STATE OF CALIFORNIA GAVIN NEWSOM, *Governor*

PUBLIC UTILITIES COMMISSION
505 VAN NESS AVENUE
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July 9, 2021

To Whom It May Concern:

In late 2019, the Safety and Enforcement Division of the California Public Utilities Commission's engaged a consultant, Technosylva Inc., to analyze the capabilities of certain new advanced wildfire risk analysis modeling. Pursuant to the engagement Technosylva has prepared a report regarding the new wildfire modeling software capabilities. This report is attached.

The Safety and Enforcement Division did not independently validate the findings of this report by Technosylva. The issuance of this report by the Safety and Enforcement Division should not be interpreted as an endorsement by the Commission of any aspect of this report.

If you have any questions regarding the report, please contact Anthony Noll at (916) 928-3315 or at Anthony.Noll@cpuc.ca.gov.

California Public Utilities Commission

2019 PSPS Event –Wildfire Analysis Report

Event Dates:

June 7-9, 2019
September 23-26, 2019
October 5-6, 2019
October 23-25, 2019
November 20-21, 2019

IOU: **Pacific Gas & Electric**

Prepared by:

Technosylva Inc. (La Jolla, CA)

technosylva

California Public Utilities Commission

2019 PSPS Event Wildfire Risk Analysis Report

Public Safety Power Shutoffs (PSPS) Event Wildfire Risk Analysis Summary Report

June 7-9, 2019
September 23-26, 2019
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Pacific Gas & Electric

PREFACE

In the wake of the unprecedented 2017 and 2018 wildfire seasons in California, and amid the increasing frequency of extreme weather events resulting from climate change, the practice of electric utilities preemptively de-energizing powerlines in response to weather and environmental conditions commensurate with rapid fire spread and related destruction has grown in use and prevalence. This practice is commonly referred to as “public safety power shutoffs” or “PSPS” by California’s investor-owned electric utilities.

From a policy perspective, while subject to consideration by the California Public Utilities Commission (CPUC) since 2008, PSPS policy is still nascent. PSPS as a wildfire risk mitigation measure wasn’t first utilized until October 2013, and even then, it was only implemented by San Diego Gas & Electric, occurred seldomly, and had relatively limited customer impacts. Since that time, as the utilization of PSPS as a wildfire risk mitigation measure has grown in practice and prevalence, thus occurring more frequently and impacting more Californians, the need for evolution and refinement in the CPUC’s assessment of this policy and practice has become evident. To this end, the CPUC has engaged Technosylva to conduct this project and present an example of the type of refined analysis that can be conducted and reported, on a per-event basis, to provide a more sophisticated assessment of PSPS events.[1]

While this study propels the CPUC’s analytical assessment of electric utility PSPS events, it should be noted that additional analyses are required to obtain a complete picture of the true impacts of such events. The fire spread simulations, based on the location and type of damages sustained to de-energized portions of powerlines during a PSPS event, provide a glimpse into “what may have been” by simulating the potential fire spread from a utility-caused ignition and quantifying the associated impacts on people, buildings, and the landscape. However, this analysis does not assess “what actually was,” in terms of the realized impacts on Californians as a result of the PSPS event. Although the instant analysis quantifies the potential wildfire related impacts avoided as a result of proactively de-energizing powerlines, it is evident from the historic execution of these events that power outages can also profoundly disrupt Californian’s daily lives, create or exacerbate emergency situations, and strain economic progress. Accordingly, further analysis of these realized impacts must also be conducted and compared to provide a robust and complete assessment of the effectiveness of PSPS implementation as a wildfire risk mitigation measure. The assessment of realized impacts is not within the scope of this report.

[1] The three large investor-owned electric utilities in California (i.e. PG&E, SCE, and SDG&E) all have access to the same Technosylva software used to conduct this analysis.

Moreover, it should be noted that not only does this analysis rely upon the simulation of potential utility-caused ignitions related to utility-reported damage sustained during a PSPS event, but also relies upon utility determination of whether the nature and conditions of the damage would have likely resulted in arcing or emission of sparks. Only damage incidents identified by utilities as resulting in arcing or emission of sparks were simulated as potential utility-caused fire ignitions. However, further study and analysis of the relationship between various damage conditions and the probability of a resultant utility-caused ignition is required, as this probability is also dependent on the fuel type, density, and conditions at the damage location. Having a deeper understanding of the probability that damage sustained during a PSPS event could result in an ignition would enhance the precision and accuracy of these wildfire simulations.

Lastly, considering the nascent, developing, and evolving nature of PSPS as a utility wildfire risk mitigation strategy, it should be noted that refined clarity, standardization, and data are needed to ensure consistency and comparability from event to event. For example, a single "PSPS event" may span several days or even weeks and would likely include the de-energization of various circuits, and some circuits potentially numerous times. As such, cross-utility comparisons at the event-level are of little use, especially if there are consecutive extreme fire weather events resulting in successive PSPS events being initiated.

1. INTRODUCTION

In response to weather driven wind events in 2019, several Public Safety Power Shutoff (PSPS) events were initiated by the Investor Owned Utilities (IOUs). A wildfire risk analysis has been conducted for each 2019 PSPS event, allowing the CPUC to better understand the severity of the weather conditions and the potential risks averted from wildfires that could have ignited from possible electric utility infrastructure ignition sources based on damages sustained following the power shutoff.

This document presents the wildfire risk analysis results for several PSPS events that occurred in **Pacific Gas and Electric Company's (PG&E)** service territory for the following dates:

- June 7-9, 2019
- September 23-26, 2019
- October 5-6, 2019
- October 23-25, 2019
- November 20-21, 2019

The analysis quantifies the potential impacts averted from wildfires that could have been ignited by electric utility infrastructure assets damaged during the PSPS events if they were not de-energized. These damage incident data are compiled from IOU field inspections on asset infrastructure after the 2019 PSPS event occurred.

A single report is provided for these events due to the relatively small number of damage incidents collected for these events. However, individual analysis reports are provided for the PG&E PSPS events of October 9-12, 2019 and October 26-29, 2019 due to the large number of damage incidents that occurred during these events.

The analysis identifies the expected spread of fire simulations based on the damage incident locations as potential ignition points, and quantifies the impacts from those potential fires, in terms of buildings, population, critical facilities and acres impacted, under worst-case fire weather conditions that occurred within the PSPS event time boundaries.

This analysis reflects "*what could have been*" had the PSPS not occurred, aiding the CPUC in conducting a richer analysis and evaluation of IOU PSPS decisions by quantifying the potential impacts that could have been avoided and providing a measure to compare against actual sustained impacts.

The analysis has been conducted using the advanced wildfire behavior and prediction modeling software Wildfire Analyst™ (Technosylva, La Jolla, CA).[2]

The analysis does not consider suppression activities during the simulated fire spread and, therefore, the final fire impact could have been less than calculated. Also, note that the fire modeling approach used in this work considers an encroachment function to analyze the fire impact on buildings and population based on fire intensity and the rate of spread near the houses. Finally, this work takes into account input data uncertainty (especially, weather and ignition parameters) to analyze the fire propagation and impacts, an innovative approach to show more reliable results.

[2] More information about Wildfire Analyst can be obtained from https://www.wildfireanalyst.com/.

2. TECHNICAL METHODS

2.1 Damage Incident Data Collection

The analysis conducted for the PSPS events relied upon PG&E's assessment of damage incidents for ignition potential. Data on the damages were obtained from patrols conducted by PG&E field personnel subsequent to reenergization. All damage identified from these field inspections was documented with standard forms including GPS recorded location, photographs and a description of the damage. The documentation was then submitted to a team of analysts who evaluated the data to determine whether the damage is likely to cause arcing and result in a potential ignition. Quality assurance was then conducted by PG&E Electric Operations personnel who have extensive field experience to make a final determination of whether the damage event would cause a potential ignition.

2.2 Fire Modeling

Fire spread simulations were undertaken for the damage incidents using the location of the damage incident as the ignition source, and the date/time estimated for the damage occurring as the start time for the fire simulation. The simulations were run for a 24-hour duration. Impacts to buildings, population, and acres burned were calculated for each fire simulation.

The analysis also calculated several other metrics to help assess the potential significance of the fire simulation. A key metric is the Initial Attack Assessment (IAA), which quantifies the likelihood of the simulated fire escaping initial attack by suppression resources.[3] This metric helps distinguish fires that may potentially take longer to suppress compared to average fires that would typically be extinguished quickly, based on spread characteristics under the specific weather conditions at the time of the event.

2.2.1 Data Processing Methods

The following technical tasks were undertaken to derive the analysis results for each event.

1. Obtain damage incident data and PSPS event data from IOUs
2. Obtain weather forecast data from IOUs
3. Compile weather station observation data
4. Geo-reference the damage locations and PSPS events boundaries
5. Compile weather data and determine best data for each simulation analysis
6. Conduct analysis of weather conditions
7. Determine the most likely ignition time for the damage incidents
8. Conduct deterministic fire spread prediction simulations
9. Calibrate outputs and revise if necessary
10. Generate summary results for all damage incidents
11. Identify the most significant damage incidents based on simulation results
12. Conduct a probabilistic simulation for the most significant damage incidents

[3] The IAA index provides an estimation of the difficulty of fire control for initial attack. The index is combination of two sub-indices based on fire behavior (rate of spread, flame length) and fire growth metrics (fire perimeter for the first hour of fire growth with no intervention of suppression resources; fire area growth between the first and second hour).

13. Generate a summary for the most significant simulations
14. Compile a summary of active wildfires during the event period
15. Conduct analysis of historical fire comparison
16. Compile results into PSPS event report

2.2.2 Fire Behavior Modeling Methods

Fire simulations were performed with Technosylva's Wildfire Analyst™ software. Wildfire Analyst is software that provides real-time analysis of wildfire behavior and simulates the spread of wildfires. Wildfire Analyst employs published and proven algorithms used to simulate fire behavior.[4] Numerous enhancements to the published science have been implemented by Technosylva that provides more advanced capabilities for spread modeling and impact analysis. The methods also utilize crown fire model and spotting algorithms. Topographic characteristics (elevation, slope, aspect), weather (temperature, relative humidity and wind fields), surface fuel types and moisture (dead and live), canopy characteristics, and foliar moisture content are all used as inputs into the fire behavior modeling.

A key enhancement incorporated into the analysis is the use of a surface fuels dataset that has been updated to reflect vegetation disturbances up to 2018. This represents the best publicly available surface and canopy fuels data for the State of California. This data also includes an enrichment of urban and non-burnable fuel delineation to facilitate more accurate urban area encroachment and associated impacts to buildings and people.

The outputs provided the simulated fire spread and associated behavior characterized by rate of spread, flame length, fire line intensity and type of fire in each pixel (unburnable, surface, torching or crowning). These are considered standard fire behavior outputs.

