the daytime period as shown in Figure 16, on the next page. This is consistent with the stronger winds shown in Figure 14, above.

For the purposes of the modeling in this report to produce the worst-case scenario, offshore winds will be assumed to be 50 mph and the onshore winds 30 mph.

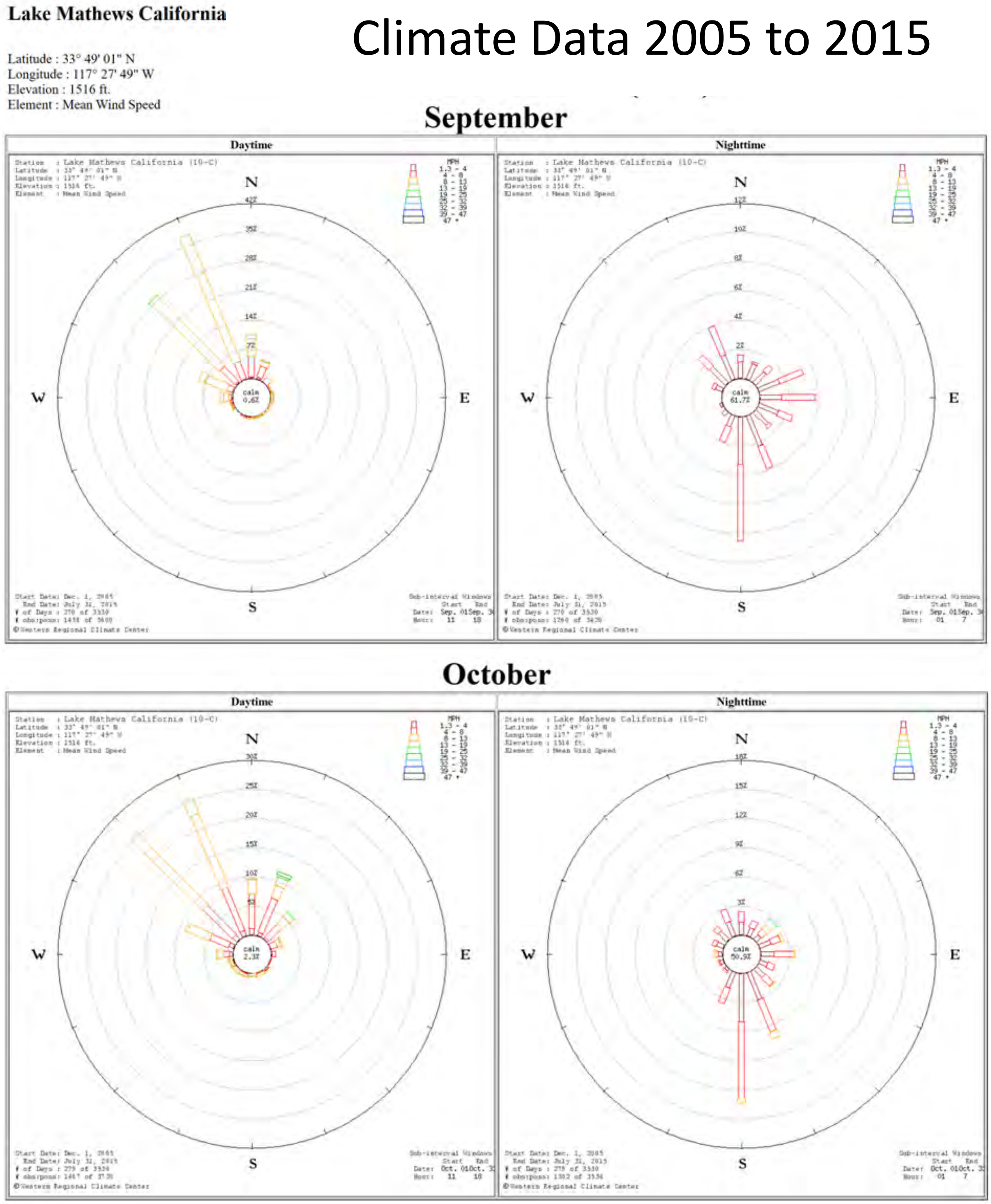
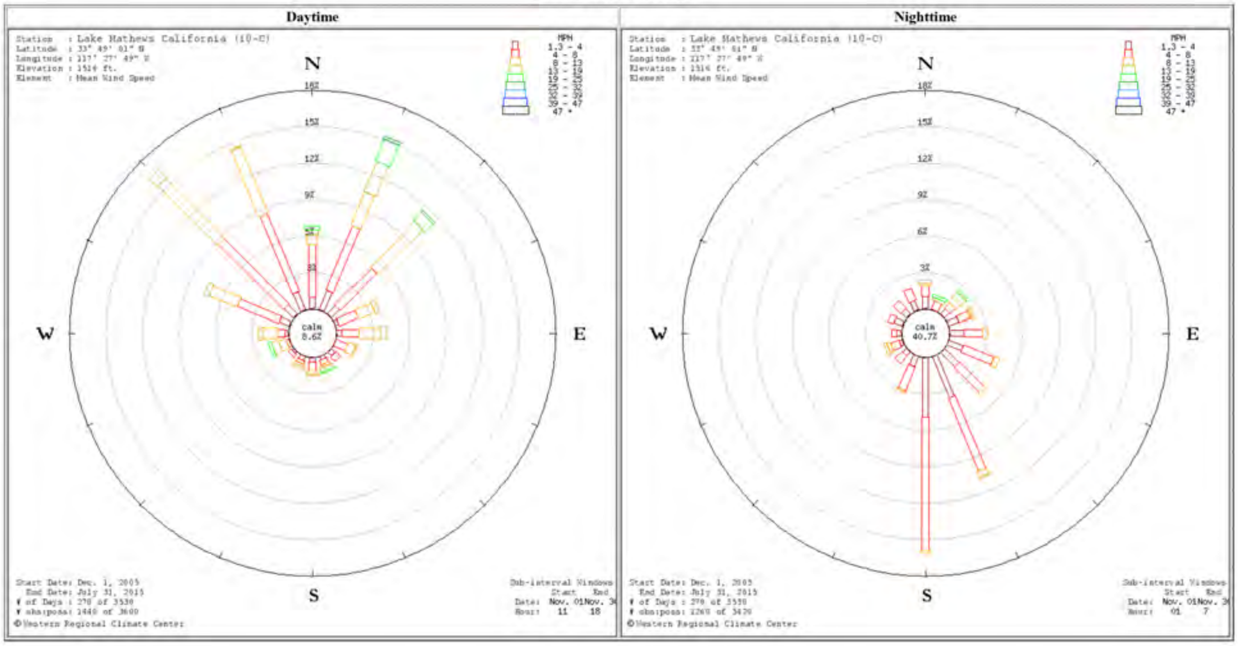


Figure 16 – Time Series Wind Direction 1

The four-month series shows the daytime/nighttime diurnal shift in wind flow and the increase NE flow (NNE, NE, ENE) associated with the Santa Ana wind events that occur each fall (they can and do occur all year long but are most impactful in the fall). Stronger daytime winds during the daytime are very pronounced in the November/December timeframe at this location (for this ten-year period 2005-2015) and are consistent with the current winds data from the RAWS site.

November



December

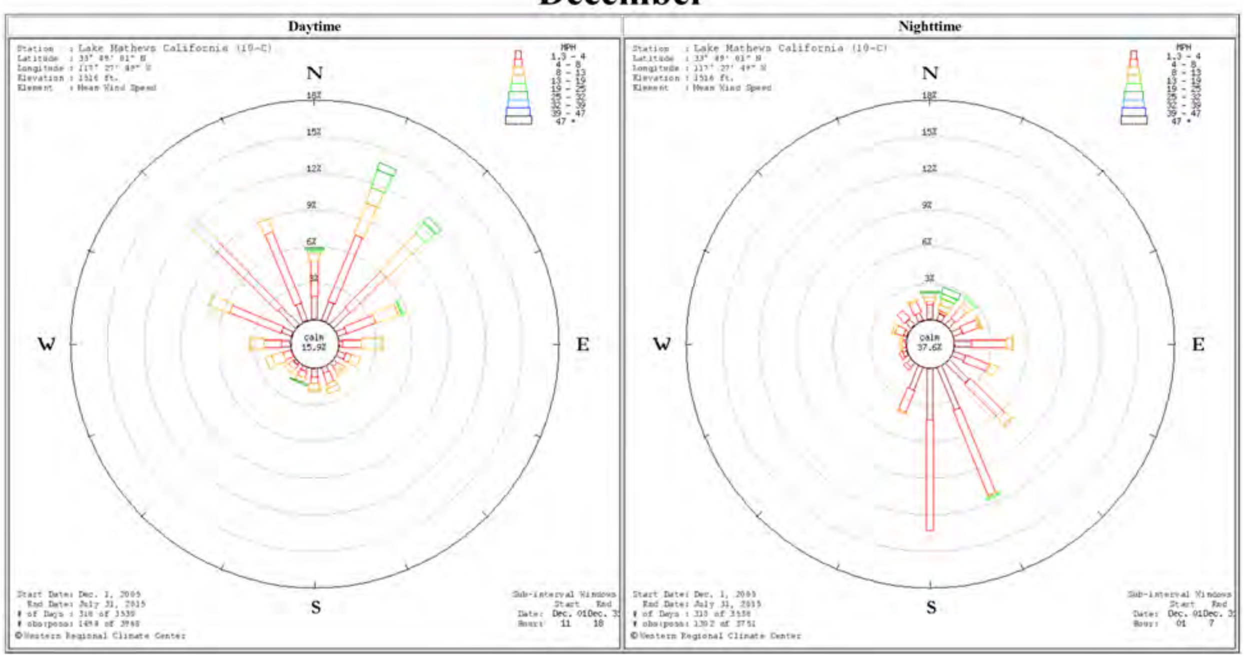


Figure 17– Time Series Wind Direction 2

Projecting these winds onto the topography is an important step in the analysis of the potential impact on the project site. This has been accomplished using Wind Ninja software, downloaded from the US Forest Service site (Missoula Fire Sciences Laboratory at the Rocky Mountain Research Station (RMRS) within the Fire, Fuel, and Smoke Science (FFS) Program). Version 3.8.1 has been used for this report.

South Wind

The south wind is prominent in the nighttime periods of the database. The impacts to the project site are provided in Figure 18. Impact areas are mostly in the southeast interface. Wind acceleration occurs in the red areas of the Wind Ninja output (overlayed onto the project site). The blue areas are wind sheltered (lower wind) and this occurs along the riparian drainage to the south for its entire length (interface). The topography does not channel the wind (change the direction) mostly due to the lack of significant changes in the elevation or large steep slope areas.

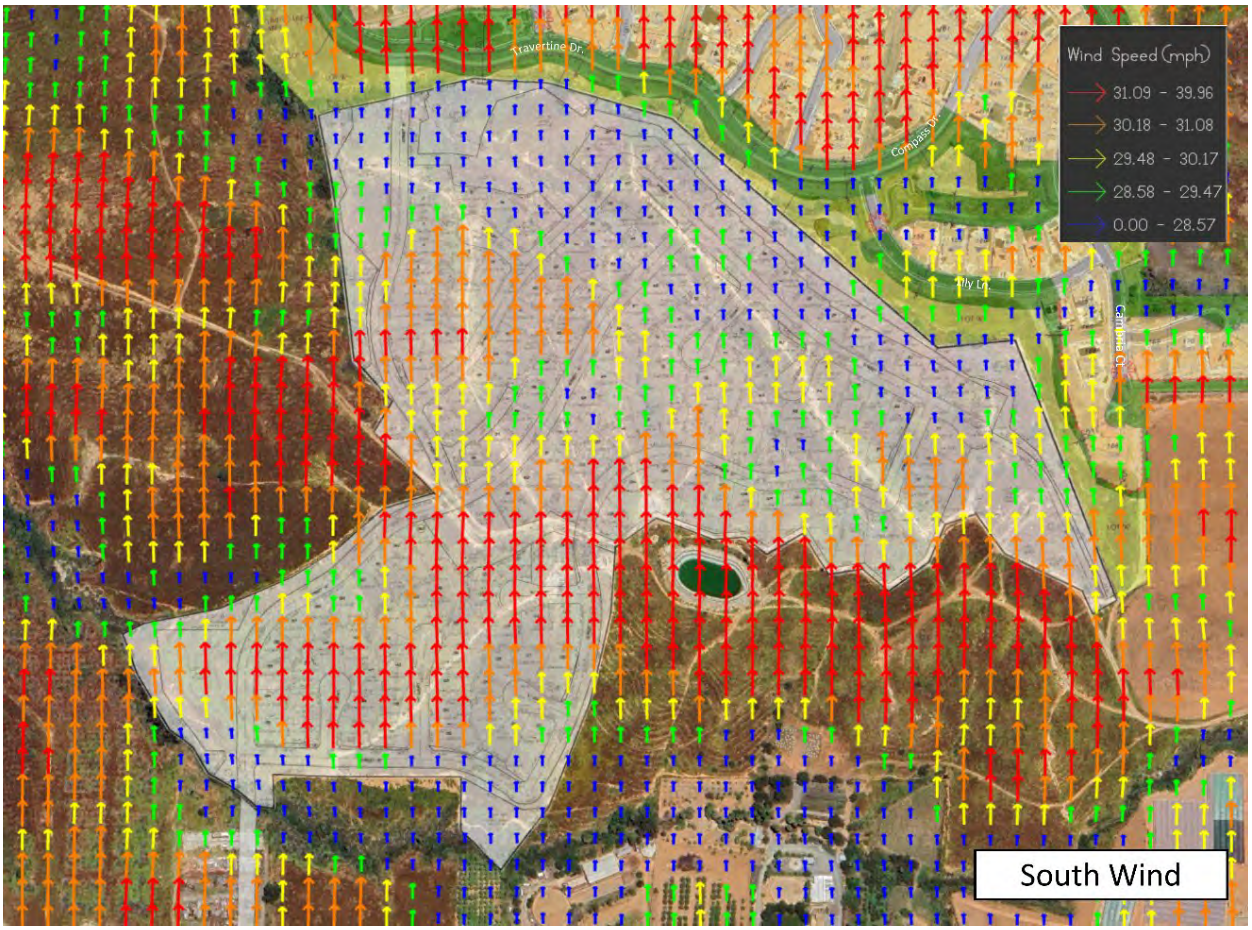


Figure 18 – South Wind

North Wind

The entire north interface is wind sheltered on the north side of the project (Figure 19). This riparian drainage is significantly lower than the adjacent areas in most of the interface. The development to the north is higher than the project site along the majority of the riparian drainage. The east end of this interface is flatter, and the wind is less sheltered at this point. This entire interface (northern) abuts the fuel modification zones of the development to the north (Citrus Heights). The amount of wildland fuel in this interface is limited. The north wind takes fire away from the majority of the project site.

Northeast Wind

The northeast wind also impacts the site mostly from the development area to the north and also has a large amount of wind sheltering along the riparian drainage for the same reasons as the north wind. For the balance of the project site, the winds either take fire away from the side or run parallel to the project site structures. Impacts are lessened in this configuration. Santa Ana winds (hot and dry) will normally come from this direction. These winds generally start from the north and move around to the ENE as they subside with the NE flow being the strongest in most cases. The strongest winds measured at the Lake Mathews RAWS came from these Santa Ana conditions.

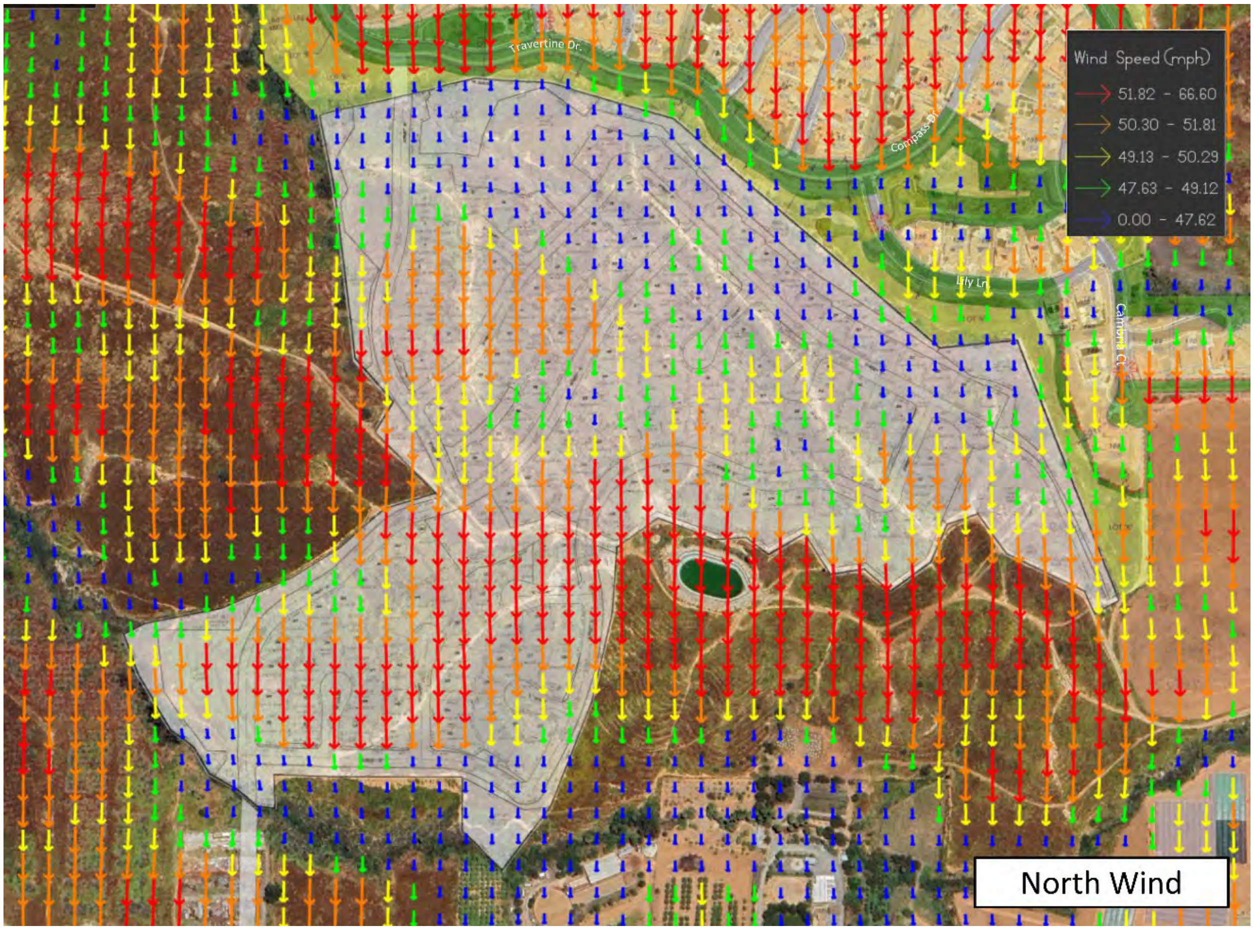


Figure 19 – North Wind

East Wind

East winds occur occasionally and are likely at the end of a Santa Ana wind event. These winds do not tend to be problematic for the project site as they either come from existing fuel modification areas or area of low to moderated wildland fuels as shown in Figure 21.

Much of the interface that has the denser fuel loading is wind sheltered by the drainage itself or by the adjacent topography. To the north and northeast, the existing development (Citrus Heights) presents both a winds obstruction and a fuel break to the riparian interface that will remain. This provides a condition where a fire cannot burn into the project site from that direction as a "line of fire" as the fuels simply do not exist. A fire in this area must originate from an ember or brand and then progress in size as the fuels are available. This is covered in more detail in the next section.

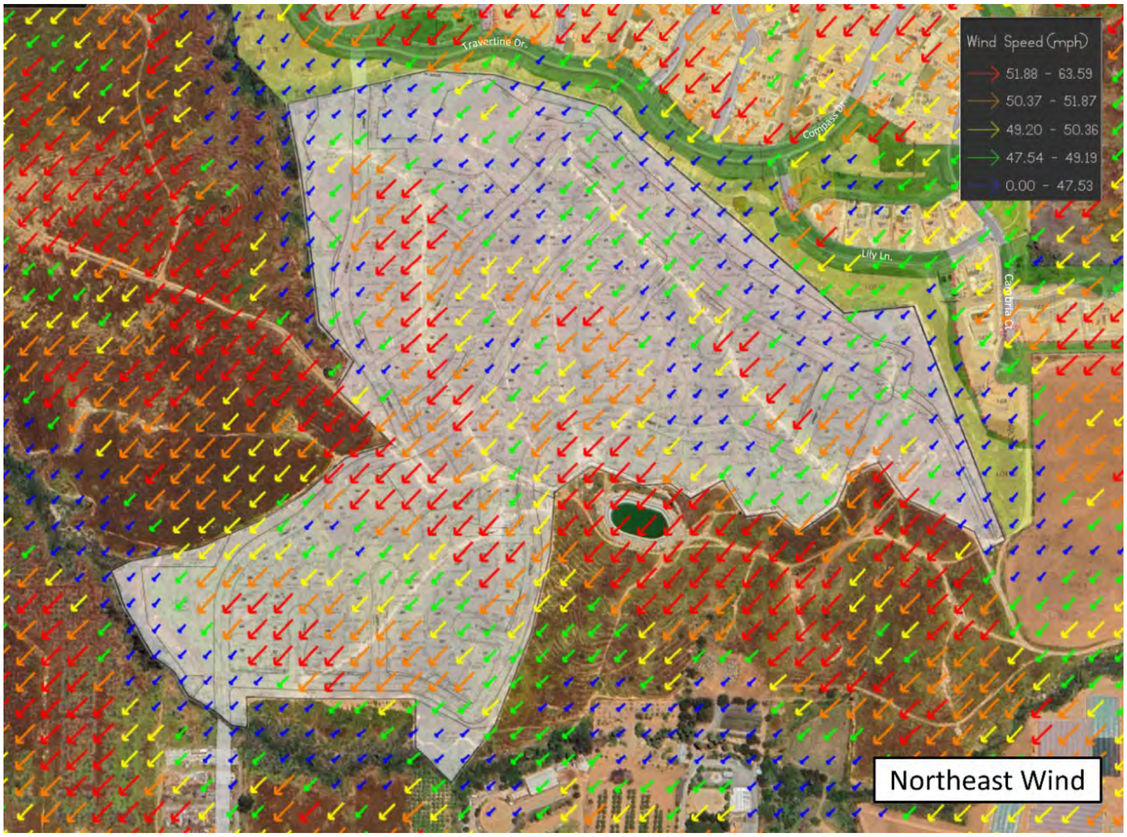


Figure 20 – Northeast Wind

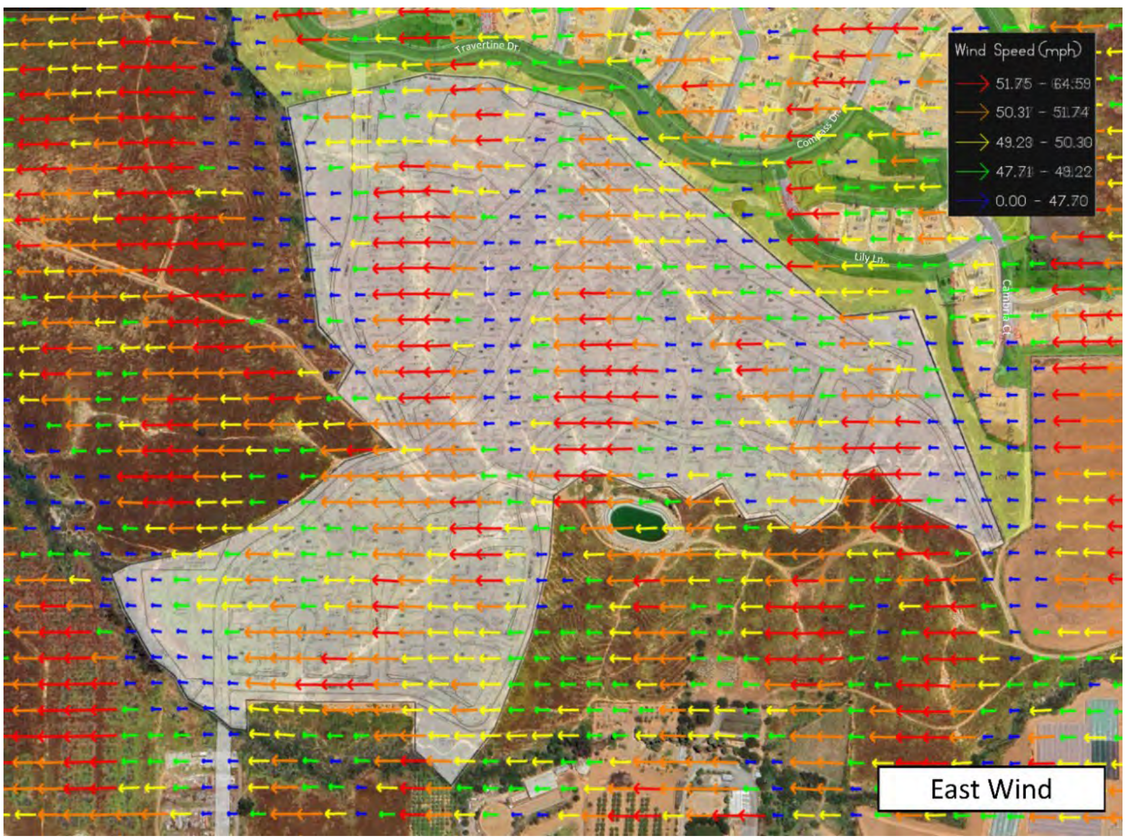


Figure 21 – East Wind

BehavePlus Fire Behavior Inputs and Results:

Inputs for the Behave Plus Fire Behavior Model were as follows:

Moisture scenarios used are extreme. One-hour fuels at 3%, ten-hour at 4% and hundred-hour at 5%. Herbaceous live fuels are modeled at fully cured (30%) and woody fuels at 50%. Model runs have been completed on the two wind scenarios.

Behave runs have been completed for both the NE Santa Ana wind and the onshore W wind. The moisture scenarios are unchanged to simulate the rear dry onshore that can occur when the Santa Ana winds break down and on shore flow is resumed but the air immediately offshore is the dry air that has been pushed out to see by the NE wind event. This condition is rare and only lasts for a short period of time as the air further out to sea, will have increased moisture level when then return to the land by the onshore breeze. The inputs for the Behave runs are shown below (Figure 22).

The Behave outputs are attached in Appendix B but have been summarized here for discussion purposes (Figure 23).

Inputs: SURFACE

Input Variables		Units	Input Value(s)
Fuel/Vegetation, Surface/Understory			
	Fuel Model		gr2, gs2, sh2, scal18, tl6
Fuel Moisture			
	1-h Fuel Moisture	%	3
	10-h Fuel Moisture	%	4
	100-h Fuel Moisture	%	5
	Live Herbaceous Fuel Moisture	%	30
	Live Woody Fuel Moisture	%	50
Weather			
	20-ft Wind Speed	mi/h	30/50
	Wind Adjustment Factor		0.4
	Wind Direction (from north)	deg	225/45
Terrain			
	Slope Steepness	%	50
	Site Aspect	deg	225/45
Fire			
	Surface Fire Spread Direction (from north)	deg	0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, 195, 210, 225, 240, 255, 270, 285, 300, 315, 330, 345, 360

Figure 22 – ***Behave Input Values***

Using the "Spread from Fire Perimeter" configuration for the modeling, it is possible to see how each portion of the fire line will be impacted by the wind and slope of the scenario provided. The fire has been modeling running directly uphill in alignment with the wind and slope. As expected, the head fire at 225 degrees (fire is from 45 degrees) the maximum outputs are found.

As shown in Figure 23 and in Appendix B, in the grass/shrub mixtures (gs2) the maximum flame length under these conditions is 19.2 feet while in the SCAL18 fuels, the maximum flame length is nearly twice that (39.4 feet). The SCAL18 fuel has more readily available fine fuels which dramatically increase the flame production. The project site has little to fuel bed of six feet or greater (sh5 or sh7) and certainly none in large continuous fuel beds. The worst-case scenario has been completed using the SCAL18 fuels for this reason.

It should be noted that the Landfire database found only small pockets of shrub fuels (145 and 147), and these were all in or adjacent to the various riparian drainages around the project perimeter. The Landfire database concluded that the project and most of its interface as a gs2 (122) due to the short height of the fuels. The site visit confirmed this conclusion but also found conditions where SCAL18 is either currently being established or is likely to be established in the future if mitigation is not undertaken to prevent that from occurring. This analysis will assume the SCAL18 hazard is present for the worst-case scenario.

Greentree NE 50 mph
Spread from Fire Perimeter
Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	2.0	2.2	1.8	4.4	1.0
15	1.8	2.0	1.7	4.0	0.9
30	1.7	1.9	1.6	3.8	0.9
45	1.7	1.9	1.6	3.8	0.9
60	1.7	1.9	1.6	3.8	0.9
75	1.8	2.0	1.7	4.0	0.9
90	2.0	2.2	1.8	4.4	1.0
105	2.3	2.6	2.1	5.1	1.2
120	2.9	3.4	2.8	6.8	1.5
135	4.4	6.1	5.0	12.2	2.7
150	6.7	10.7	8.9	21.9	4.8
165	8.6	14.1	11.7	28.9	6.3
180	9.9	16.4	13.6	33.7	7.4
195	10.9	18.0	14.9	37.0	8.1
210	11.4	18.9	15.7	38.8	8.5
225	11.6	19.2	16.0	39.4	8.6
240	11.4	18.9	15.7	38.8	8.5
255	10.9	18.0	14.9	37.0	8.1
270	9.9	16.4	13.6	33.7	7.4
285	8.6	14.1	11.7	28.9	6.3
300	6.7	10.7	8.9	21.9	4.8
315	4.4	6.1	5.0	12.2	2.7
330	2.9	3.4	2.8	6.8	1.5
345	2.3	2.6	2.1	5.1	1.2
360	2.0	2.2	1.8	4.4	1.0

Greentree SW 30 mph
Spread from Fire Perimeter
Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	9.9	12.0	10.2	27.9	5.4
15	10.9	13.2	11.2	30.5	5.9
30	11.4	13.8	11.7	32.0	6.2
45	11.6	14.0	11.9	32.5	6.3
60	11.4	13.8	11.7	32.0	6.2
75	10.9	13.2	11.2	30.5	5.9
90	9.9	12.0	10.2	27.9	5.4
105	8.6	10.4	8.8	24.1	4.6
120	6.7	8.1	6.9	18.7	3.6
135	4.4	5.3	4.5	12.0	2.4
150	2.9	3.5	2.9	7.7	1.5
165	2.3	2.7	2.3	6.0	1.2
180	2.0	2.3	1.9	5.1	1.0
195	1.8	2.1	1.8	4.7	0.9
210	1.7	2.0	1.7	4.5	0.9
225	1.7	2.0	1.7	4.4	0.9
240	1.7	2.0	1.7	4.5	0.9
255	1.8	2.1	1.8	4.7	0.9
270	2.0	2.3	1.9	5.1	1.0
285	2.3	2.7	2.3	6.0	1.2
300	2.9	3.5	2.9	7.7	1.5
315	4.4	5.3	4.5	12.0	2.4
330	6.7	8.1	6.9	18.7	3.6
345	8.6	10.4	8.8	24.1	4.6
360	9.9	12.0	10.2	27.9	5.4

Figure 23 – Behave Results Summary

The NE wind at 50 mph results in a significant spread across the entire leading head of the fire as shown by the graphic below.