The duration of all incident fire simulations was 24 hours.

2.2.3 Using Deterministic and Probabilistic Fire Simulations

The primary concern with any fire ignition is the spread of the fire and potential impacts from that fire spread. This is particularly important in adverse weather conditions that lead to PSPS events. Two methods exist to predict fire spread and analyze potential impacts - deterministic and probabilistic.

Deterministic methods apply well established and proven fire spread models using forecasted and observed weather data to calculate the estimated time of arrival, behavior characteristics, and the consequence of a fire. This method allows for virtual real-time analysis of a fire and can be adjusted based on a fixed set of input data values. This method provides well understood and reliable results if input data is accurate. However, the capability of accurately predicting the fire spread and impact is linked to input data uncertainty, such as the time of ignition, ignition location, forecasted weather conditions, etc., as well as the model's inherent inaccuracy. Results can vary greatly depending on the accuracy of these key input parameters. Deterministic modeling was used to calculate the fire spread and impacts for each of the damage incident locations for every PSPS event. The following figure presents an example deterministic fire simulation. Hourly perimeters are shown along with buildings and topographic information.

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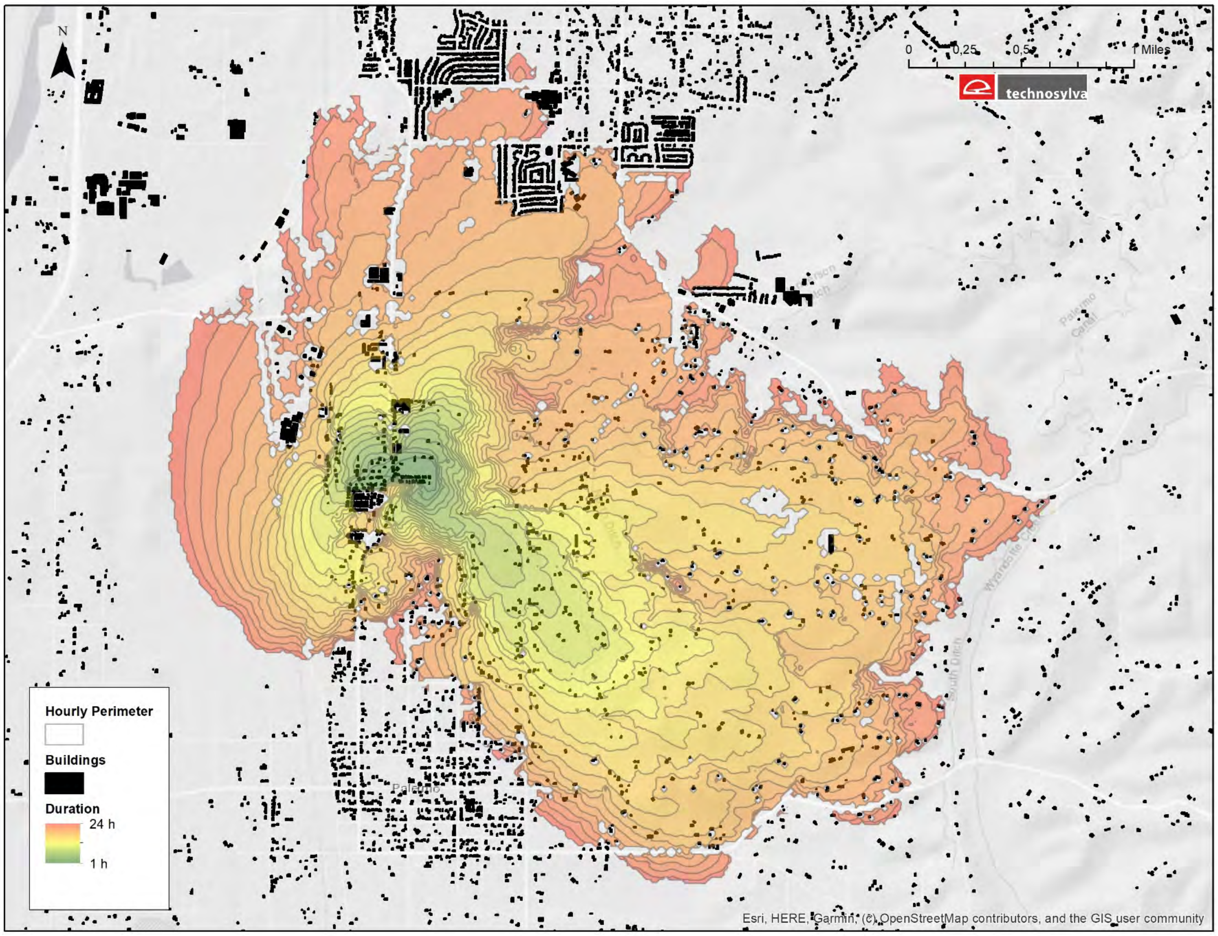
[4] Rothermel, R., 1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Intermt. For. Range Exp. Stn. Res. Pap. INT-115. Ogden, UT.

Figure 1. Example deterministic fire simulation.



Probabilistic methods apply the same fire spread models with a variation of inputs to determine the probability of occurrence. The probabilistic approach performs approximately 100 fire simulations with varied input data for each damage incident considering advisable thresholds for each input according to scientific literature[5]. The inputs that are varied are dead fuel moisture, wind speed, and wind speed. The model provides probability-based outcomes, estimating the time and probability of a fire reaching a specific point of the landscape and associated impact as a function of that probability. The aim of probabilistic modelling is to provide decision-makers a representative scheme of the possible outcomes of the fire simulations after analyzing the nature of the uncertainties in the fire incident[6]. This analysis may be helpful in structuring the problems,

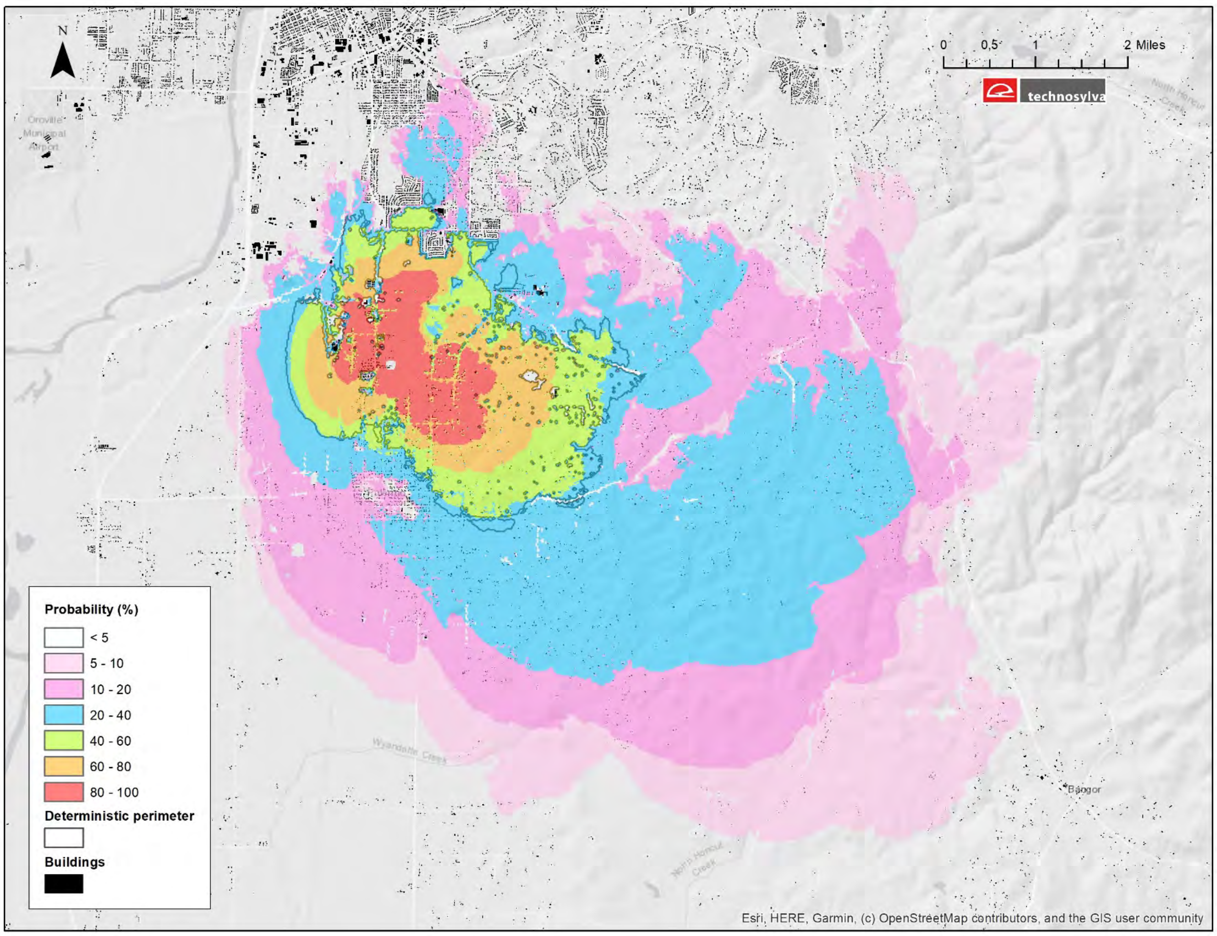
[5] Alexander, M.E., Cruz, M.G., 2013. Are the applications of wildland fire behavior modeling. Environ. Model. Softw. 41, 65–71. https://doi.org/10.1016/j.envsoft.2012.11.001

[6] Power, M., McCarty, L.S., 2006. Environmental risk management decision-making in a societal context. Hum. Ecol. Risk Assess. An Int. J. 12, 18–27. https://doi.org/10.1080/10807030500428538.

integrating knowledge, visualizing the results[7] as well as easing the work of decision-makers by supporting consistent and justifiable decisions.[8]

Since some of the inputs for the damage incidents could vary, probabilistic methods were applied for those most significant fire simulations identified through deterministic simulations. This accounts for possible variation in key input data providing an enhanced analysis of possible spread and consequence. Figure 2 presents an example probabilistic fire simulation for the same ignition location shown in Figure 1. Note that the deterministic boundary is shown as reference to aid in comparison of the two outputs.

Figure 2. Example probabilistic fire simulation.



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[7] Kiker, G.A., Bridges, T.S., Varghese, A., Seager, T.P., Linkov, I., 2005. Application of multicriteria decision analysis in environmental decision making. Integr. Environ. Assess. Manag. 1, 95–108. https://doi.org/10.1897/IEAM_2004a-015.1.

[8] Uusitalo, L., Lehikoinen, A., Helle, I., Myrberg, K., 2015. An overview of methods to evaluate uncertainty of deterministic models in decision support. Environ. Model. Softw. 63, 24–31. https://doi.org/10.1016/j.envsoft.2014.09.017.

2.2.4 Identifying the Most Significant Incidents

Once the fire spread prediction analysis was completed for all damage incidents, specific criteria was applied to identify the most significant incidents for each event. Worst cases were identified using the following criteria. This was not specific to thresholds or distributions.

1. Total population impacted, using the LandScan 2016 population count data.[9] This data provides an accurate definition of population count for the USA. It is ideal for identifying population for wildland, Wildland Urban Interface (WUI), and urban areas. LandScan data has become the de facto standard for quantifying impacts to population for wildfire risk assessments conducted across the nation. Data is synchronized with the most recent Census update to accurate reflect population totals for geo-administrative areas.
2. Total buildings impacted. Original source is the Microsoft Buildings dataset 2018.[10] Building footprints enhanced by Technosylva to include missing data areas and misclassification for California.
3. Size of the fire, given that large fires typically result in high costs for suppression and restoration in addition to greater population and building impacts.
4. Initial Attack Assessment index rating – identifies those fires that would likely escape initial attack suppression and would spread quickly.[11]

2.2.5 Defining Ignition Parameters

Ignition Location

The ignition location used for each fire simulation is based on the GPS coordinates (latitude/longitude) for the individual damage incidents provided by PG&E from their field inspections. Some variation was used in the specific location if the point was found to fall on non-burnable fuels. This was used to accommodate for possible spatial inaccuracy of the ignition location and possible variation of the ignition location due to wind conditions. It is known that in extreme wind conditions sparks from equipment damage may not fall directly below the equipment.

Determining the Time of Ignition

The time of possible ignition for a damage incident is a difficult variable to accurately predict within the PSPS event timeframes given the transient nature of weather conditions influencing damage caused by line slap, pole failure, flying debris and tree falling on electrical assets. Accordingly, an estimated time of ignition was used for the damage incident fire simulations based on the following criteria:

1. Estimated time of damage provided by PG&E, ensuring the estimated ignition time occurred within PSPS event boundaries.

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[9] LandScan 2016 data was used as the source for population analysis. More information can be found at https://landscan.ornl.gov/.

[10] More information about the US Building Footprints data released by Microsoft can be found at https://github.com/microsoft/USBuildingFootprints.

[11] IAA is a metric developed by Technosylva in concert with experienced fire professionals to define the likelihood of a fire to escape initial attack suppression. It is based solely on fire behavior and fire growth characteristics. It is used to help distinguish fires that are likely to spread quickly and become large fires.

2. In any instance in which the estimated ignition time was not within the PSPS event boundaries, time was adjusted to within the outage start and end times to ensure the simulations were consistent with the intent of the evaluation – assessing potential impacts averted while the power was shutoff.
3. Additionally, in certain cases where the estimated ignition time was within the PSPS event boundaries but coincident with additional weather conditions more likely to result in fire simulations with higher impacts on buildings, population and acres burned, the estimated ignition times were adjusted. In these simulations the worst weather scenario was used through a quantitative analysis of hourly wind speed and fuel moisture content considering a temporal window of ± 12 hours within the shutdown.

These criteria were applied for the deterministic simulations for the damage incidents.

For analysis of the most significant damage incidents, the probabilistic simulations inherently accommodate for input data uncertainty and, indirectly, with the issues related to the time of ignition since the model considers varying input data (especially fuel moisture content and wind speed).

Probability of Ignition from Damage

Damage to an electrical asset may result in a wildfire depending on the probability of that damaged electrical asset causing an ignition from arcing. The probability of ignition for an electrical asset can vary given that multiple factors influence it, including the type and condition of asset, nature of the damage, vegetation near the incident and weather conditions.

For these PSPS events, damage incidents and locations are identified by PG&E field personnel performing post-PSPS event patrols pursuant to Commission Resolution ESRB-8. The damage incident data provided by PG&E includes supporting documentation comprised of photographs and damage descriptions made by PG&E field personnel for each damage location. The damage documentation is then provided to a PG&E technical analyst who reviews and quality assures each location's documentation in order to provide a preliminary determination of the likelihood of arcing (assuming the system had remained energized). Final determination of the likelihood of arcing is determined by PG&E Electric Operations Director. Each Electric Operations Director involved in the final determination has extensive field or engineering experience. . It should be noted that these determinations are binary, and each damage incident is determined to either likely cause arcing or not. In general, locations where arcing would likely occur were identified when:

- Non-insulated conductors were in contact directly or indirectly (e.g. a tree branch laying across two or more conductors).
- A non-insulated conductor or conductors were in contact with the ground directly or indirectly (e.g. a tree failure where the tree was leaning against the line without causing the line to fall to the ground)

3. PSPS EVENT ANALYSIS FOR JUNE 7-9, 2019

3.1 Overview

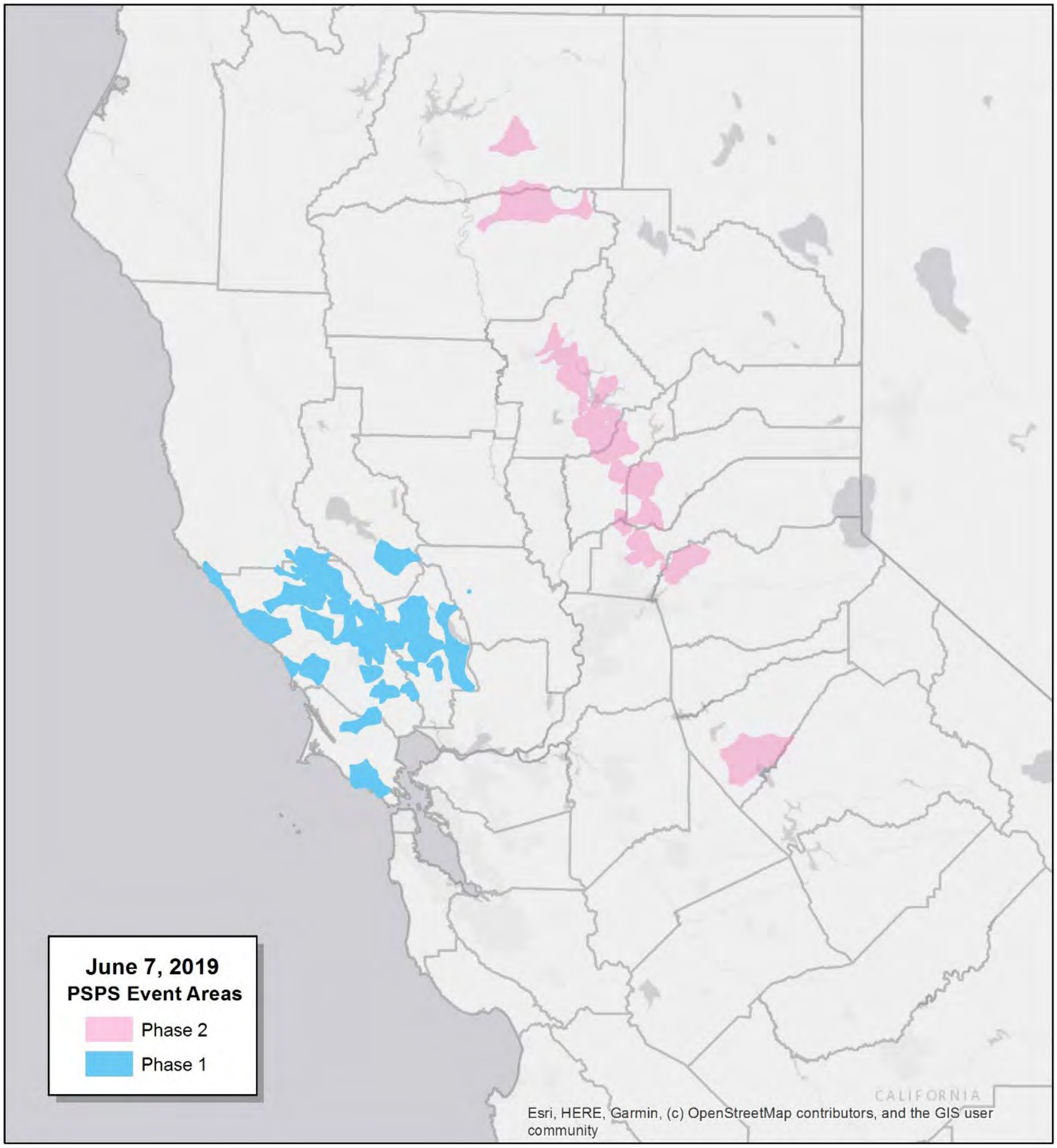
On June 7th and 9th, 2019, PG&E proactively de-energized portions of its service territory for public safety. Approximately 22,000 customers in two locations, the North Bay and the Sierra Nevada Foothills, were impacted by the de-energization, which began at approximately 0600 on June 8th for the North Bay and at approximately 2100 on June 8th for the Sierra Nevada Foothills. As PG&E prepared to take these steps for public safety, they communicated to customers directly and provided warning notification.

The decision was based on the risk derived from the combination of gusty offshore winds, poor overnight moisture recoveries, and dry relative humidity. PG&E's Meteorology team was also forecasting an offshore (Diablo) wind event to unfold over Northern California from June 7th through June 9th that would escalate fire danger and increase the probability of wind-related outages and damage. PG&E's Fire Potential Index (FPI), which combines weather (wind, temperature, and relative humidity) and fuels (10hr dead fuel moisture, live fuel moisture, and fuel type) indicated increasing fire danger from June 7th to June 9th due to increased wind, lowering relative humidity, and further drying of 10hr dead fuel moisture.

The following map shows the areas affected by the PSPS event during this time period. A detailed description of the event, including time periods and locations for de-energization footprints, can be obtained from the CPUC web site at:

https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/PGE%20PSPS%20Report%20Letter_06-21-19.pdf

Figure 3. PSPS event areas.



3.2 Analysis of Weather Conditions

3.2.1 Overview

The overall weather pattern for the PSPS event was dominated by an upper-level trough that advanced over California and the western US on June 7th, 2019.[12] This trough advected cool dry air into the Great Basin which developed a surface high-pressure feature. Over California, an inverted surface trough was established with its axis aligned parallel to the Central Valley.[13] These meteorological features resulted in a strong surface pressure gradient along the crest of the Sierra Nevada which are known to develop strong downslope windstorms in northern California.

Strong surface winds were observed to be widespread over northern California with sustained winds of 15-22 knots (17-25 mph) among the incident damage locations identified. The highest wind measurements were recorded in Sonoma County and were associated with gusts upwards of 45 knots (52 mph). The low atmospheric moisture associated with this event provides further evidence that downslope winds may have occurred. The minimum relative humidity observed by the surface weather stations analyzed ranged from 10 to 20%.