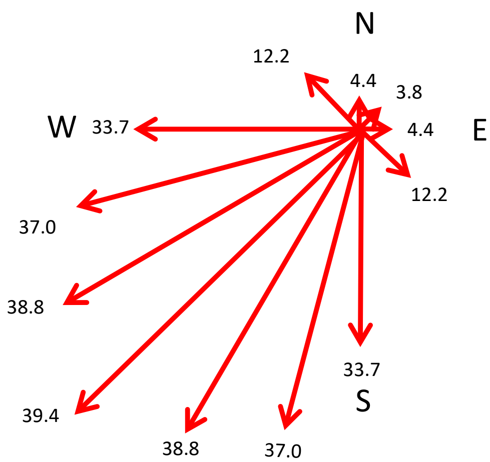


Figure 24 – Fire Direction Ellipse

As shown on the charts and graphic in Figure 23 and Figure 24, the calculated flame lengths for each of the directions of spread for the worst-case scenarios modeled produce a long narrow fire pattern. We find that a maximum flame length of 39.4 feet is possible at the head of the fire, when the fire is running directly upslope with a continuous fuel bed that is consistent enough to produce a self-sustaining, self-propagating fire. It is important to note that flames up to 45 degrees out of the perfect alignment of all the factors are still significant. Flanking and backing fire are significantly reduced with only the backing fire capable of suppression with hand tools and hoselines.

The example shown is for the 50-mph wind running upslope (50% slope) in full alignment with the wind, topography and fuels using a SCAL18 fuel model. These outputs assume that the fire is burning at full equilibrium and that the worst-case factors are constant and continuous as the fire moves into the development area. Similar relationships exist with the rate of spread and the fireline intensity.

The general defensible space requirements have been based on the northeast winds and have resulted in the need for 80-foot fuel modification areas adjacent to the SCAL18 fuels, but these are reduced to 50 for the sh2 and gs2 fuels (16.0/19.2-foot maximum flame length respectively). Grass only interfaces are not currently present in large areas and are unlikely to be present in the future as the interface pushes out to the riparian areas and most of the interface areas will be on slopes. A grass only interface is not a recommendation that can be made from the modeling and factors found in this report.

Results for the 30 mph west or southwest winds (onshore) are similar, but flame lengths are slightly less. The SCAL18 maximum is 32.5 (requiring a 65-foot fuel modification area from the onshore wind), the sh2 is 11.9 and the gs2 is 14.0. This report does not recommend a distance less than 50 feet, regardless of the modeling results unless a physical barrier is provided to shield the subject lot from the radiant heat of a fire in the native fuels. This will be covered in more detail in the location specific discussion later in this report.

Application of Findings

The next analysis in the determination of the fire hazard profile is to examine the potential for a fire within the interface to damage or ignite a structure within the Project Site. This can happen in one of four ways. First is direct contact with the fire. The maximum flame length is 40 feet (39.4 feet). Any distance greater than this will keep the flames off of the structure. Second is radiant heat. The laws of physics indicate that the decay of radiant heat is calculated by dividing the energy produced by the square of the distance from the heat source. While this is simplified, it is overall very accurate.

The NFPA Fire Protection Research Foundation published a report entitled *Pathways for Building Fire Spread at the Wildland Urban Interface*, in 2015. The work was done by staff at the University of Maryland. The report states:

> *The first is radiant exposure. Unlike convection heat transfer, which requires a moving fluid medium, radiation can travel relatively undeterred until impeded by a solid object, typically thought of here as the exterior of a home which may potentially ignite. As the separation distance from the home to the fire increases, the radiant exposure significantly decreases (**proportional to one over the distance squared**), eventually making it impossible at some distance to ignite. This analysis is often used for assessment of safe separation distances between structures and potential fuels.*
>
> Michael J. Gollner, Raquel Hakes, Sara Caton, and Kyle Kohler, *Pathways for Building Fire Spread at the Wildland Urban Interface, Final Report*, prepared by: Department of Fire Protection Engineering, University of Maryland, Published by Fire Protection Research Foundation/NFPA March 2015, Page 26

In Figure 25, this principle has been applied to the heat generated by the worst-case fire scenarios. In this matrix, the remaining energy at specific distances is provided in the colored boxes. Green boxes are an energy level at or below 10 kW/m^2 (generally considered to be safe for hardened structures) and those in the red boxes are more than 20 kW/m^2 (the level at which structures may ignite with extended exposure). Figure 26, on the next page) provides a chart to show the impacts of selected energy rates.

It cannot be understated that this applies to structure and not to people. While a structure could take a radiant heat rate of 20 kW/m^2, and not ignite for over five minutes, at 18 kW/m^2, 50% of the people exposed to this rate will die after 30 seconds. At 12.5 kW/m^2, this level of heat will produce second degree burns in 8 seconds but will take 20 minutes to ignite exposed wood.

Jack Cohen's Structural Ignition Assessment Model (SIAM) also provided data on radiant heat flux as a factor of the amount of time for which the exposure to radiant heat impacted the ignition of the building material. In the example shown in Figure 27, on the next page, the as the temperature decreases, the time to ignition increases dramatically.

For reference it should be noted again that the same level of radiant heat (16 kW/m^2) that will produce 2nd degree burns on exposed skin in five seconds requires 27 minutes to ignite a wood wall in Jack Cohen's testing of radiant heat flux. This is about time and distance. The values shown in Figure 28 (Table 1 from Cohen's report) show the various heat flux values that have been used as thresholds for many of the fire safety zone studies and radiant heat studies on structures. These come from *Modeling Potential Structure Ignitions from Flame Radiation Exposure with Implications for Wildland/Urban Interface Fire Management*, by Jack D. Cohen and Bret W. Butler, presented at the13th Fire and Forest Meteorology 81 Conference. Lorne, Australia 1996 and are in line with the values used from several sources to produce Figure 26.

Fuel Model gs2 — Distance to Fire (ft)

20-ft Wind Wind	Flame Length (ft)	Fireline Intensity (kW/m^2)	Flame Angle		Flame Height	10	15	20	25	30	35	40	45	50	55	60	65	70	75
						100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625
0	5.1	677	90	1.000000	5.1	7	3	2	1	1	1	0	0	0	0	0	0	0	0
10	7.9	1,775	30	0.500000	4.0	18	8	4	3	2	1	1	1	1	1	0	0	0	0
20	11.1	3,692	15	0.258819	2.9	37	16	9	6	4	3	2	2	1	1	1	1	1	1
30	14.0	6,122	10	0.173648	2.4	61	27	15	10	7	5	4	3	2	2	2	1	1	1
40	16.7	8,960	10	0.173648	2.9	90	40	22	14	10	7	6	4	4	3	2	2	2	2
50	19.2	12,145	10	0.173648	3.3	121	54	30	19	13	10	8	6	5	4	3	3	2	2

3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope

Fuel Model sh2 — Distance to Fire (ft)

20-ft Wind Wind	Flame Length (ft)	Fireline Intensity (kW/m^2)	Flame Angle		Flame Height	10	15	20	25	30	35	40	45	50	55	60	65	70	75
						100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625
0	4.8	585	90	1.000000	4.8	6	3	1	1	1	0	0	0	0	0	0	0	0	0
10	7.1	1,387	30	0.500000	3.6	14	6	3	2	2	1	1	1	1	0	0	0	0	0
20	9.6	2,688	15	0.258819	2.5	27	12	7	4	3	2	2	1	1	1	1	1	1	0
30	11.9	4,279	10	0.173648	2.1	43	19	11	7	5	3	3	2	2	1	1	1	1	1
40	14.0	6,095	10	0.173648	2.4	61	27	15	10	7	5	4	3	2	2	2	1	1	1
50	16.0	8,098	10	0.173648	2.8	81	36	20	13	9	7	5	4	3	3	2	2	2	1

3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope

Fuel Model SCAL18 — Distance to Fire (ft)

20-ft Wind Wind	Flame Length (ft)	Fireline Intensity (kW/m^2)	Flame Angle		Flame Height	10	15	20	25	30	35	40	45	50	55	60	65	70	75
						100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625
0	13.1	5,314	90	1.000000	13.1	53	24	13	9	6	4	3	3	2	2	1	1	1	1
10	22.6	17,212	30	0.500000	11.3	172	76	43	28	19	14	11	8	7	6	5	4	4	3
20	28.2	27,891	15	0.258819	7.3	279	124	70	45	31	23	17	14	11	9	8	7	6	5
30	32.5	38,152	10	0.173648	5.6	382	170	95	61	42	31	24	19	15	13	11	9	8	7
40	36.2	48,152	10	0.173648	6.3	482	214	120	77	54	39	30	24	19	16	13	11	10	9
50	39.4	57,962	10	0.173648	6.8	580	258	145	93	64	47	36	29	23	19	16	14	12	10

3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope

Fuel Model tu5 — Distance to Fire (ft)

20-ft Wind Wind	Flame Length (ft)	Fireline Intensity (kW/m^2)	Flame Angle		Flame Height	10	15	20	25	30	35	40	45	50	55	60	65	70	75
						100	225	400	625	900	1225	1600	2025	2500	3025	3600	4225	4900	5625
0	7.3	1,493	90	1.000000	7.3	15	7	4	2	2	1	1	1	1	0	0	0	0	0
10	10.8	3,454	30	0.500000	5.4	35	15	9	6	4	3	2	2	1	1	1	1	1	1
20	13.8	5,918	15	0.258819	3.6	59	26	15	9	7	5	4	3	2	2	2	1	1	1
30	16.4	8,616	10	0.173648	2.8	86	38	22	14	10	7	5	4	3	3	2	2	2	2
40	18.7	11,479	10	0.173648	3.2	115	51	29	18	13	9	7	6	5	4	3	3	2	2
50	20.8	14,471	10	0.173648	3.6	145	64	36	23	16	12	9	7	6	5	4	3	3	3

3, 4, 5, 30, 50 moisture scenario, 0.5 wind adjustment, 50% slope

Figure 25 – Heat Decay Matrix

In the test fires that Jack Cohen used for this study, a fire which was 2.5-meter-wide, and 20 meters high was used to show the impacts on radiant heat flux of spacing within the fuel bed. All four burn scenarios had radiant heat flux values of 20 kW/m^2 or less at a distance of 40 meters (2 times the flame height) as shown in Figure 29.

The conclusion Jack Cohen reached was that after 40 meters, radiant heat was no longer a problem regardless of the size of the fire. At 30 meters and about 30 kW/m^2 ignition time was only 90 seconds but at 40 meters and 20kW/m^2 the ignition time was over 800 seconds. In this test, the flame was 20m high and 50m wide. The 2x flame length ratio was achieved in this test fire as well. See Figure 30 for a graphic example of this conclusion.

Btu/s/ft² Rate	kW/m² Rate	Time to Ignition seconds	Time to Ignition minutes	
17.3	60	10	0.17	
14.4	50	16	0.27	
11.6	40	28	0.47	
10.7	37			Damage to process equipment and collapse of mechanical structures
9.0	31	60	1.00	
8.7	30	66	1.10	
6.4	22	210	3.50	
5.8	20	337	5.50	Piloted wood ignition after 5.5 minutes
5.2	18			Death in 50% of victims after 30 seconds
4.6	16			Blistering of exposed skin after 5 seconds
3.6	12.5	1,200	20.00	20 minutes to ignition/2nd degree burn in 8 seconds
2.9	10			Pain on exposed skin after 3 sec/ death in 1% of victims after 40 seconds
2.0	7			Max exposure in PPE for 90 sec
1.8	6.4			Pain on exposed skin after 8 sec
1.4	5.0			2nd degree burns on exposed skin in 40 seconds
1.2	4.3	18,000	300.00	5 hours to ignition
1.2	4.0			First degree burns after 20 seconds
0.7	2.3			Pain on exposed skin after 2 minutes
0.6	2.1			Minimum to cause pain after 60 second
0.5	1.7			Minimum to cause pain
0.3	1.0			Equal to the maximum radiant heat transfer on a clear sunny day

Figure 26 – Impact of Radiant Heat

Jack Cohen's SAIM (Structural Ignition Assessment Model) uses a radiant heat flux threshold of 20 kWm2 for 5.5 minutes as the baseline for structure ignition. (Cohen, J. D., 1995, Structure Ignition Assessment Model (SAIM), USDA Forest Service Gen. Tech. Rep. PWS-GTR-158)

Minimum Ignition Time
vs Incident Radiant Heat

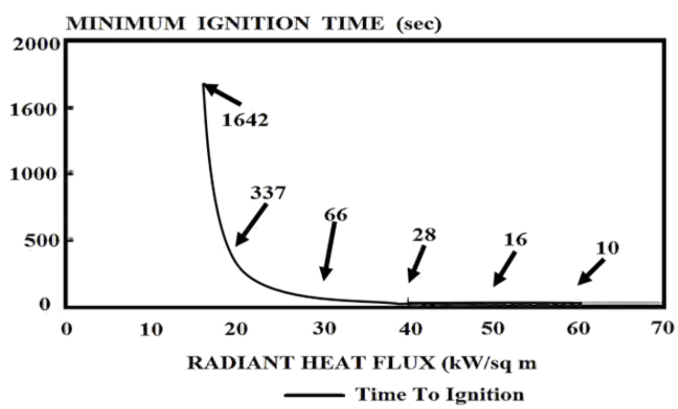


Figure 3. The minimum time for piloted wood ignition depends on the incident radiation heat flux (given as a constant_ that is greater than the critical heat flux of 13.1 kW/m².

Figure 27 – Radiant Heat vs. Minimum Ignition Time

Table 1. The effects of radiant exposure on human skin and wood indicate that humans are greatly more sensitive than wood during a WUI fire.

Heat Flux (kW/m^2)	Effect of Exposure
6.4	Pain on exposed skin after 8 secs. (Drysdale 1985).
7.0	Maximum estimated exposure for a firefighter wearing wildland firefighting clothing and head and neck protection over a period of approximately 90 secs, (Butler and Cohen 1997).
10.4	Pain on exposed skin after 3 secs. (Drysdale 1985)
16.0	Blistering of exposed skin after 5 secs. (Stoll 1969).
20.0	Piloted wood ignition after more than 5.5 minutes (ignition model).

Figure 28 - Jack Cohen, *Modeling Potential Structure Ignitions from Flame Radiation Exposure with Implications for Wildland/Urban Interface Fire Management Table 1*

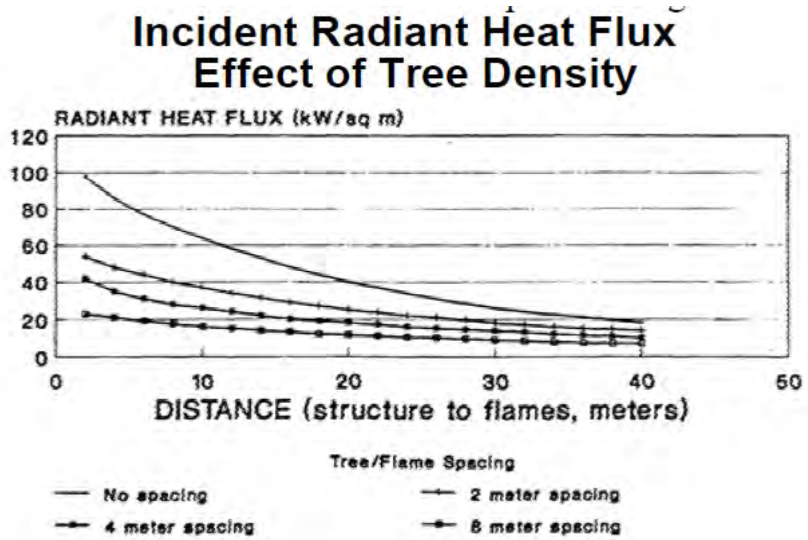


Figure 5. Given a constant flame size, the flame/trees are 2.5 meters wide, 20 meters high, and extend along a 50 meter flame front. The incident radiation heat flux depends on the flame-wall distance and the flame/tree spacing.

Figure 29 – Radiant Heat vs Distance

The third method of fire encroachment is convected heat. This impact area is generally about 75% of the radiant heat impact zone. While small pulses of convected heat may exceed the radiant heat zone and be a danger to the respiratory tracts of firefighters, these pulses are not sufficient enough in duration to cause ignition of structural materials.