The significance of the event in California is highlighted by:

- The weak upper-level trough produced dry offshore flow across California.
- A modest pressure gradient over the region stimulated downslope winds.
- Dry atmospheric conditions persisted for nearly 24 hours concurrent with strong winds.
- Widespread surface wind measurements of 15-22 knots (17-25 mph) sustained and gusts upwards of 45 knots (52 mph) were recorded.

3.2.2 Observed Weather Versus Modeled Conditions

Observed and modeled weather conditions (especially, wind speed and direction) were analyzed and compared for all PSPS damage incidents. Both modelled weather prediction data provided by PG&E, and weather station observations data, were used to conduct the analysis. A comparison between weather data from the nearest weather station to each damage incident and the modeled weather data at both the damage incident ignition point and the modeled weather conditions is provided. Appendix A provides summary weather analysis results for each significant damage incident through two different charts. The first chart shows the comparison between the weather station values and the simulation modeled values at ignition point. The second chart shows the comparison between the weather station values and the modeled weather values at the station coordinates.

Modeled wind direction data is for the most part consistent with weather station at the same geographical point (modeled wind) and ignition point (simulation wind) in almost all damage incident simulations, reflecting that this input is consistent to model potential fire behavior and progression. However, interestingly, differences between modeled wind speed data, simulation and the nearest weather station were identified. Some simulations have higher modeled wind speed than in the nearest weather station (see Appendix A). Also, simulation winds are usually

[12] A trough is an elongated region of relatively low atmospheric pressure often associated with weather fronts.

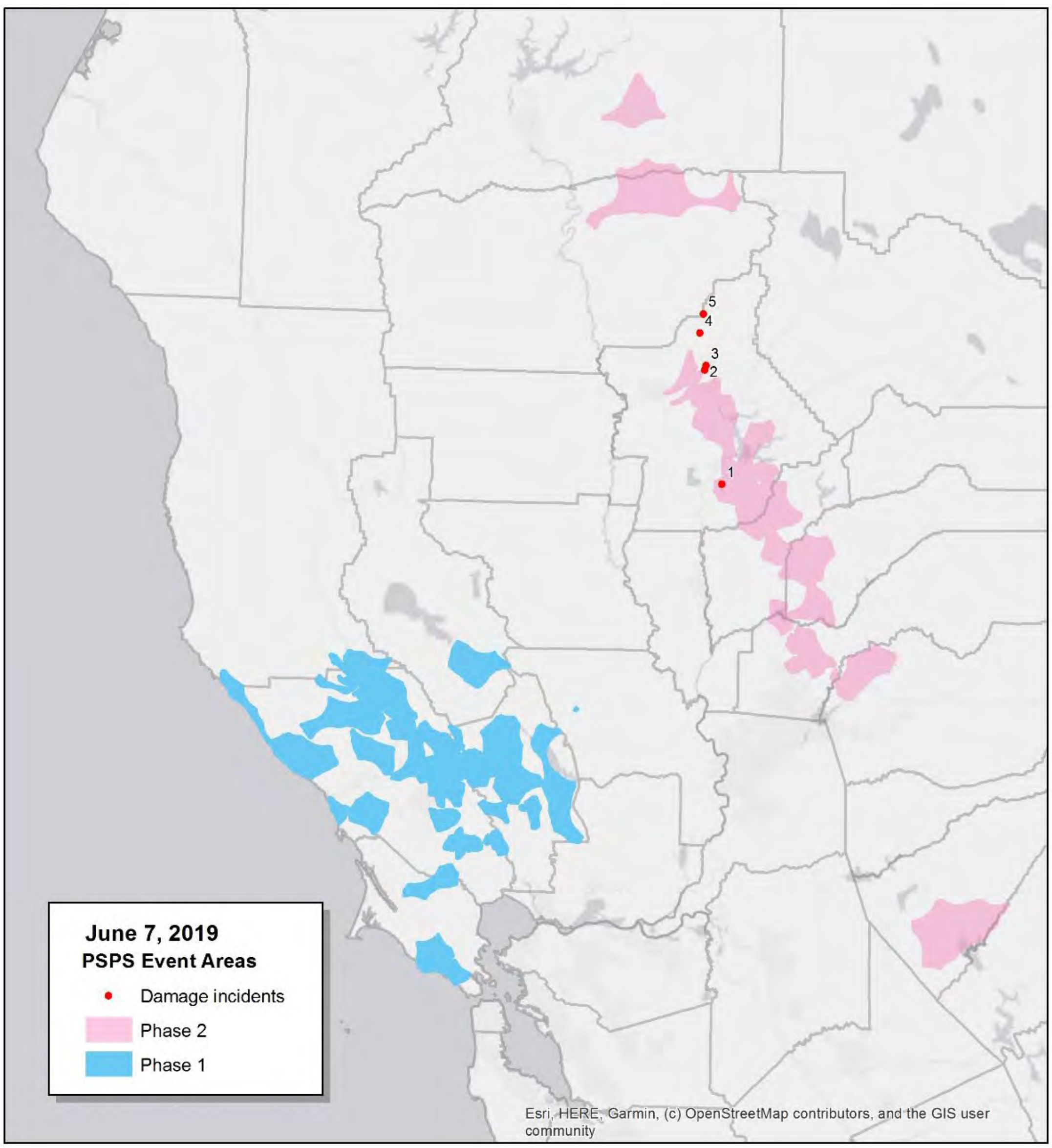
[13] An inverted surface trough is an atmospheric trough which is oriented opposite to most troughs of the mid-latitudes.

higher than station and modeled winds. This finding may explain the damage incident locations with higher wind speeds. Our analysis has found that it is not surprising for weather station data to deviate from modeled and observed wind conditions at the damage incident locations.

3.3 Summary of Damage Incidents

This event's analysis relied upon PG&E's assessment of damage incidents for ignition potential. A total of 5 damage incidents were reported by PG&E for June 7-9th, 2019 PSPS event, including the location (coordinates) and estimated time of damage. The following map presents the locations of the damage incidents relative to the PSPS event areas. All these damage incidents were considered with potential to ignite a wildfire through electric arcing according to the detailed report received from PG&E and field inspections. However, only one damage incident was located inside the PSPS boundaries. Accordingly, an analysis was only undertaken for this single damage incident..

Figure 4. Damage incidents relative to PSPS event areas.



3.4 Summary of Analysis Results

3.4.1 Summary of All Damage Incident Simulations

The following table shows the number of buildings affected, population impacted, and acres burned for the damage incident located inside PSPS boundaries. The damage incident is located in Butte County and a potential fire could burn more than 4,700 acres, causing an impact of 859 buildings and 1,412 people in 24 hours. However, the fire would start spreading slowly from an urban area with low IAA (1) and rate of spread and may be suppressed in the initial attack by the corresponding fire agency easily. The fire simulation reaches lots of buildings scattered across the landscape with moderate-high rate of spread.

Table 1. List of significant simulated fires for this PSPS event.

Damage Incident	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	Butte	1,412	859	4,741	**1**

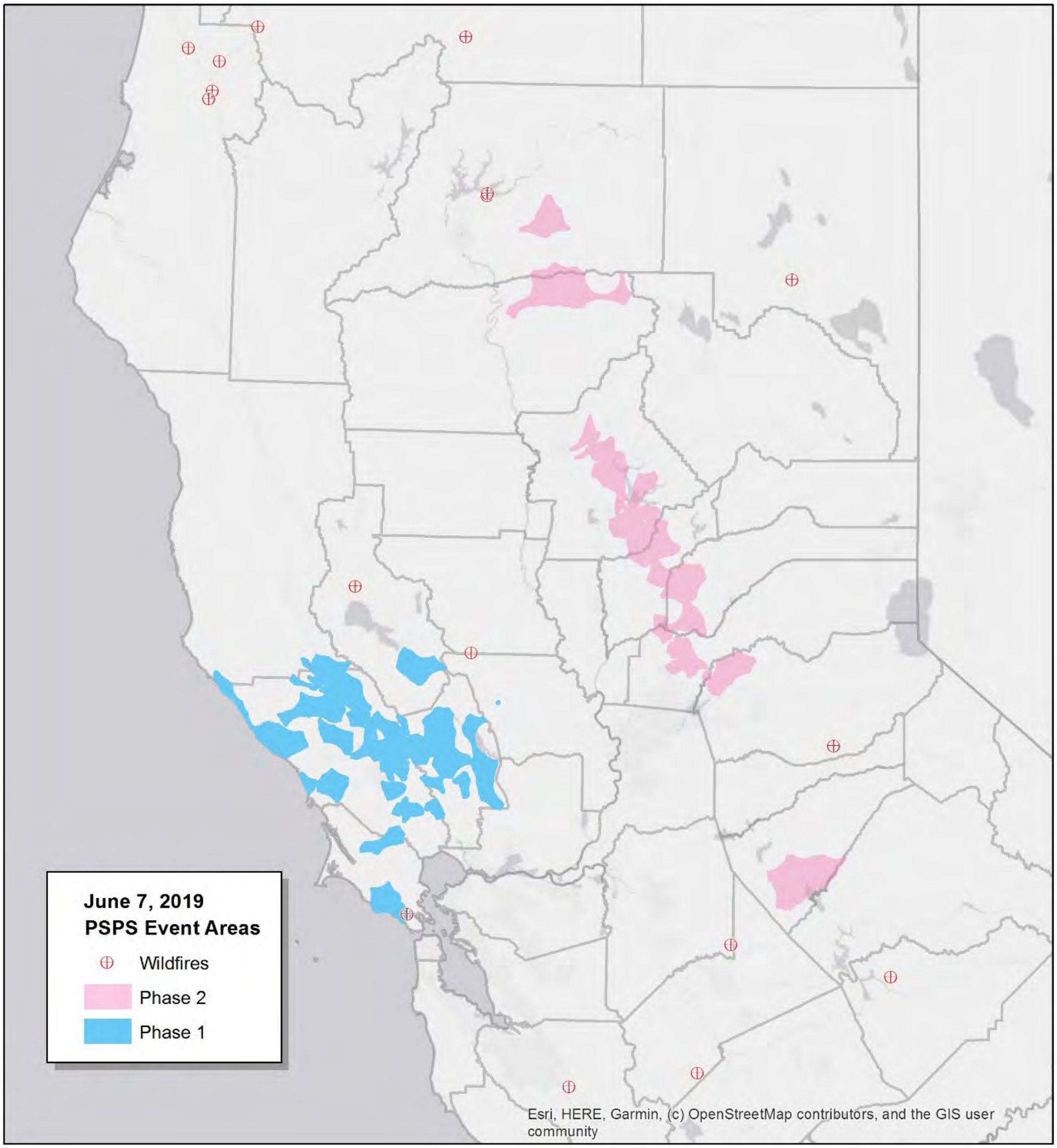
● Low (1) ● Moderate (2) ● High (3) ● Very High (4) ● Extreme (5)

3.5 Summary of Active Wildfires During the PSPS Event

Sixty seven (67) fire incidents were recorded in the Integrated Reporting of Wildland-Fire Information (IRWIN) system from June 6th to 9th, 2019.[14] Three medium to large wildfires were recorded including the SAND (2,512 acres), STURH (600 acres) and JORDAN (593 acres) wildfires. Only one small fire (< 1 acre) was located inside the PSPS event boundaries. Figure 5 presents a map of these fires.

[14] The IRWIN system records wildfires in California through integration with CAL FIRE, all federal agencies and LA County. Wildfires in other local responsibility areas are not recorded in IRWIN or shown on this map.

Figure 5. Wildfires occurring during the PSPS event.



3.6 Event Conclusions

- Damages sustained to de-energized PG&E facilities during the June 7th, 2019 PSPS event would have low fire impacts in terms of burned area, buildings and population compared to the other 2019 PSPS events since only one damage incident was identified by PG&E inside PSPS areas. However, it could potentially burn more than 4,700 acres, potentially impacting 859 buildings and 1,412 people in 24 hours. Therefore, this example shows that an adverse combination of specific environmental conditions (i.e., fuels, weather, topography, etc.) and the exposure of assets (buildings, population) may lead to higher impacts if damage incidents were to occur.
- The fire simulation for this damage incident location would start spreading slowly from an urban area with low IAA (1) and rate of spread and may be suppressed in the initial attack by the authoritative fire agency. However, after the initial period, the fire behavior would accelerate to reach many buildings due to moderate to high rate of spread.
- The wind direction was not consistent during the fire between the weather station at the same geographical point (modeled wind) and ignition point. Also, modeled wind speed was higher than measured. The modeled wind speed at the ignition point was more similar to weather station although direction was rotated during the 24 hour simulation period. Note that the input data uncertainty in this fire simulation is really high and fire impacts could change accordingly.
- Fire impacts are based on modeled winds at the ignition point given that the weather station was located more than 8 miles away from the damage incident. In this regard, the custom weather and fuel types of Technosylva's Wildfire Analyst software allow for the adjustment of input data based on real world observations. This report highlights the importance of having these adjustment capabilities to improve the fire simulation outputs by integrating input data from multiple different sources during operational settings (i.e. cameras, weather station integration, IRWIN, etc.).
- The total fire activity in California was generally low compared to other 2019 PSPS events with only one small fire (< 1 acre) occurring inside the PSPS event boundary. However, note that three medium to large wildfires were recorded in California including the SAND (2,512 acres), STURH (600 acres) and JORDAN (593 acres) wildfires, showing that fire potential was high in several locations exceeding suppression capabilities. Therefore, potential impacts could be different for this PSPS event based on other damage incident locations.

4. PSPS EVENT ANALYSIS FOR SEPTEMBER 23-26, 2019

4.1 Overview

This event included two consecutive time periods of wind events in the September 23 through September 25, 2019 timeframe, resulting in two consecutive PSPS de-energizations. The first time period occurred on the night of September 23rd and affected approximately 26,000 customers. The second time period occurred in the early morning of September 25th affected approximately 49,000 customers. Both time periods took place in approximately the same geographic areas of the North Bay and Sierra foothills. These two time periods are referred to as "location Alpha" and "location Bravo." This event was the first time PG&E initiated back-to-back PSPS de-energizations in the same geographic areas on consecutive timelines.

Location Alpha

- It was determined that portions of Butte, Nevada, El Dorado, Placer, and Yuba counties, referred to as the "Sierra foothills" or "Sierra", were in scope for potential de-energization. Portions of Sonoma, Napa, and Lake county, referred to as the "North Bay," were being actively monitored.
- On September 23 at 1055, the decision was made to de-energize the Sierra area only, and to not deenergize the North Bay at this time, and instead monitor conditions as forecast models had trended weaker in this area.
- On September 23 at approximately 1706, de-energization was initiated impacting 26,121 customers.
- All lines and all 26,121 customers were re-energized as of September 24 at 1840.

Location Bravo

- PG&E Meteorology identified a second period of wildfire potential in the Sierra foothills and North Bay on the evening of September 24 into the morning of September 25. On September 24 at 1720, the decision was made to de-energize both the North Bay and Sierra scopes.
- On September 25 at 0242, de-energization of the Sierra scope was initiated, followed by the initiation of North Bay de-energization at approximately 0409. The de-energizations impacted a combined total of 49,264 customers.
- All lines and all 49,264 customers were re-energized as of September 26 at 1101.

The following map shows the areas affected by the PSPS event during this time period.

A detailed description of the event can be obtained from the CPUC web site at:

https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/Public%20Safety%20Power%20Shutoff%20October%2010%202019%20Report.pdf

Figure 6. September 23, 2019 PSPS event areas.

4.2 Analysis of Weather Conditions

4.2.1 Overview

The overall weather pattern for the PSPS event was dominated by a weak upper-level trough that advanced over California and the western US on September 23rd, 2019.[15] This trough advected cool air into the Great Basin which developed a surface high-pressure feature. Over California,

[15] A trough is an elongated region of relatively low atmospheric pressure often associated with weather fronts.

an inverted surface trough was established with its axis aligned parallel to the Central Valley.[16] These meteorological features resulted in a moderate surface pressure gradient along the crest of the Sierra Nevada which are known to develop offshore flow and the potential for downslope windstorms in northern California.

Moderate intensity surface winds were observed to be widespread over northern California with sustained winds of 15-20 knots (17-23 mph) among the incident damage locations identified. The highest wind measurements were recorded in the Sierra Nevada range and were associated with gusts upwards of 40 knots (46 mph). The low atmospheric moisture associated with this event was brief, but single digit relative humidity was recorded in Sonoma County. The surface weather stations that were analyzed generally observed relative humidity between 15 to 40%.

The significance of the event in California is highlighted by:

- The weak upper-level trough produced a modest surface pressure gradient which yielded moderate offshore flow.
- Very dry conditions were brief concurrent with wind of moderate intensity.
- Widespread surface wind measurements of 15-20 knots (17-23 mph) sustained and gusts upwards of 40 knots (46 mph) were recorded.

4.2.2 Observed Weather Versus Modeled Conditions

Observed and modeled weather conditions (especially, wind speed and direction) were analyzed and compared for all PSPS damage incidents. Both modelled weather prediction data provided by PG&E, and weather station observations data, were used to conduct the analysis. A comparison between weather data from the nearest weather station to each damage incident and the modeled weather data at both the damage incident ignition point and the modeled weather conditions is provided. Appendix B provides summary weather analysis results for each significant damage incident through two different charts. The first chart shows the comparison between the weather station values and the simulation modeled values at ignition point. The second chart shows the comparison between the weather station values and the modeled weather values at the station coordinates.

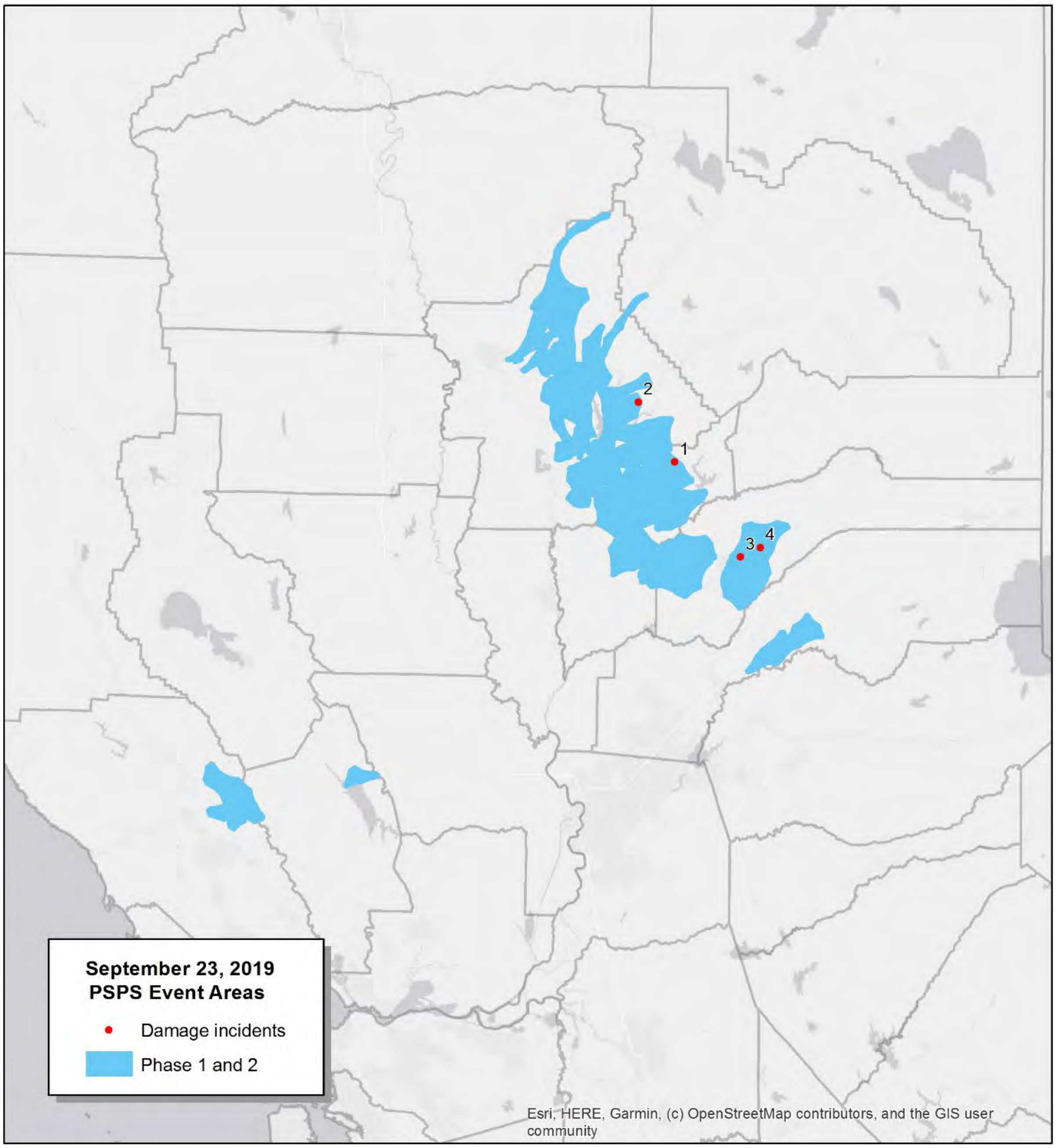
Modeled wind direction data is for the most part consistent with weather station at the same geographical point (modeled wind) and ignition point (simulation wind) in almost all damage incident simulations, reflecting that this input is consistent to model potential fire behavior and progression. However, interestingly, differences between modeled wind speed data, simulation and the nearest weather station were identified. Some simulations have higher modeled wind speed than in the nearest weather station (see Appendix B). Also, simulation winds are usually higher than station and modeled winds. This finding may explain the damage incident locations with higher wind speeds. Our analysis has found that it is not surprising for weather station data to deviate from modeled and observed wind conditions at the damage incident locations.