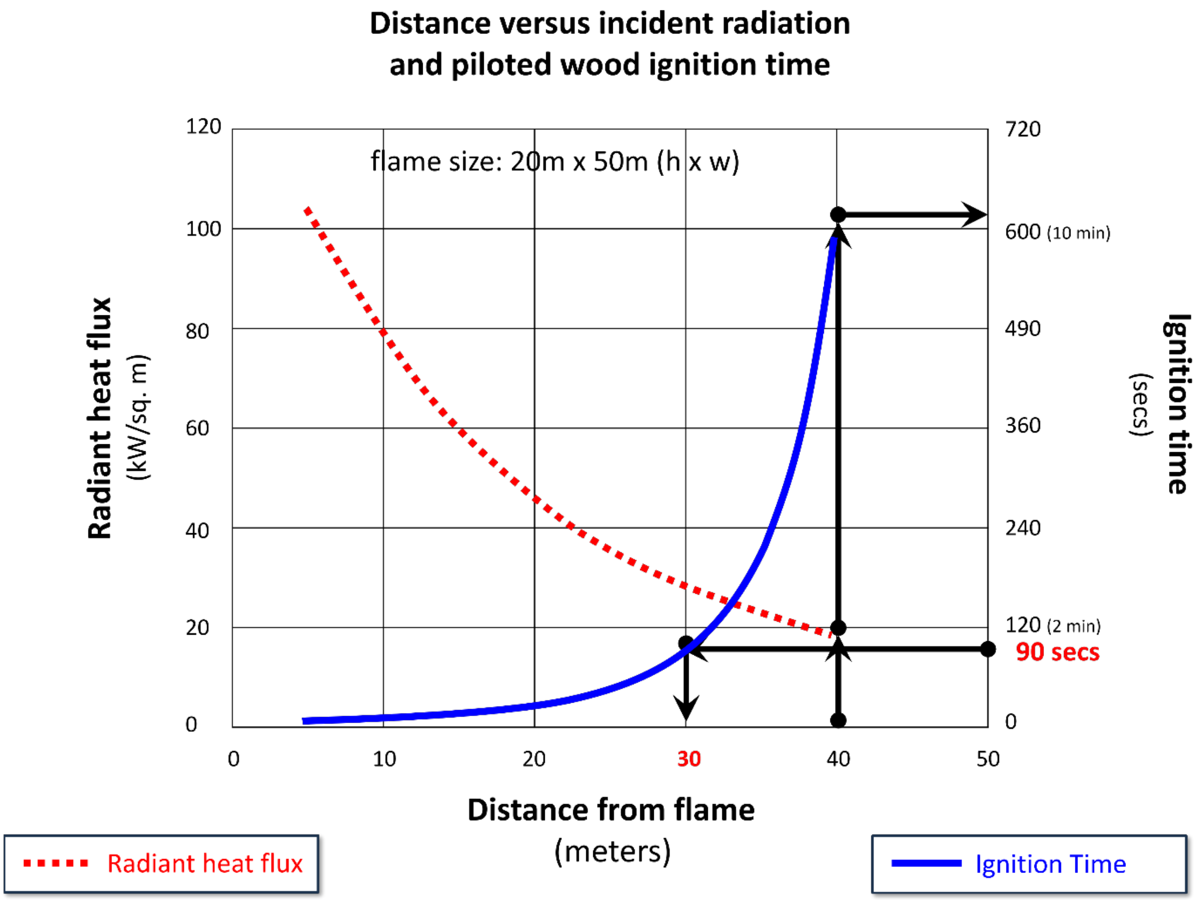


Figure 30 – SAIM Calculations for Radiant Heat Flux

Convection exposure is a more difficult issue as the science of this factor is limited with current studies underway to further expand our knowledge of this area of wildland fire science. Some facts are known:

> Radiative heat fluxes peak between 20 and 300 kW/m^2. The convective heat flux is characterized by rapid fluctuation between positive and negative convective values owing to alternating packets of cool air intermingled with hot combustion products. The convective heat flux peaks between 22 and 140 kW/m^2. *Frankman 2013, Measurements of convective and radiative heating in wildland fires, CSIRO Publishing, International Journal of Wildland Fire http://dx.doi.org/10.1071/WF11097, page K.*

> In a time-resolved heat flux data study from two different locations and times in the same prescribed fire event data was collected. They were grouped into a low intensity set (hereafter labelled Burn 1) and a moderate intensity set (hereafter labelled Burn 2). Both sets were evaluated to determine the effect of sampling rate on the interpretation of convective and radiative heat fluxes. Findings from the analyses have direct application to measurement methods and interpretation of energy transport measurements in wildland fires. *Frankman 2013b, The effect of sampling rate on interpretation of the temporal characteristics of radiative and convective heating in wildland flames, CSIRO Publishing, International Journal of Wildland Fire 2013, 22, 168–173 http://dx.doi.org/10.1071/WF12034*

Overall, fire convective energy is lower than fire radiative energy, but the peak energy pulses of the convective heat flux are greater in the convective heat than in the radiant heat (Figure 318 below). Convective heat has pulses of cooler air which lower the overall energy average as shown in Figure 32.

The point here is not to get into a discussion of how convective heat energy vs. radiant heat energy contributes to ignition of fuels but rather to show on the macro level that convective energy is not as likely to be a factor in structure ignition if the distance provided between the fire and structure are great enough to stop radiant heat from igniting it.

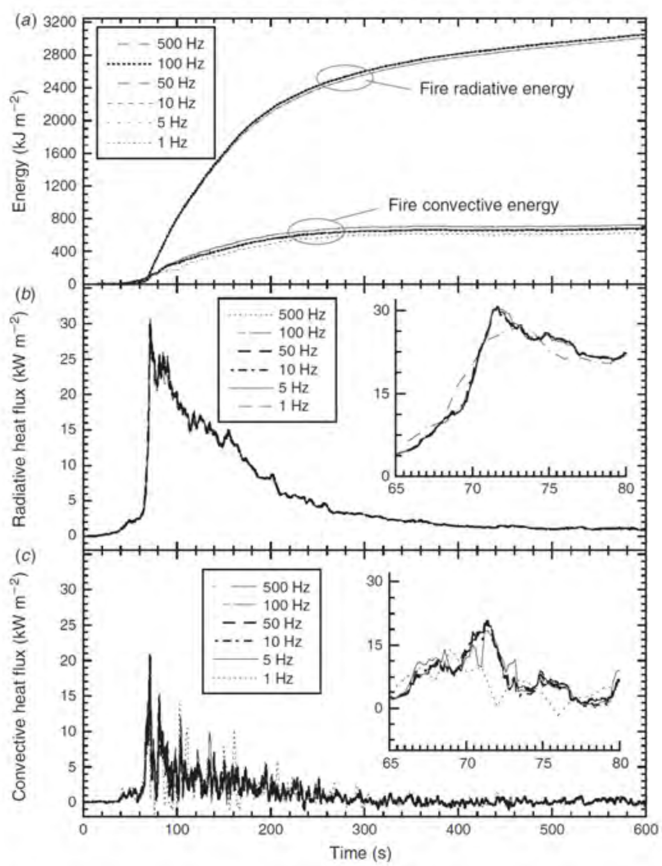


Fig. 2. Integrated energy and 2-s moving averages for Burn 2. (*a*) Fire radiative energy and convective energy calculated from integral of measured fluxes, (*b*) fluxes calculated using a 2-s moving average of the 500-, 100-, 50-, 10-, 5- and 1-Hz radiative flux signals, (*c*) fluxes calculated using a 2-s moving average the 500-, 100-, 50-, 10-, 5- and 1-Hz convective flux signals. Inset figures in (*b*) and (*c*) are included to further illustrate the difference in signal between the moving averages of the various sample rates over a short time frame.

Figure 31 – Convective Heat vs Radiant Heat

In Figure 32, notice how the blue lines (convective heat) exceed the red lines (radiant heat) but the overall average is less for the blue line AND the blue lines have negative (cooling) values whereas the red lines do not. It is not that convective heating by superheated gases does not play a role in fire propagation or in fire phenomena such as “area ignitions”, they do but the fuels and topography around the Project Site do not lend themselves to these issues.

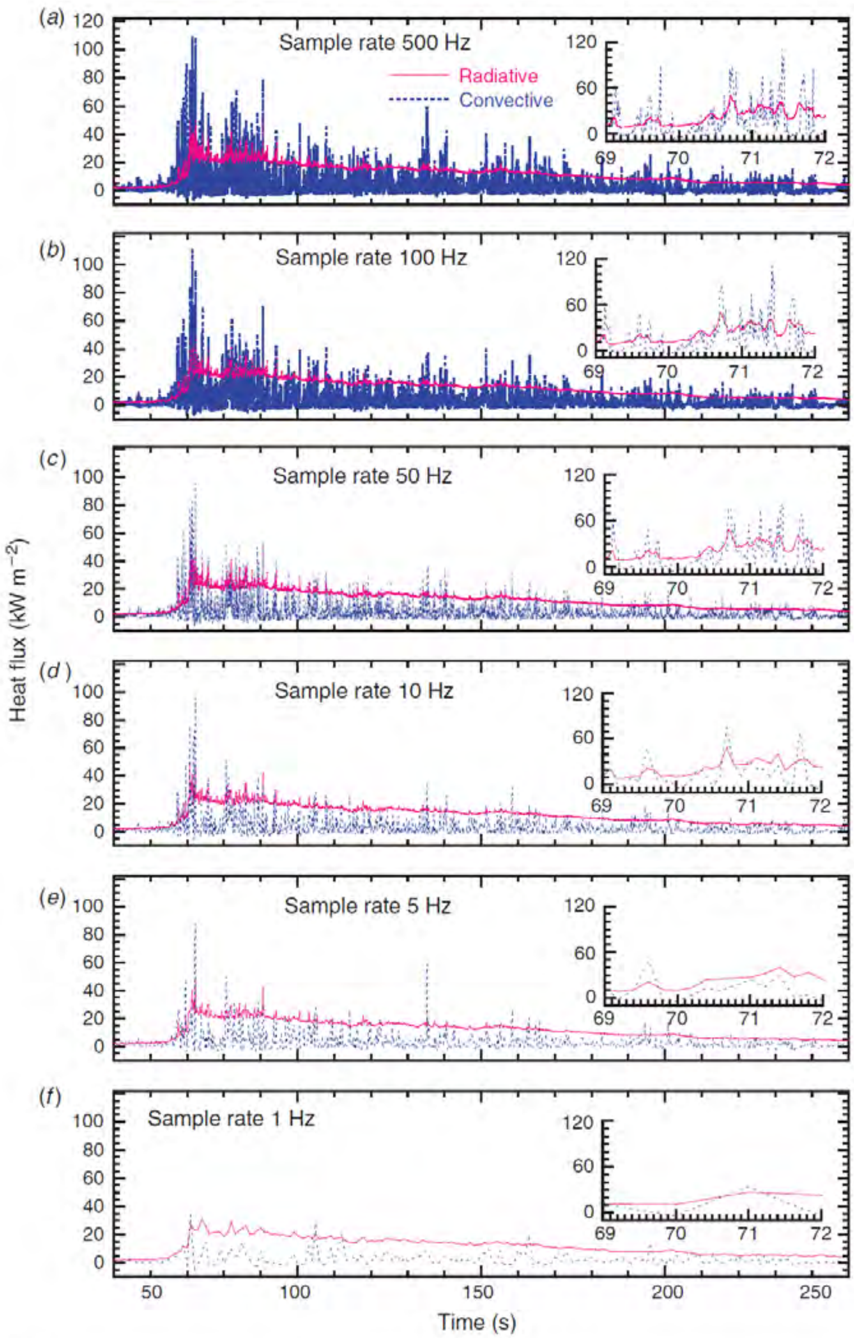


Fig. 1. The effect of sample rate on measured heat flux in Burn 2. (*a*) presents the initial signal captured at 500 Hz, (*b*) presents the 500-Hz signal down-sampled to 100 Hz and so on to 1 Hz for (*f*). The inset figures depict the signal over a 4-s time period centred at or near ignition.

Figure 32 – Convective Heat Rate

The final method of fire encroachment would be embers and brands. The Institute for Business and Home Safety (IBHS) makes the following statement:

> Buildings are ignited by embers and flames during wildfires. Flying embers and wind-blown, ground-traveling burning debris are by far the most prevalent attack mechanisms threatening structures during a wildfire. CAL FIRE identified embers

> as the major cause of home loss (Mell et al., 2010). Potter and Leonard (2011) reported that "well over 90% of houses were ignited in the absence of direct flame attack or radiant heat (exceeding 12 kW/m2) from the main fire front." Hence, embers cause a great deal of damage, whether directly or indirectly. *WILDLAND FIRE EMBERS AND FLAMES: Home Mitigations That Matter,Faraz Hedayati, PhD, Stephen L. Quarles, PhD, Steven Hawks, IBHS Research, April 2023,page 6.*

Embers can, and will, travel great distances. The Project Site will be protected from this threat by compliance with California Building Code Chapter 7A and California Residential Code Section R337 throughout.

Micro Modeling

Overall fire behavior calculations have been completed based on generalized site conditions using the worst-case conditions for each input to the model. At site specific locations, the model inputs can be adjusted to the actual data from those locations. Four such conditions will be addressed here. These areas include:

1) Lots 1, 14 and 15
2) Lots 19 - 32
3) Lots 33 and 34
4) Lots 100 -115 (except Lot 112)

Lots 1, 14 and 15

The area north of Lots 1, 14 and 15 has a large riparian area which will remain unmanaged and contains California Sage Scrub and will likely remain in this condition. While the project will remove the palm trees and pampas grass within the riparian areas, native species will not be abated in any fashion. Aligned with the NE and NNE wind, this fuel is below the project site building pads. It is possible to have a fire burn the entire 350 foot of fuel prior to impacting these three lots.

The only change in the inputs for the model is the slope which was reduced from 50% to 20% to reflect the actual locations conditions. This resulted in the maximum Flame Length (FL) being reduced to from 39.4 to 38.2, the Fireline Intensity (FI) calculating out at 54,084 kW/m and the Rate of Spread (ROS) being 229.1 feet per minute. As shown in Figure 34, a Radiant Heat Value of under 10 kW/m is achieved at a distance of 75 feet.

In order to protect these three lots, a combined distance of 75 feet (Zone 1 entirely) on and off the lot will be needed. The Lots will need to be deed restricted for "no combustible construction" within this distance (75 feet). Figure 33 details the interface and location of the required distance. A radiant heat wall will be required at the top of the slope on the lots (red lines next to the 20-foot setback (light blue area).

Figure 33 – Lots 1, 14 and 15 Setback

Lot 1 Behave Calculation

Dividing the Fireline Intensity by the distance squared, the Radiant Heat Value on the structure can be approximated. At 75 feet, the Radiant Heat Value is under 10 kW/m as shown below.

Flame Length 38.2'	Fireline Intensity 54,084 kW./m	Rate of Spread	229.1 ft/m

Radiant Heat Value	Distance (D)	D sq'd
21.6	50	2500
17.9	55	3025
15.0	60	3600
12.8	65	4225
11.0	70	4900
9.6	75	5625
8.5	80	6400

Figure 34

Lots 19 – 32

The riparian north and east of Lots 19 through 32 is comprised of a single drainage with riparian in the bottom of the flowline. This unmanaged area varies from 75 feet to just over 200 feet in width but is generally 100 to 150 feet in width with a significant change in elevation from the rim to the bottom and back up to the development on the opposite side. This area is connected to larger wildland areas only at the ends and not in the direction of the onshore or offshore winds.

Figure 35 – Lots 19 to 32 (yellow highlight)

Due to the limited amount of fuel in this area, a fire with a 40-foot flame length is simply not possible in the direction of the project site. It could occur running parallel to the project site but not in the direction of the project site. The reason for this is that a fire cannot burn into this area as an established "line of fire" but rather must burn from the ends or a fire must start from an ember or brand that land in a receptive fuel bed and accelerates to a fire burning in equilibrium to achieve a maximum flame length. Because of this factor, the area simply does not have the quantity of fuel necessary to accelerate and burn to the maximum flame length modeled in the Behave assumptions for this site.