[16] An inverted surface trough is an atmospheric trough which is oriented opposite to most troughs of the mid-latitudes.

4.3 Summary of Damage Incidents

This event's analysis relied upon PG&E's assessment of damage incidents for ignition potential. A total of 4 damage incidents were reported by PG&E for the September 23rd PSPS event, including the damage location (coordinates) and estimated time of damage. All these damage incidents had the potential to ignite a wildfire through electric arcing according to the detailed report received from PG&E and field inspections. The following map presents the locations of the damage incidents relative to the PSPS event areas. A unique identification number is provided for each damage incident representing a ranking based on population impacted.

Figure 7.Damage incidents relative to PSPS event areas.



4.4 Summary of Analysis Results

4.4.1 Summary of All Damage Incident Simulations

Table 1 shows the number of buildings affected, population impacted, and acres burned for all 4 damage incident locations, after averaging 100 fire simulations during a 24 hours fire duration for each incident location, resulting in a total of 400 fire simulations. The fire impacts of this event are very low compared to other 2019 PSPS events. All simulations had a low IAA (1) and, therefore, the fires would likely have been suppressed by fire agencies during initial attack. A total of 2,394 acres, 400 people and 47 buildings could have been threatened by wildfires ignited by the reported incident damage locations.

Even though there are a low amount of damage incidents in this PSPS event, note that the variability in fire impact between damage incidents is moderate, reflected as the difference between the mean, maximum values and standard deviation. The fire impacts of each incident depends on specific environmental conditions (i.e., fuels, weather, topography, etc.) and the exposure of assets (buildings, population).

Table 1. Total expected impact, mean and maximum per fire simulation for all damage incident predictions.

Impact Type	Total	Mean	Maximum	Standard deviation
Population	400	100	53	61
Buildings	47	12	27	12
Acres Burned (ac)	2,394	598	1,644	701

4.4.2 Summary of Significant Incidents

Using the criteria described in Section 2.2.4 a list of the most significant fire incidents were identified from the 4 damage incidents based on criteria described in the previous section. The following table lists these incidents. Incidents are numbered by a ranking of potential impacts starting at 1 (i.e. most population impacts). The IAA is shown as guide for potential to spread rapidly and exceed initial attack.

The following table summarizes the population and buildings impacted, and acres burned for the damage incident simulations. The IAA is color coded from **Low 1** to **Extreme 5**.

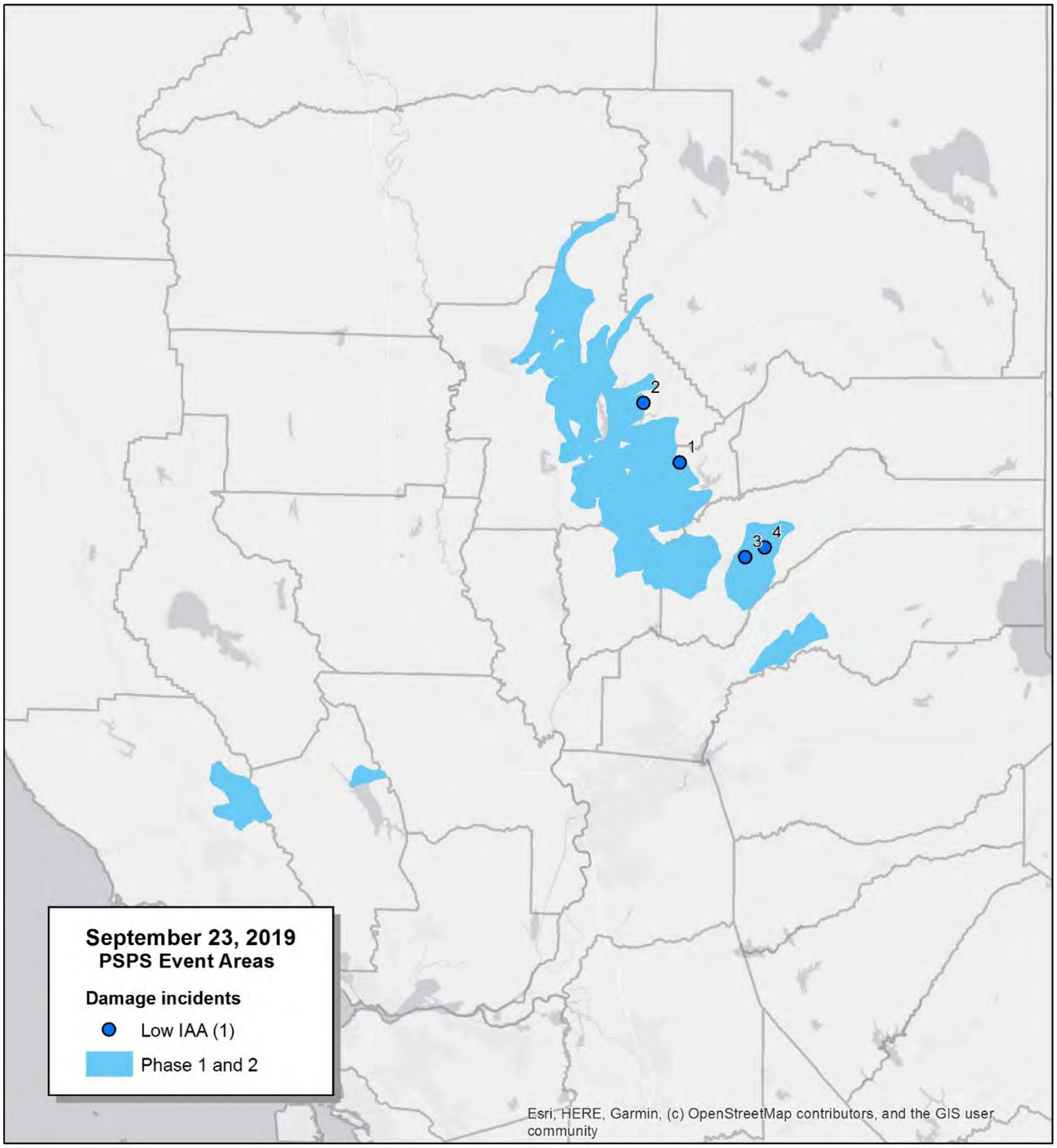
Table 2. List of significant simulated fires for this PSPS event.

Damage Incident	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	Yuba	153	3	172	**1**
2	Butte	143	1	352	**1**
3	Nevada	82	27	1,664	**1**
4	Nevada	22	16	224	**1**

Low (1) Moderate (2) High (3) Very High (4) Extreme (5)

Figure 8 presents a map showing the location of the significant incidents identified in Table 2.

Figure 8. Map of the significant damage ignition locations.



Fire behavior is related to fuel types, topography and weather conditions (i.e. low fuel moisture and high wind speed). Although small fires can also result in large impacts due to their specific location and proximity of buildings and people, large fires, in terms of acres burned, usually correlate to higher impacts for buildings and population impacted. However, in this PSPS event, fires were small in size giving rise low impacts in terms of population and building loss. Additionally, fire behavior characterized by rate of spread and fire intensity (i.e., flame length) directly influences building loss. In this PSPS event, the fire could have threatened more buildings than “impacted” buildings reflected in summary tables given the low rate of spread and fire intensity in these simulations. More details can be found in Appendix B for each simulation.

Fire simulations with an intense fire behavior (high flame length and high rate of spread) typically result in an Initial Attack Assessment Index (IAA) value of high (4) or extreme (5), and have the largest burned areas based on a 24-hour fire simulations. The IAA index is intended to be used to analyze the fire simulation and the initial attack difficulty, not to analyze potential impacts in terms of buildings of population. All fires had a low IAA (1) and, therefore, they could be easily suppressed by the corresponding fire agency.

Figure 9. Summary of population and buildings impacted for the significant incidents.