Fire Acceleration

Fire acceleration can be defined as the rate of increase in spread rate/fire line intensity from a given source or as the rate of increase in spread rate from the current rate to an equilibrium spread rate under constant environmental conditions. Fire acceleration measures the amount of time required for a fire spread rate to achieve the theoretical steady state spread rate given: 1) current burning conditions and 2) constant environmental conditions. It should be noted that Fire acceleration is fuel dependent but independent of fire behavior. Acceleration is significantly impacted by wind conditions. The incorporation of acceleration means that fire spread rates will not immediately adjust to the equilibrium spread rates when conditions change but will have some lag time in reaching the new equilibrium.

The rate of fire acceleration is dependent on a “rate factor”. The default rate for acceleration to 90% of equilibrium rates is 20 minutes from a point source fire for brush and trees but less for grass fuels. Line source fires are known to accelerate much faster (Johansen 1987) than point source fires. Although the equilibrium spread rate is dependent on fuel conditions, the buildup or acceleration rate has been found to be fuel independent for a variety of fuel types (excelsior, pine needles, and conifer understories).

A single acceleration rate may not be accurate for all fuel types (McAlpine and Wakimoto 1991), especially between very different fuel types. Fire in grass fuels is expected to accelerate more rapidly than in slash fuels, but there is little data to guide these settings. Acceleration is presumed to be independent of fire behavior or eventual spread rate.

Fire acceleration is important because the flame lengths that are being discussed from the modeling in the Behave program assume that the fire has reached a self-sustaining equilibrium state. In the smaller areas of the project site and where fire could establish itself within an area that is perpendicular to the wind, the fire will not reach this point before it runs out of fuel. This is the rationale for diminished distances for some of the defensible spaces from interior fuel beds which are not directly connected to exterior fuel beds. In these instances, the fire must spot into the fuel bed, build to a steady burning state, and then continue to a state of equilibrium. When the amount of fuel is simply not available within the interface area, to complete this process, the over risk can be adjusted to the actual risk present for these areas.

If we assume that a fire doubles in size (flame length) every two minutes during the acceleration phase (wind driven fire), it is possible to see how far the fire might travel as it accelerated. Since the early acceleration does not use much fuel, we will begin to examine the fire when it reaches a five-foot flame length. At this point, it will be moving forward at about 3 feet per minute; two minutes later it will be a ten-foot flame length and will be traveling at 14 feet per minute; two minutes more (six total) the flame length is now 20 feet, and the fire is moving at 53 feet per minute. Somewhere around the seven-minute mark, this fire will have consumed over 100 feet of fuel and will only have a 25 foot +/- flame length. It would not be possible to exceed the 40-foot flame length maximum used in this report. The calculations are provided in Figure 38, to the left.

	Flame Length			
	5	**10**	**20**	feet
	2.7	13	48	chains
	66	66	66	
	178	858	3,168	feet
	60	60	60	
	3	14	53	ft/min
	60	60	60	
	0.05	0.24	0.88	ft/sec
2 min	5.94			feet
4 min		28.6		feet
6 min			105.6	feet
Running total (distance)	5.94	34.54	140.14	feet

Figure 36

The available fuel would be consumed before a flame length over 25 feet could be achieved.

Lots 33 and 34

Lots 33 and 34 are more problematic in that they do have a large upwind riparian area and they also have less fuel modification area available between the lot and the riparian. On these two lots, the distance will need to be provided on the lot (similar to Lot 1) OR a physical barrier will need to be provided to shield the proposed structure from the fire OR a combination of the two approaches.

Figure 37 – Lots 33 and 34 (yellow highlight)

There are three options to achieving this protection. The first option is to manage the slope and distance to achieve the desired heat shield using a radiant heat wall at the top of the slope. This is depicted in Figure 38. Option 2 (Figure 39) restricts the height of the proposed structure when the slope is not steep enough to provide the needed difference in elevation to allow the radiant heat wall to function as intended. Option 3 (Figure 40) utilizes a boulder wall or second radiant heat wall to create the heat shield needed for shorter distances or when the slope cannot be used effectively.

All three approaches are valid and can be used in combination to achieve the needed results. Details will need to be provided in the Final/Precise Fuel Modification Plan that justify the alternative selected for each of the two lots when the details regarding the building footprints and building profiles are known.

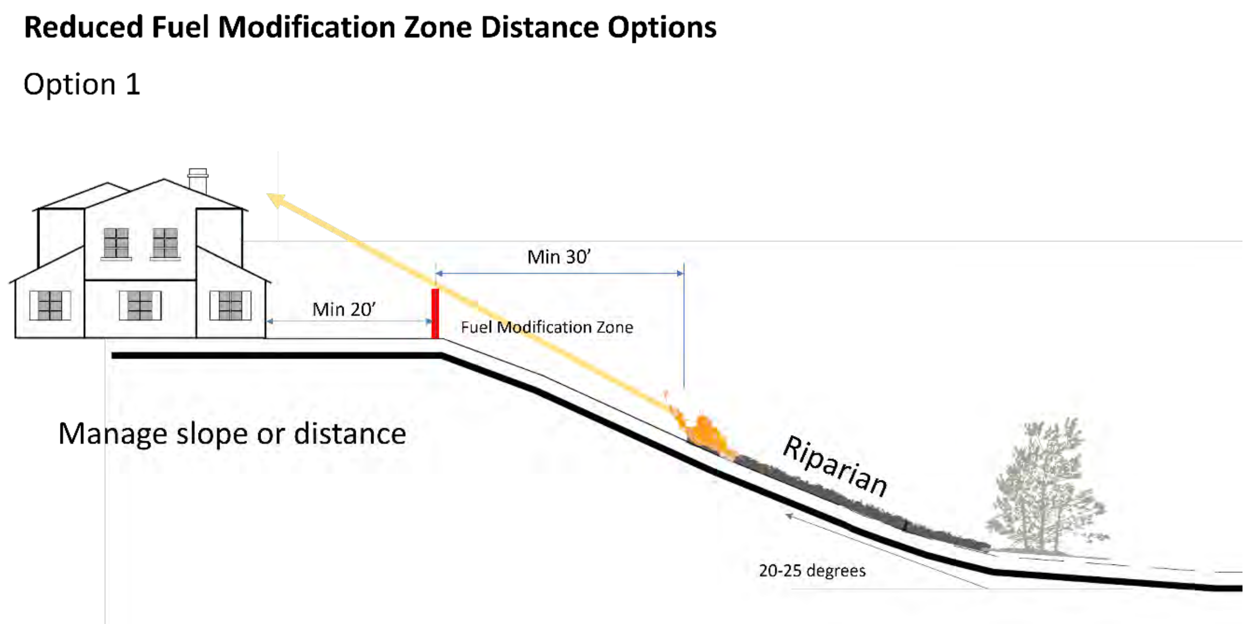


Figure 38 – Option 1

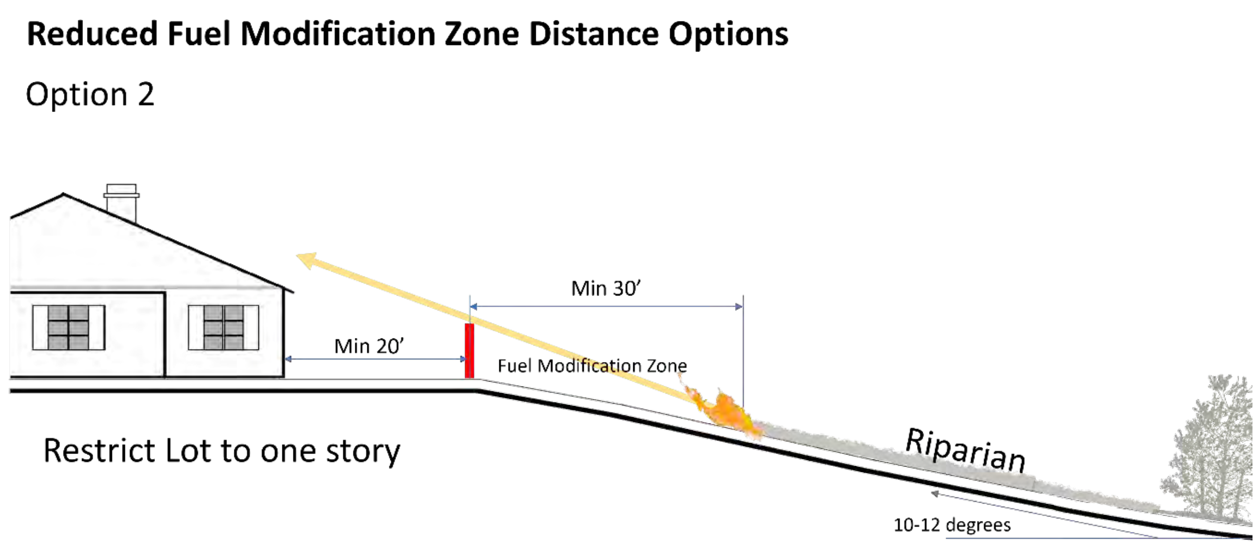


Figure 39 – Option 2

Option 3 can also be achieved by creating a series of shorter walls or terraces to step the slope up more quickly (effectively extending the lot) to a point where the wall provides an effective heat shield.

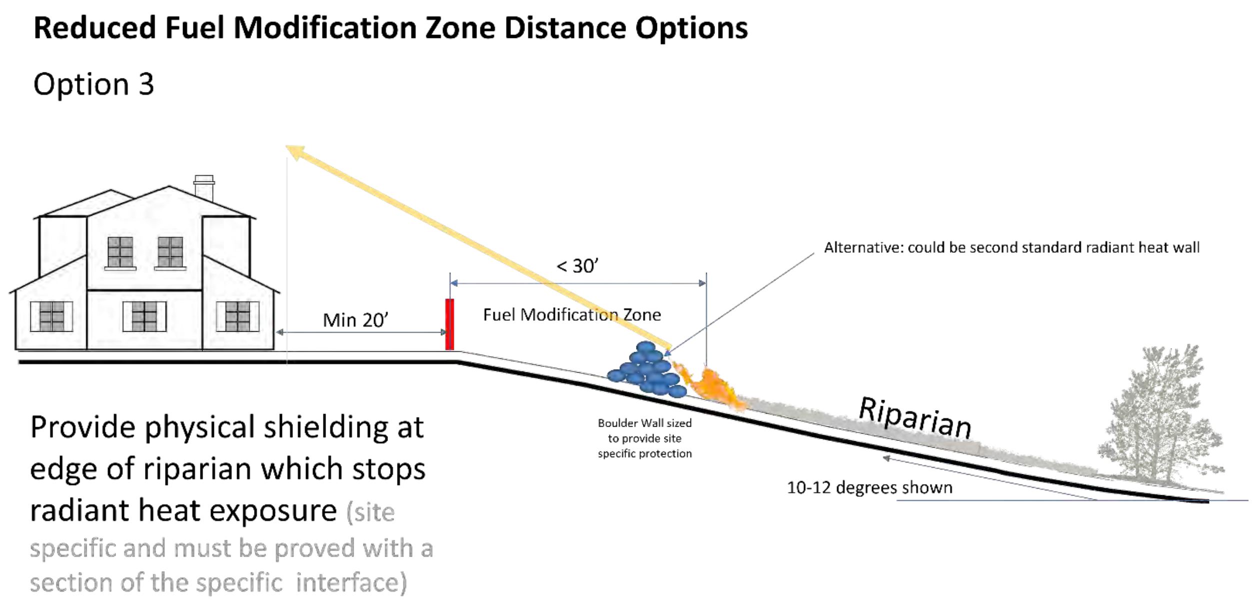
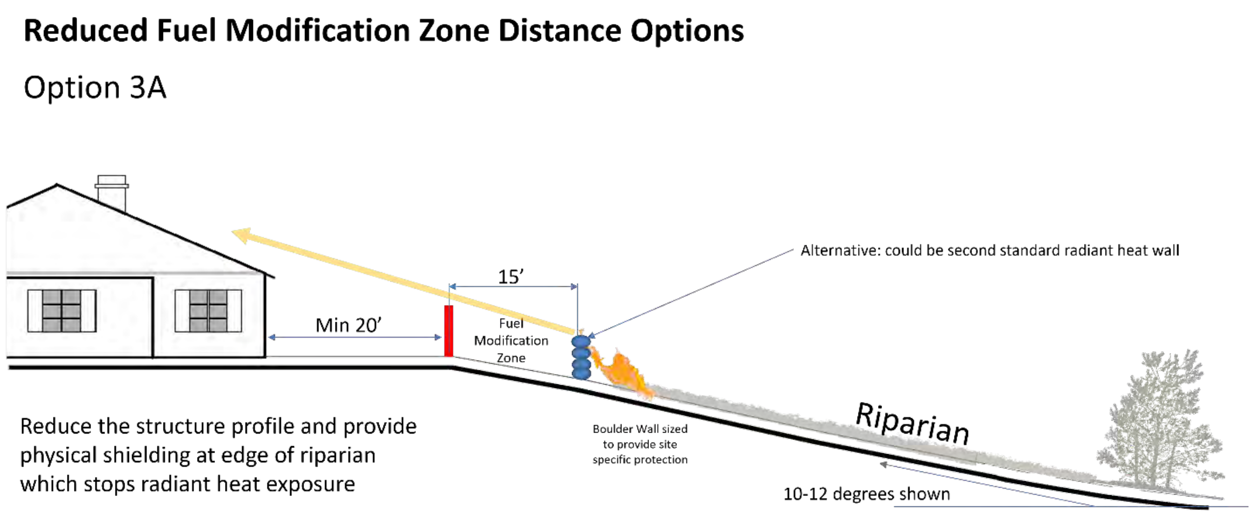


Figure 40 - Option 3



<u>Lots 100 -115 (except Lot 112)</u>

Lots 100 through 115 (except Lot 112) will need to have a distance of 65 feet from the native fuels to the structures. This is two times the maximum flame length of the SCAL18 fuel (32.5 feet) with an onshore wind at 30 mph. These lots will have a radiant heat wall at the top of slope and Zone 2 areas do not have to be irrigated but the Zone 1 areas will need to be extended to the radiant heat wall or 30 feet whichever is greater. If the slope areas of these lots are to be irrigated, they must conform to the spacing and thinning requirements of the fuel modification guideline. Lot 112 is not included as it does not have an interface issue. The Zone 1 standards can be extended to the entire fuel modification zone without issue.

Figure 41 – Lots 100 to 115, except Lot 112 (yellow highlight)

Fire Behavoir Summary

Modeling indicates that flame lengths of approximately 40 feet (39.4 eeet) are possible under perfect conditions, this scenario is possible on the project site at the site boundaries. SCAL18 fuels exist or are expected to be present in wet years if not abated by discing or other mitigation measures. This fuel (SCAL18) is probable in the riparain areas.

For the majority of the development flanking fire of twelve feet or less is expected at the property line of the lots within the development or at the base of the fuel modification zones or radiant heat walls, however, the fire defense system has been developed to make sure it works in all conditions. For this reason, a fuel modification zone has been used in all areas where the interface has a direct impact on the adjacent structures. The distances vary depending on the adjacent fuels and the topography of the interface. Using a minimum 2x ratio of flame length to separation distance between the structures and the native fuels, a 50-foot zone is more than adequate in some areas whereas 65 foot or 75 foot is more appropriate in other areas. All areas within this development area (perimeter) will have a fuel modification zone that starts at the edge of the pad. Defensible space will start at the structure and move outwards to a distance of 100 feet or the property line in accordance with the Public Resources Code (PRC) Section 4291. Fuel Modification is a part of defensible space.

Zone A distances can be reduced by up to 50% in areas where a radiant heat fence is used as a physical barrier between the wildland and the development but the overall distances between the native fuels and the structures should not be reduced without specific mitigation to achieve the "same practical effect" as the 100 feet required by the PRC.

While not currently required, Zone 0 will be applied to this project, either at the time of construction is the standards are approved at that time or retroactively as the laws requires this zone on existing structures one year after the implementation on new construction is in place.

Regardless of the modeling, when 100 feet is available to comply with the requirement of the PRC, the prescriptive level of protection should be applied as this provides for an additional level of protection beyond the level of protection provided by meeting the criteria in this report.