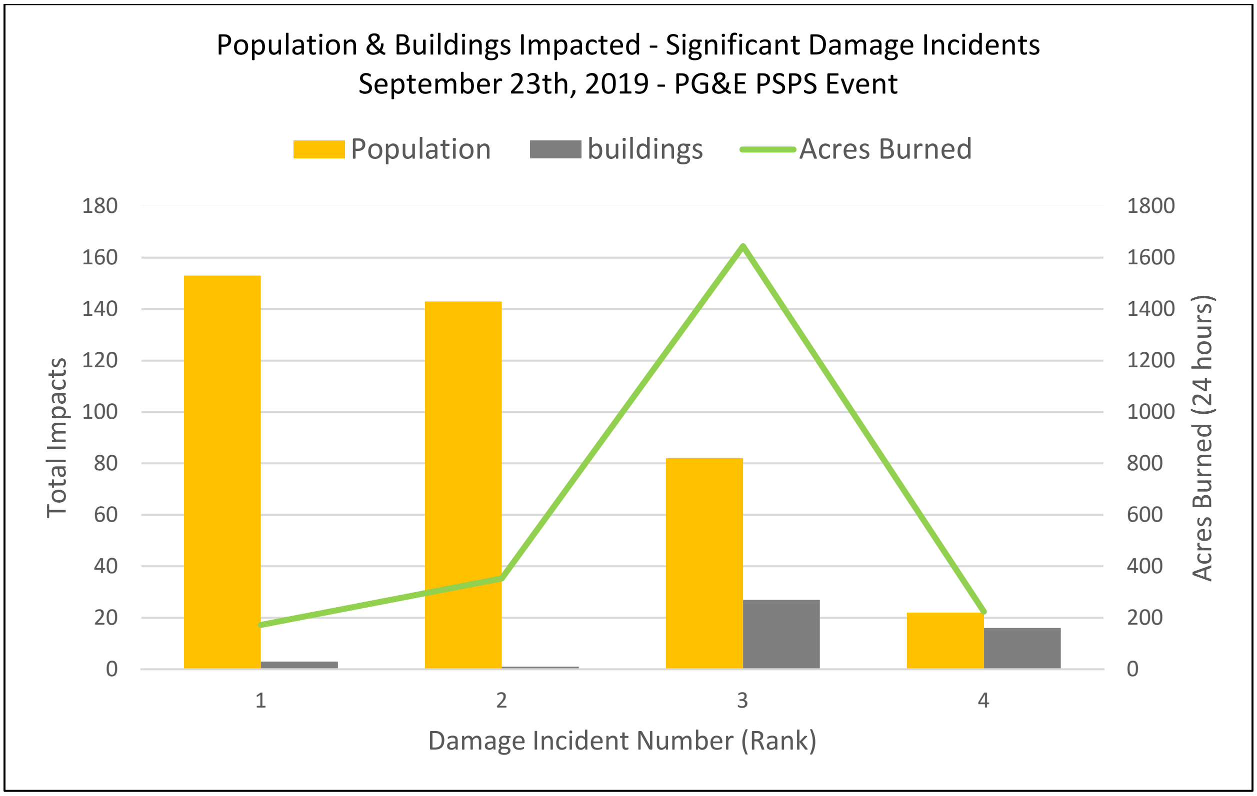
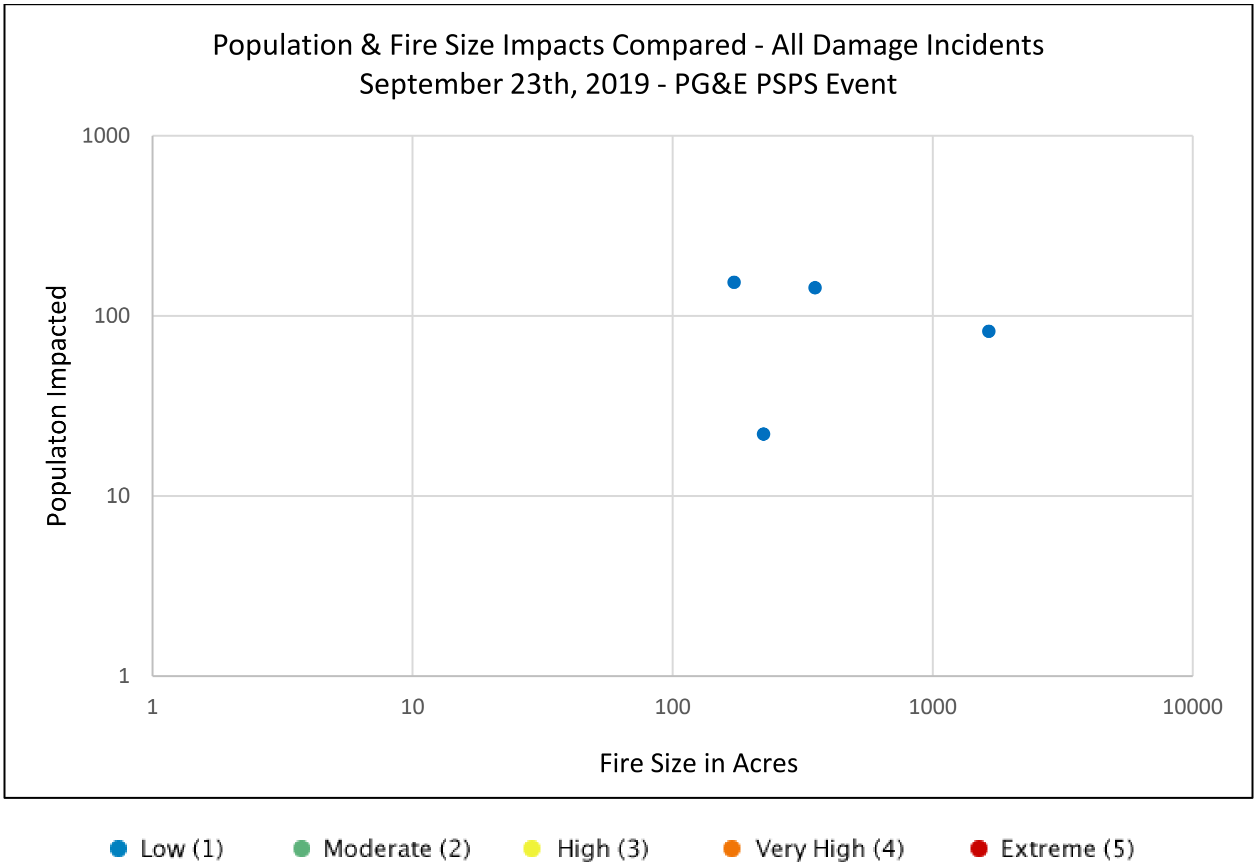


Figure 10 presents the population impacts of each fire simulation as a function of size (acres burned). Fires are color coded by IAA although all simulations had low IAA (1) leading to small fires with low impacts. These fire simulations are not likely to escape initial attack.

Figure 10. Number population impacts as a function of fire size. Colors represents IAA values from low (blue) to extreme (red)



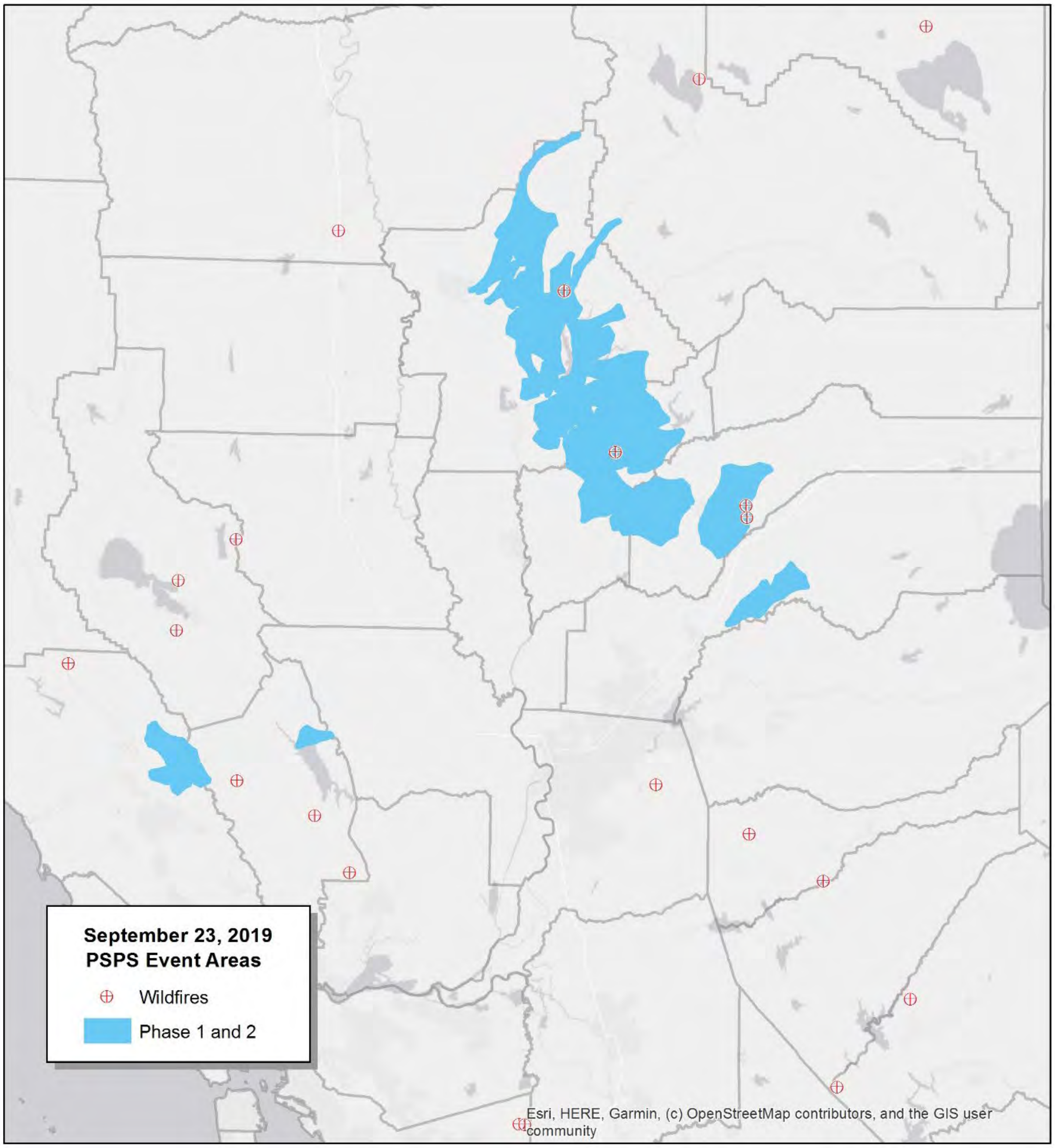
In summary, the following conclusions are reached:

- All fires derived from recorded damage incidents would be small
- The fire impact in terms of population and building loss would be low. This analysis illustrates that some circuits or segments thereof could be good candidates for sectionalizing to reduce PSPS impact.
- Expectedly, all fires would have been easily suppressed by the fire agency given the low IAA (1) and fire behavior.

4.5 Summary of Active Wildfires During The PSPS Event

Seventy five (75) fire incidents were recorded in the IRWIN system from September 23 to 26, 2019.[17] Only a single medium size fire (DEHESA fire; 200 ac) occurred. Only four (4) fires, all less than 1 acre, were located in the PSPS event areas. Figure 11 shows the location of these wildfires.

Figure 11. Wildfires occurring during the PSPS event.



[17] The IRWIN system records wildfires in California through integration with CAL FIRE, all federal agencies and LA County. Wildfires in other local responsibility areas are not recorded in IRWIN or shown on this map.

4.6 Event Conclusions

- Damages sustained to de-energized PG&E facilities during the September 23rd, 2019 PSPS event could have a low to moderate impact in terms of buildings (47), population (400) and area affected (2,394 ac) compared to the October 9th and October 26th PSPS events.
- Fires would have spread slowly with low fire intensity in all simulations due to the absence of crowning. Fire behavior characterized by rate of spread and fire intensity (i.e., flame length) directly influence building loss. In this PSPS event, the low rate of spread limited the buildings and population impacted.
- The fire activity reflected by IRWIN incidents (75 fires during the PSPS event but only 4 located in PSPS areas) was low and fires were small.

5. PSPS EVENT ANALYSIS FOR OCTOBER 5-6, 2019

5.1 Overview

On October 5th to 6th, 2019, PG&E executed a PSPS event in the north Sierra foothills area because of a period of expected high wildfire risk. The event impacted approximately 11,300 customers across three counties, Butte, Yuba, and Plumas. As PG&E prepared to take these steps for public safety, it followed established protocols and communicated to customers directly, providing advanced notification when and where possible via automated calls, texts, e-mails and online notices. Throughout the PSPS event, PG&E communicated continuously with state and local officials and proactively engaged the media via news briefings, news releases, interviews and social media updates.