Additional Fire Protection Features

As indicated, a block wall/radiant heat wall may be constructed when a fuel modification zone is not possible without offsite improvements or due to the impacts of protected open space. In all cases where 100 feet of defensible space cannot be provided, the wall should be placed where the fuels are below or above the structures when in alignment with the Santa Ana winds or the predominant wind (W or SW).

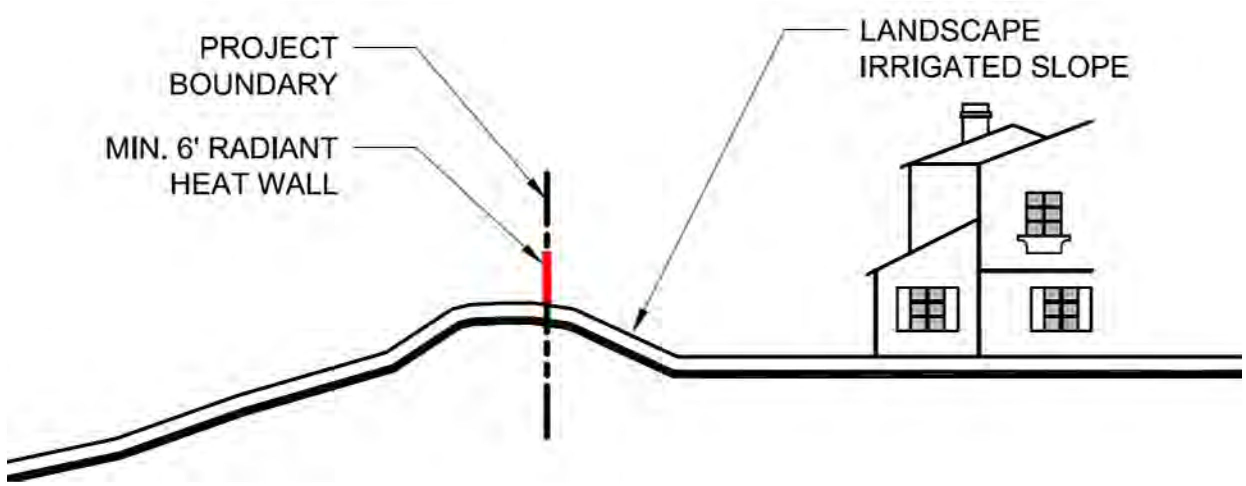


Figure 42 – Radiant Heat Wall Location

These walls will be either block or tempered glass over block similar to those shown below.

These types of walls are extremely effective when used at the top of the slope in light to moderate fuels. The extreme fire behavior that can be produced by high winds also bends the fire over making it travel more parallel to the ground. The harder the wind, the greater the flame angle will be and the more effective the radiant heat wall can become. Radiant heat wall cannot protect from extremely large flame length, radiant heat that is not shielded from impacting the structure or embers/brands that are produced by upwind fire behavior. When place strategically and appropriately, radiant heat walls are very effective in protecting structure from direct flame contact, radiant heat and provide a “hard stop” on fire progression when utilized with fuel modification zone and fire resistive vegetation.

Details for the radiant heat walls are provided in Figure 46 and the location of those lots requiring radiant heat walls are provided in Figure 47.

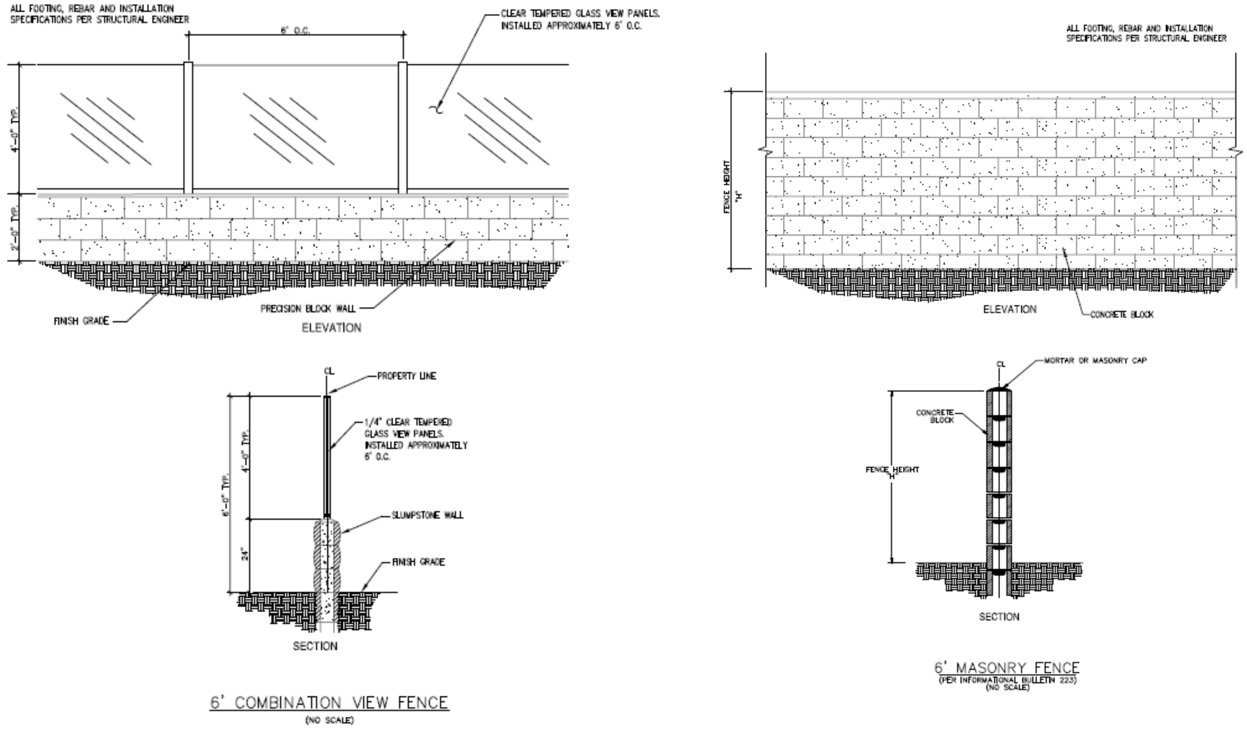


Figure 43 – Radiant Heat Wall Detail

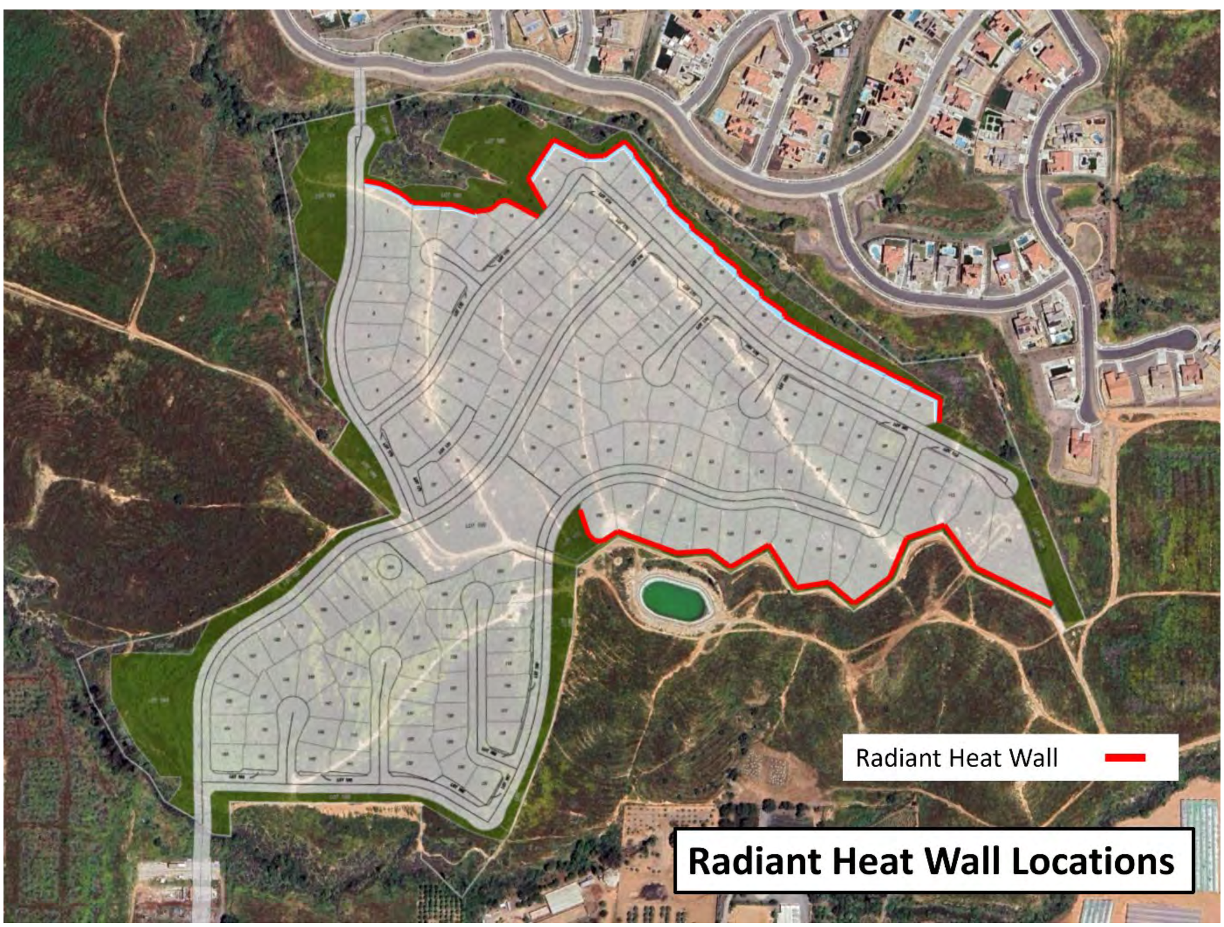


Figure 44

Report Summary

Firesafe has used the Behave model to measure the intensity of a fire moving towards this development to design a protection system that will ensure that the project will be safe from wildland fires even without fire department suppression activities . Flame lengths and fire intensity are ultimately reduced by the installation and maintenance of the fuel modification plan through the use of the irrigated Zone 1 and thinning Zone 2 and the possible use of radiant head walls surrounding the homes on the perimeter.

Based on the scientific fire bahavior analysis, exterior portions of future structures or attic spaces will not ignite from the exterior fire exposure from a wildland vegetation fire when proper construction and defensible space are applied. This is primarily because the greatest fire energy is too far away from the structures due to the low plant densities within the defensible space zones and the fire resistve construction feature requirements.

The codes enforced by the Riverside County Fire Department for defensible space were developed to handle the exact type of fuels that are interfacing with this future development. We recommend approval of this Fire Behavior Report as a design criterion for the Fuel Modification Zones in the Greentree Ranch project.

Principal
Fire Safe Planning Solutions

Fire Protection Analyst
Fire Safe Planning Solutions

Appendix A

Site Photos Locations

Photo locations are shown on the map above as reference points. Several photos were taken from each general location and are within a few feet of each other. For simplicity, these photo sites have been grouped in the locations shown above.

Photo Site 1 – Looking Southwest

Looking East

Photo Site 1(cont.) – Looking West Southwest

Looking West

Photo Site 2 – Looking Southwest

Looking West

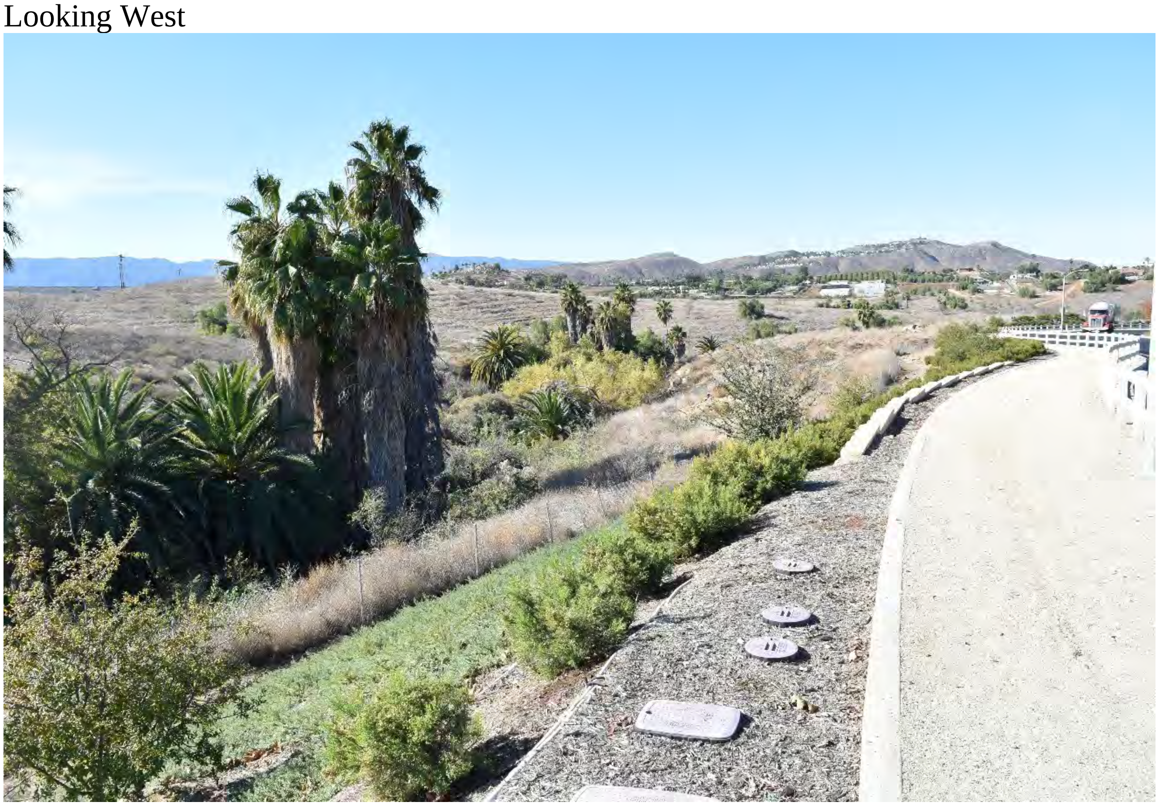


Photo Site 3 – Looking South

Looking West

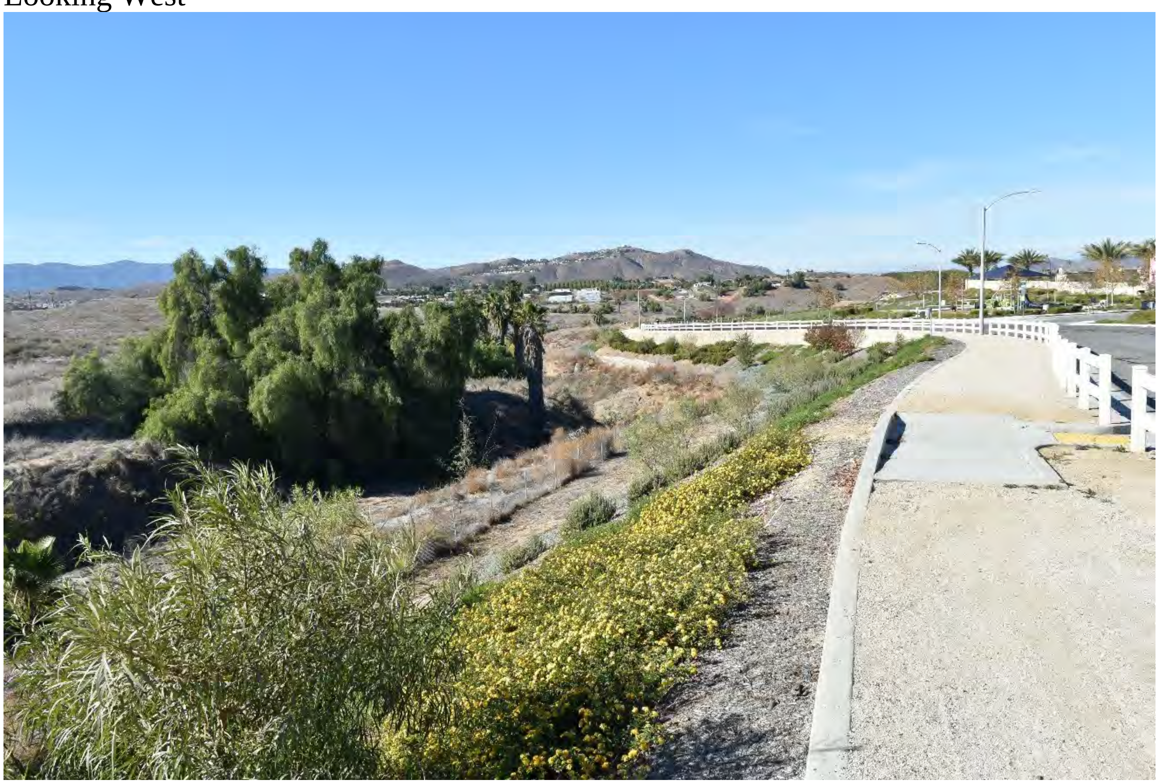


Photo Site 4 – Looking West Southwest

Looking West

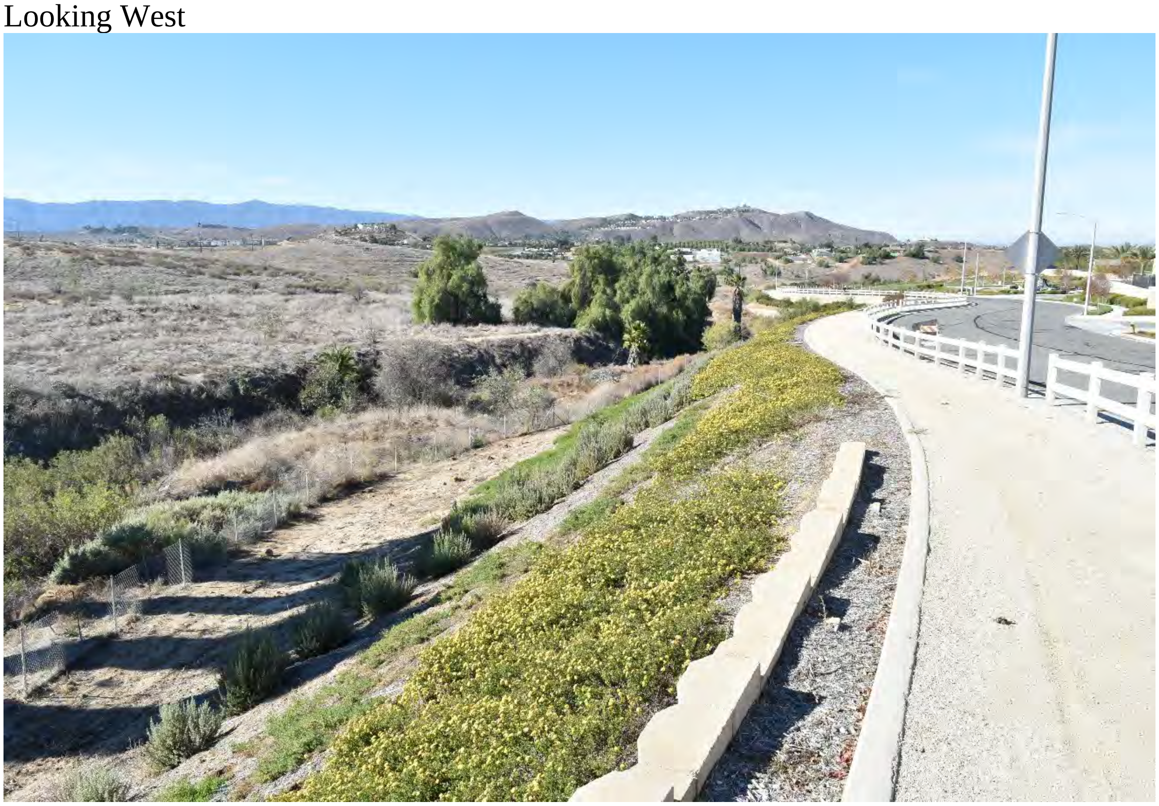


Photo Site 5 – Looking West

Looking Southeast

Photo Site 6 – Looking West

Looking West Southwest

Photo Site 7 – Looking Southeast

Looking West Northwest

Photo Site 8 –Looking South Southeast

Looking Southwest

Photo Site 9 – Looking West

Looking South Southwesgt

Photo Site 10 – Looking West

Looking Northwest

Photo Site 11 – Looking Northeast

Looking Northwest

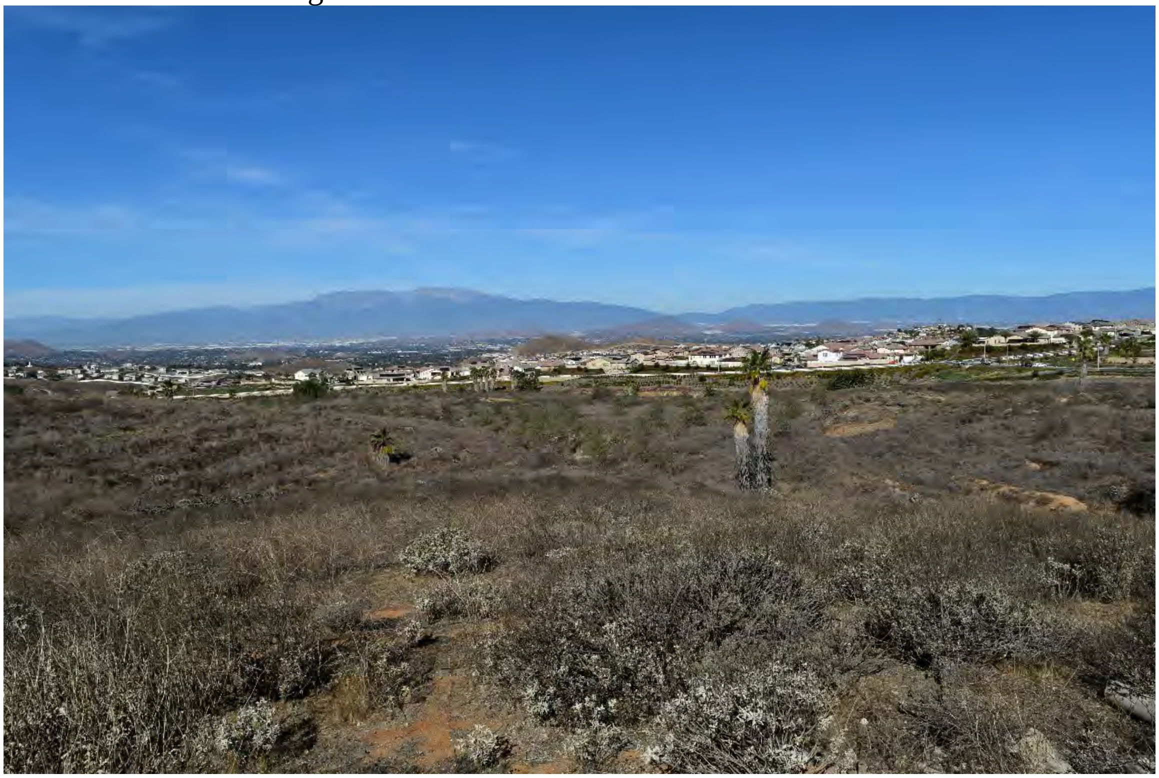
Photo Site 12 – Looking Northeast

Looking West

Photo Site 13 – Looking Northeast

Looking South

Photo Site 14 – Looking North



Looking Northwest

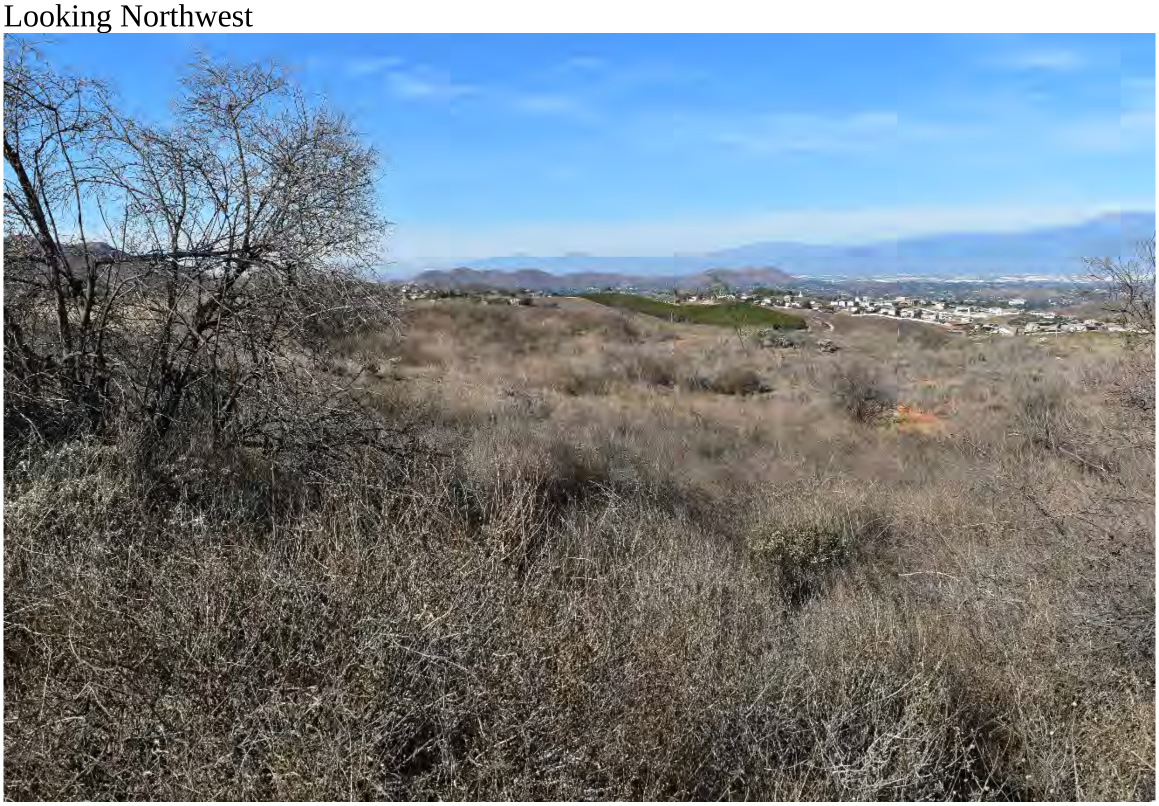


Photo Site 15 – Looking East

Looking South

Photo Site 16 – Looking South

Looking Southeast

Photo Site 17 – Looking South

Looking North

Photo Site 18 –Looking South

Looking Southwest

Photo Site 19 – Looking West

Looking Southwest

Photo Site 20 – Looking East

Looking West

Photo Site 21 – Looking West

Looking East

Photo Site 22 – Looking Southeast

Looking South

Photo Site 23 –Looking West

Looking South

Photo Site 24 – Looking Southeast

Looking West

Photo Site 25 – Looking Northwest

Looking East

Photo Site 26 – Looking North Northwest

Looking West Northwest

Photo Site 27 – Looking South Southeast

Looking Northwest

Photo Site 28 –Looking Northeast

Looking Southwest

Photo Site 29 – Looking Southwest

Looking Northeast

Photo Site 30 – Looking East Northeast

Looking North

Photo Site 31 – Looking North

Looking Northwest

Photo Site 32 – Looking

Looking Northwest from ridge (zoomed)

Photo Site 33 - Looking West

Looking Southwest

Photo Site 34 – Looking Southeast

Looking North

Appendix B

Behave Reports

Inputs: SURFACE

Description		Radiant Heat Decay

Fuel/Vegetation, Surface/Understory

Fuel Model		gs2, sh2, scal18, tu5

Fuel Moisture

1-h Fuel Moisture	%	3
10-h Fuel Moisture	%	4
100-h Fuel Moisture	%	5
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	50

Weather

20-ft Wind Speed	mi/h	0, 10, 20, 30, 40, 50, 60,
Wind Adjustment Factor		0.4
Wind Direction (from north)	deg	45

Terrain

Slope Steepness	%	50
Site Aspect	deg	45

Fire

Surface Fire Spread Direction (from north)	deg	225

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the specified directions from the FIRE PERIMETER [SURFACE].

Wind is in specified directions [SURFACE].

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

Surface Fire Rate of Spread (ft/min) [SURFACE]

Surface Fireline Intensity (kW/m) [SURFACE]

Surface Fire Flame Length (ft) [SURFACE]

Flame Residence Time (min) [SURFACE]

(continued on next page)

Input Worksheet (continued)

Notes

Radiant Heat Decay

Spread from Fire Perimeter

Surface Fire Rate of Spread (ft/min)

20-ft Wind Speed mi/h	Fuel Model gs2	sh2	SCAL18	tu5
0	20.5	6.8	22.5	8.5
10	53.6	16.2	72.9	19.6
20	111.6	31.4	118.1	33.6
30	185.0	50.0	161.6	49.0
40	270.8	71.3	204.0	65.2
50	367.1	94.7	245.5	82.2
60	472.6	120.0	286.4	99.8
70	565.2	147.1	326.8	118.0
80	565.2	175.7	366.8	136.5

Radiant Heat Decay

Spread from Fire Perimeter

Surface Fireline Intensity (kW/m)

20-ft Wind Speed mi/h	Fuel Model gs2	sh2	SCAL18	tu5
0	677	585	5314	1493
10	1775	1387	17212	3454
20	3692	2688	27891	5918
30	6122	4279	38152	8616
40	8960	6095	48152	11479
50	12145	8098	57962	14471
60	15638	10265	67623	17569
70	18700	12578	77161	20758
80	18700	15023	86597	24029

Radiant Heat Decay

Spread from Fire Perimeter

Surface Fire Flame Length (ft)

20-ft Wind Speed mi/h	Fuel Model gs2	sh2	SCAL18	tu5
0	5.1	4.8	13.1	7.3
10	7.9	7.1	22.6	10.8
20	11.1	9.6	28.2	13.8
30	14.0	11.9	32.5	16.4
40	16.7	14.0	36.2	18.7
50	19.2	16.0	39.4	20.8
60	21.6	17.8	42.3	22.8
70	23.4	19.5	45.0	24.6
80	23.4	21.2	47.5	26.3

Radiant Heat Decay

Spread from Fire Perimeter

Flame Residence Time (min)

20-ft Wind Speed mi/h	Fuel Model gs2	sh2	SCAL18	tu5
0	0.21	0.23	0.49	0.31
10	0.21	0.23	0.49	0.31
20	0.21	0.23	0.49	0.31
30	0.21	0.23	0.49	0.31
40	0.21	0.23	0.49	0.31
50	0.21	0.23	0.49	0.31
60	0.21	0.23	0.49	0.31
70	0.21	0.23	0.49	0.31
80	0.21	0.23	0.49	0.31

Discrete Variable Codes Used
Radiant Heat Decay

Fuel Model

122	gs2	Moderate load, dry climate grass-shrub (D)
142	sh2	Moderate load, dry climate shrub (S)
18	SCAL18	Sage / Buckwheat
165	tu5	Very high load, dry climate timber-shrub (S)

Inputs: SURFACE

Description		Greentree Lot 1 SCAL18 Fuel

Fuel/Vegetation, Surface/Understory

Fuel Model		SCAL18

Fuel Moisture

1-h Fuel Moisture	%	3
10-h Fuel Moisture	%	4
100-h Fuel Moisture	%	5
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	50

Weather

20-ft Wind Speed	mi/h	0, 5, 10, 15, 20, 25, 30, 35, 40, 45
Wind Adjustment Factor		0.4
Wind Direction (from north)	deg	45

Terrain

Slope Steepness	%	20
Site Aspect	deg	45

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the HEADING direction only [SURFACE].

Wind is in specified directions [SURFACE].

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

Surface Fire Rate of Spread (ft/min) [SURFACE]

Surface Fireline Intensity (kW/m) [SURFACE]

Surface Fire Flame Length (ft) [SURFACE]

Notes

Greentree Lot 1 SCAL18 Fuel

Head Fire

20-ft Wind Speed mi/h	Surface Fire Rate of Spread ft/min	Surface Fireline Intensity kW/m	Surface Flame Length ft
0	6.1	1436	7.2
5	32.6	7707	15.6
10	56.5	13334	20.1
15	79.4	18743	23.5
20	101.7	24013	26.3
25	123.6	29183	28.8
30	145.2	34274	31.0
35	166.5	39301	33.0
40	187.5	44274	34.9
45	208.4	49200	36.6
50	229.1	54084	38.2

Discrete Variable Codes Used
Greentree Lot 1 SCAL18 Fuel

Fuel Model

18	SCAL18	Sage / Buckwheat

Inputs: SURFACE

Description		Greentree SCAL18 Fuel

Fuel/Vegetation, Surface/Understory

Fuel Model		SCAL18

Fuel Moisture

1-h Fuel Moisture	%	3
10-h Fuel Moisture	%	4
100-h Fuel Moisture	%	5
Live Herbaceous Fuel Moisture	%	30
Live Woody Fuel Moisture	%	50

Weather

20-ft Wind Speed	mi/h	0, 5, 10, 15, 20, 25, 30, 35, 40, 45
Wind Adjustment Factor		0.4
Wind Direction (from north)	deg	45

Terrain

Slope Steepness	%	20
Site Aspect	deg	45

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the HEADING direction only [SURFACE].

Wind is in specified directions [SURFACE].

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

Surface Fire Rate of Spread (ft/min) [SURFACE]

Surface Fireline Intensity (kW/m) [SURFACE]

Surface Fire Flame Length (ft) [SURFACE]

Notes

Greentree SCAL18 Fuel

Head Fire

20-ft Wind Speed mi/h	Surface Fire Rate of Spread ft/min	Surface Fireline Intensity kW/m	Surface Flame Length ft
0	6.1	1436	7.2
5	32.6	7707	15.6
10	56.5	13334	20.1
15	79.4	18743	23.5
20	101.7	24013	26.3
25	123.6	29183	28.8
30	145.2	34274	31.0
35	166.5	39301	33.0
40	187.5	44274	34.9
45	208.4	49200	36.6
50	229.1	54084	38.2

Discrete Variable Codes Used
Greentree SCAL18 Fuel

Fuel Model

18	SCAL18	Sage / Buckwheat

Inputs: SURFACE

Description		Greentree SW 30 mph

Fuel/Vegetation, Surface/Understory

Fuel Model		gr2, gs2, sh2, scal18, tl6

Fuel Moisture

1-h Fuel Moisture	%	3.
10-h Fuel Moisture	%	4.
100-h Fuel Moisture	%	5.
Live Herbaceous Fuel Moisture	%	30.
Live Woody Fuel Moisture	%	50.

Weather

20-ft Wind Speed	mi/h	30.
Wind Adjustment Factor		0.4
Wind Direction (from north)	deg	225

Terrain

Slope Steepness	%	50.
Site Aspect	deg	225

Fire

Surface Fire Spread Direction (from north)	deg	0, 15, 30, 45, 60, 75, 90,

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the specified directions from the FIRE PERIMETER [SURFACE].

Wind is in specified directions [SURFACE].

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

Surface Fire Rate of Spread (ft/min) [SURFACE]

Surface Fireline Intensity (kW/m) [SURFACE]

Surface Fire Flame Length (ft) [SURFACE]

Flame Residence Time (min) [SURFACE]

(continued on next page)

Input Worksheet (continued)

Notes

Greentree SW 30 mph

Spread from Fire Perimeter

Surface Fire Rate of Spread (ft/min)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	192.8	132.7	35.9	115.7	24.7
15	233.8	161.0	43.5	140.5	30.0
30	259.8	178.9	48.4	156.2	33.3
45	268.7	185.0	50.0	161.6	34.5
60	259.8	178.9	48.4	156.2	33.3
75	233.8	161.0	43.5	140.5	30.0
90	192.8	132.7	35.9	115.7	24.7
105	140.0	96.3	26.0	83.8	17.9
120	81.7	56.0	15.1	48.3	10.4
135	32.8	22.2	5.9	18.4	4.1
150	13.2	8.8	2.3	7.0	1.6
165	7.7	5.1	1.4	4.0	0.9
180	5.6	3.7	1.0	2.9	0.7
195	4.6	3.1	0.8	2.4	0.6
210	4.1	2.8	0.7	2.2	0.5
225	4.0	2.7	0.7	2.1	0.5
240	4.1	2.8	0.7	2.2	0.5
255	4.6	3.1	0.8	2.4	0.6
270	5.6	3.7	1.0	2.9	0.7
285	7.7	5.1	1.4	4.0	0.9
300	13.2	8.8	2.3	7.0	1.6
315	32.8	22.2	5.9	18.4	4.1
330	81.7	56.0	15.1	48.3	10.4
345	140.0	96.3	26.0	83.8	17.9
360	192.8	132.7	35.9	115.7	24.7

Greentree SW 30 mph

Spread from Fire Perimeter

Surface Fireline Intensity (kW/m)

Spread Dir from North deg	Fuel Model gr2	gs2	sh2	SCAL18	tl6
0	2896	4390	3067	27317	761
15	3513	5327	3723	33180	924
30	3903	5920	4137	36886	1027
45	4037	6122	4279	38152	1062
60	3903	5920	4137	36886	1027
75	3513	5327	3723	33180	924
90	2896	4390	3067	27317	761
105	2104	3187	2225	19779	552
120	1227	1853	1291	11395	321
135	493	735	507	4333	127
150	198	292	199	1648	50
165	116	170	116	949	29
180	84	123	84	687	21
195	69	101	69	566	17
210	62	91	62	509	16
225	60	88	60	492	15
240	62	91	62	509	16
255	69	101	69	566	17
270	84	123	84	687	21
285	116	170	116	949	29
300	198	292	199	1648	50
315	493	735	507	4333	127
330	1227	1853	1291	11395	321
345	2104	3187	2225	19779	552
360	2896	4390	3067	27317	761

Greentree SW 30 mph

Spread from Fire Perimeter

Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	9.9	12.0	10.2	27.9	5.4
15	10.9	13.2	11.2	30.5	5.9
30	11.4	13.8	11.7	32.0	6.2
45	11.6	14.0	11.9	32.5	6.3
60	11.4	13.8	11.7	32.0	6.2
75	10.9	13.2	11.2	30.5	5.9
90	9.9	12.0	10.2	27.9	5.4
105	8.6	10.4	8.8	24.1	4.6
120	6.7	8.1	6.9	18.7	3.6
135	4.4	5.3	4.5	12.0	2.4
150	2.9	3.5	2.9	7.7	1.5
165	2.3	2.7	2.3	6.0	1.2
180	2.0	2.3	1.9	5.1	1.0
195	1.8	2.1	1.8	4.7	0.9
210	1.7	2.0	1.7	4.5	0.9
225	1.7	2.0	1.7	4.4	0.9
240	1.7	2.0	1.7	4.5	0.9
255	1.8	2.1	1.8	4.7	0.9
270	2.0	2.3	1.9	5.1	1.0
285	2.3	2.7	2.3	6.0	1.2
300	2.9	3.5	2.9	7.7	1.5
315	4.4	5.3	4.5	12.0	2.4
330	6.7	8.1	6.9	18.7	3.6
345	8.6	10.4	8.8	24.1	4.6
360	9.9	12.0	10.2	27.9	5.4

Greentree SW 30 mph

Spread from Fire Perimeter

Flame Residence Time (min)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	0.21	0.21	0.23	0.49	0.20
15	0.21	0.21	0.23	0.49	0.20
30	0.21	0.21	0.23	0.49	0.20
45	0.21	0.21	0.23	0.49	0.20
60	0.21	0.21	0.23	0.49	0.20
75	0.21	0.21	0.23	0.49	0.20
90	0.21	0.21	0.23	0.49	0.20
105	0.21	0.21	0.23	0.49	0.20
120	0.21	0.21	0.23	0.49	0.20
135	0.21	0.21	0.23	0.49	0.20
150	0.21	0.21	0.23	0.49	0.20
165	0.21	0.21	0.23	0.49	0.20
180	0.21	0.21	0.23	0.49	0.20
195	0.21	0.21	0.23	0.49	0.20
210	0.21	0.21	0.23	0.49	0.20
225	0.21	0.21	0.23	0.49	0.20
240	0.21	0.21	0.23	0.49	0.20
255	0.21	0.21	0.23	0.49	0.20
270	0.21	0.21	0.23	0.49	0.20
285	0.21	0.21	0.23	0.49	0.20
300	0.21	0.21	0.23	0.49	0.20
315	0.21	0.21	0.23	0.49	0.20
330	0.21	0.21	0.23	0.49	0.20
345	0.21	0.21	0.23	0.49	0.20
360	0.21	0.21	0.23	0.49	0.20

Discrete Variable Codes Used
Greentree SW 30 mph

Fuel Model

102	gr2	Low load, dry climate grass (D)
122	gs2	Moderate load, dry climate grass-shrub (D)
142	sh2	Moderate load, dry climate shrub (S)
18	SCAL18	Sage / Buckwheat
186	tl6	High load broadleaf litter (S)

Inputs: SURFACE

Description		Greentree NE 50 mph

Fuel/Vegetation, Surface/Understory

Fuel Model		gr2, gs2, sh2, scal18, tl6

Fuel Moisture

1-h Fuel Moisture	%	3.
10-h Fuel Moisture	%	4.
100-h Fuel Moisture	%	5.
Live Herbaceous Fuel Moisture	%	30.
Live Woody Fuel Moisture	%	50.

Weather

20-ft Wind Speed	mi/h	50.
Wind Adjustment Factor		0.4
Wind Direction (from north)	deg	45

Terrain

Slope Steepness	%	50.
Site Aspect	deg	45

Fire

Surface Fire Spread Direction (from north)	deg	0, 15, 30, 45, 60, 75, 90,

Run Option Notes

Maximum effective wind speed limit IS imposed [SURFACE].

Fire spread is in the specified directions from the FIRE PERIMETER [SURFACE].

Wind is in specified directions [SURFACE].

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

Surface Fire Rate of Spread (ft/min) [SURFACE]

Surface Fireline Intensity (kW/m) [SURFACE]

Surface Fire Flame Length (ft) [SURFACE]

Flame Residence Time (min) [SURFACE]

(continued on next page)

Input Worksheet (continued)

Notes

Greentree NE 50 mph

Spread from Fire Perimeter

Surface Fire Rate of Spread (ft/min)

Spread Dir from North deg	Fuel Model gr2	gs2	sh2	SCAL18	tl6
0	5.6	3.4	0.9	2.1	0.6
15	4.6	2.8	0.7	1.7	0.5
30	4.1	2.5	0.6	1.5	0.5
45	4.0	2.4	0.6	1.5	0.5
60	4.1	2.5	0.6	1.5	0.5
75	4.6	2.8	0.7	1.7	0.5
90	5.6	3.4	0.9	2.1	0.6
105	7.7	4.8	1.2	2.9	0.9
120	13.2	8.7	2.2	5.3	1.6
135	32.8	29.9	7.6	19.1	5.6
150	81.7	103.1	26.6	68.5	19.4
165	140.0	187.1	48.3	124.9	35.2
180	192.8	261.3	67.4	174.6	49.2
195	233.8	318.6	82.2	213.0	60.0
210	259.8	354.7	91.5	237.2	66.8
225	268.7	367.1	94.7	245.5	69.1
240	259.8	354.7	91.5	237.2	66.8
255	233.8	318.6	82.2	213.0	60.0
270	192.8	261.3	67.4	174.6	49.2
285	140.0	187.1	48.3	124.9	35.2
300	81.7	103.1	26.6	68.5	19.4
315	32.8	29.9	7.6	19.1	5.6
330	13.2	8.7	2.2	5.3	1.6
345	7.7	4.8	1.2	2.9	0.9
360	5.6	3.4	0.9	2.1	0.6

Greentree NE 50 mph

Spread from Fire Perimeter

Surface Fireline Intensity (kW/m)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	84	113	74	492	20
15	69	93	61	403	16
30	62	83	55	362	15
45	60	81	53	350	14
60	62	83	55	362	15
75	69	93	61	403	16
90	84	113	74	492	20
105	116	158	104	687	28
120	198	287	188	1254	50
135	493	989	654	4502	173
150	1227	3410	2271	16165	597
165	2104	6190	4126	29493	1084
180	2896	8644	5763	41229	1514
195	3513	10541	7029	50296	1846
210	3903	11737	7826	56011	2055
225	4037	12145	8098	57962	2127
240	3903	11737	7826	56011	2055
255	3513	10541	7029	50296	1846
270	2896	8644	5763	41229	1514
285	2104	6190	4126	29493	1084
300	1227	3410	2271	16165	597
315	493	989	654	4502	173
330	198	287	188	1254	50
345	116	158	104	687	28
360	84	113	74	492	20

Greentree NE 50 mph

Spread from Fire Perimeter

Surface Fire Flame Length (ft)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	2.0	2.2	1.8	4.4	1.0
15	1.8	2.0	1.7	4.0	0.9
30	1.7	1.9	1.6	3.8	0.9
45	1.7	1.9	1.6	3.8	0.9
60	1.7	1.9	1.6	3.8	0.9
75	1.8	2.0	1.7	4.0	0.9
90	2.0	2.2	1.8	4.4	1.0
105	2.3	2.6	2.1	5.1	1.2
120	2.9	3.4	2.8	6.8	1.5
135	4.4	6.1	5.0	12.2	2.7
150	6.7	10.7	8.9	21.9	4.8
165	8.6	14.1	11.7	28.9	6.3
180	9.9	16.4	13.6	33.7	7.4
195	10.9	18.0	14.9	37.0	8.1
210	11.4	18.9	15.7	38.8	8.5
225	11.6	19.2	16.0	39.4	8.6
240	11.4	18.9	15.7	38.8	8.5
255	10.9	18.0	14.9	37.0	8.1
270	9.9	16.4	13.6	33.7	7.4
285	8.6	14.1	11.7	28.9	6.3
300	6.7	10.7	8.9	21.9	4.8
315	4.4	6.1	5.0	12.2	2.7
330	2.9	3.4	2.8	6.8	1.5
345	2.3	2.6	2.1	5.1	1.2
360	2.0	2.2	1.8	4.4	1.0

Greentree NE 50 mph

Spread from Fire Perimeter

Flame Residence Time (min)

Spread Dir from North	Fuel Model				
deg	gr2	gs2	sh2	SCAL18	tl6
0	0.21	0.21	0.23	0.49	0.20
15	0.21	0.21	0.23	0.49	0.20
30	0.21	0.21	0.23	0.49	0.20
45	0.21	0.21	0.23	0.49	0.20
60	0.21	0.21	0.23	0.49	0.20
75	0.21	0.21	0.23	0.49	0.20
90	0.21	0.21	0.23	0.49	0.20
105	0.21	0.21	0.23	0.49	0.20
120	0.21	0.21	0.23	0.49	0.20
135	0.21	0.21	0.23	0.49	0.20
150	0.21	0.21	0.23	0.49	0.20
165	0.21	0.21	0.23	0.49	0.20
180	0.21	0.21	0.23	0.49	0.20
195	0.21	0.21	0.23	0.49	0.20
210	0.21	0.21	0.23	0.49	0.20
225	0.21	0.21	0.23	0.49	0.20
240	0.21	0.21	0.23	0.49	0.20
255	0.21	0.21	0.23	0.49	0.20
270	0.21	0.21	0.23	0.49	0.20
285	0.21	0.21	0.23	0.49	0.20
300	0.21	0.21	0.23	0.49	0.20
315	0.21	0.21	0.23	0.49	0.20
330	0.21	0.21	0.23	0.49	0.20
345	0.21	0.21	0.23	0.49	0.20
360	0.21	0.21	0.23	0.49	0.20

Discrete Variable Codes Used
Greentree NE 50 mph

Fuel Model

102	gr2	Low load, dry climate grass (D)
122	gs2	Moderate load, dry climate grass-shrub (D)
142	sh2	Moderate load, dry climate shrub (S)
18	SCAL18	Sage / Buckwheat
186	tl6	High load broadleaf litter (S)