The decision to de-energize was made by a designated Officer-in-Charge (OIC) at PG&E's EOC, which was staffed by PG&E's electric operations, meteorology, customer care, public information and government liaison functions, as well as other functions. On October 5, 2019, at approximately 2200, PG&E initiated de-energization. The next morning, October 6, 2019, the weather had cleared by approximately 0900 and safety patrols began in earnest. Restoration was completed by 1600 the same day, restoring all customers within 18 hours of being de-energized.

Figure 12 shows the areas affected by the PSPS event during this time period.

A detailed description of the event can be obtained from the CPUC web site at:

https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/News_Room/NewsUpdates/2019/PGE%20Public%20Safety%20Power%20Shutoff%20Oct.%205-6%20Report.pdf

Figure 12. PSPS event areas.

5.2 Analysis of Weather Conditions

5.2.1 Overview

The overall weather pattern for this PSPS event on October 5-6, 2019 was characterized by a weak upper-level trough that matured over the Great Basin on October 6, 2019. In the wake of the trough, weak surface high-pressure developed in the Great Basin, which was associated with a surface inverted trough over Southern California. These features developed a weak cross-barrier surface pressure gradient along the Sierra Nevada. Initial analysis revealed that relatively dry air advected into localized parts of California. Data indicated that the event only impacted the Sierra region. Surface weather stations near crest height experienced increased wind speeds from the E to NE but did not influence the lower elevations. The occurrence of a downslope windstorm in northern California was very unlikely on October 6, 2019.

The significance of the event is highlighted by:

- A very weak upper-level trough that matured over the Great Basin
- A weak cross-barrier pressure gradient along the Sierra Nevada crest
- Strong winds were confined to high elevations of the Sierra region associated with mild drying

5.2.2 Observed Weather Versus Modeled Conditions

Observed and modeled weather conditions (especially, wind speed and direction) were analyzed and compared for all PSPS damage incidents. Both modelled weather prediction data provided by PG&E, and weather station observations data, were used to conduct the analysis. A comparison between weather data from the nearest weather station to each damage incident and the modeled weather data at both the damage incident ignition point and the modeled weather conditions is provided. Appendix C provides summary weather analysis results for each significant damage incident through two different charts. The first chart shows the comparison between the weather station values and the simulation modeled values at ignition point. The second chart shows the comparison between the weather station values and the modeled weather values at the station coordinates.

Modeled wind direction data is for the most part consistent with weather station at the same geographical point (modeled wind) and ignition point (simulation wind) in almost all damage incident simulations, reflecting that this input is consistent to model potential fire behavior and progression. However, interestingly, differences were identified between modeled wind speed data, simulation and the nearest weather station. Some simulations have higher modeled wind speed than in the nearest weather station (see Appendix C). Also, simulation winds are usually higher than station and modeled winds. This finding may explain the damage incident locations with higher wind speeds. Our analysis has found that it is not surprising for weather station data to deviate from modeled and observed wind conditions at the damage incident locations.

5.3 Summary of Damage Incidents

The analysis relied upon PG&E's assessment of damage incidents for ignition potential according to data received from PG&E and field inspections. Two damage incidents with potential to ignite a wildfire were reported by PG&E for the October 5th PSPS event. One incident (Incident ID =1) was located inside the PSPS area, and one incident was located outside the PSPS area (the ignition point is 3 km away the PSPS area).

The following map presents the locations of the damage incidents reported by PG&E for the PSPS event. A unique identification number is provided for each damage incident.

Figure 13. Damage incidents relative to PSPS event areas.

5.4 Summary of Analysis Results

5.4.1 Summary of All Damage Incident Simulations

Fire spread simulations were undertaken for 1 of the 2 damage incidents. Table 3 shows the number of buildings and population impacted, and acres burned after averaging 100 fire simulations during a 24 hour fire duration for each incident location. The damage incident inside the PSPS event boundary has zero impacts and only 379 acres burned.

Table 3. List of simulated fires for this PSPS event.

Damage Incident	Description	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	Topography-driven fire starting near a road. The rate of spread was very low (IAA = 1) and there were no buildings or population near the fire propagation. Thus, the fire impact on these values was 0.	Butte	0	0	379	**1**

● Low (1) ● Moderate (2) ● High (3) ● Very High (4) ● Extreme (5)

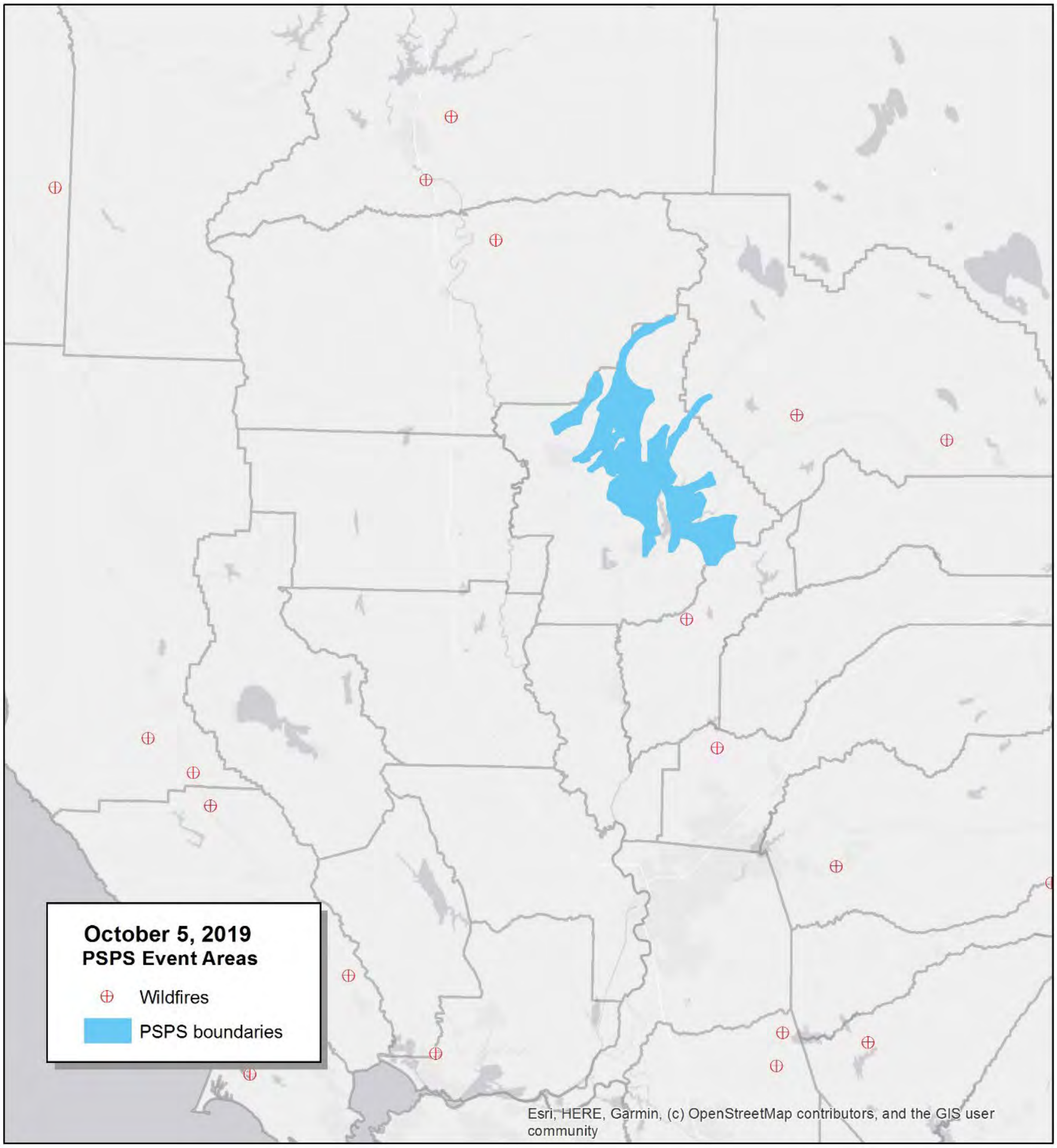
5.5 Summary of Active Wildfires During the PSPS Event

This section summarizes the active wildfires (93) that occurred during the PSPS event in California according to the IRWIN system from October 5 (2200) to 12 (1600), 2019.[18] Figure 14 shows the location of these wildfires.

Most fires (27) were less than one acre. Two large wildfires started during the PSPS event in California, but they were located far from the PSPS areas: the Briceburg (5,563 ac) and American (532 ac) fires. No fires are located in the PSPS areas.

[18] The IRWIN system records wildfires in California through integration with CAL FIRE, all federal agencies and LA County. Wildfires in other local responsibility areas are not recorded in IRWIN or shown on this map.

Figure 14. Wildfires occurring during the PSPS event.



5.6 Event Conclusions

- During the October 5, 2019 PSPS event there were two recorded damage incidents reported by PG&E although only one of them was located inside the PSPS boundaries. The incident inside the PSPS area had no population or buildings impacted and only had 379 acres burned.
- Fire behavior in the two studied fires was very low with low rate of spread (< 2ch/h) and flame length (< 2 ft) and they probably would have been suppressed quickly by firefighters given the low IAA (1).

- The fire activity reflected by IRWIN incidents is moderate (29 fires during the PSPS event in California) but most of the fires were smaller than 1 ac in the largest ones were located far from PSPS event areas.

6. PSPS EVENT ANALYSIS FOR OCTOBER 23-25, 2019

6.1 Overview

Between October 23rd and October 25th, 2019, PG&E responded to an offshore wind event by proactively turning off power in an effort to reduce the risk of catastrophic wildfire. This PSPS event was executed in phases across four different geographic areas as represented in Table 4. In total, approximately 177,000 customers were impacted. Once the weather returned to safe conditions, power was restored to the majority of customers within 12 hours of the 'all clear'.

PG&E considered many factors in weighing the risk of catastrophic wildfire if PG&E relies upon alternatives to de-energization against the risk of de-energization. These factors include meteorological forecasts and wildfire risk data to determine the scope and impact of de-energization, as well as the efficacy of alternatives and mitigations to the extent possible prior to the potential de-energization. Forecast models showed high windspeeds, low humidity levels, and critically dry fuels in areas of PG&E electrical assets. PG&E's internal models and forecasts were in consensus with external forecasting services, including the European Center for Medium-Range Weather Forecasts (ECMWF), Global Forecast System (GFS), Northern Operations Predictive Services and the National Weather Service. Red flag warnings were in effect in the areas identified for de-energization. High resolution weather modeling providing forecasts specific to 3-kilometer x 3-kilometer areas were used to identify localized areas of high risk. This granular area identification establishes the foundation of the PSPS scope. Approaching the event, PG&E's weather model is updated every 6 hours, and scope is adjusted accordingly for increase or decreases in area of risk.

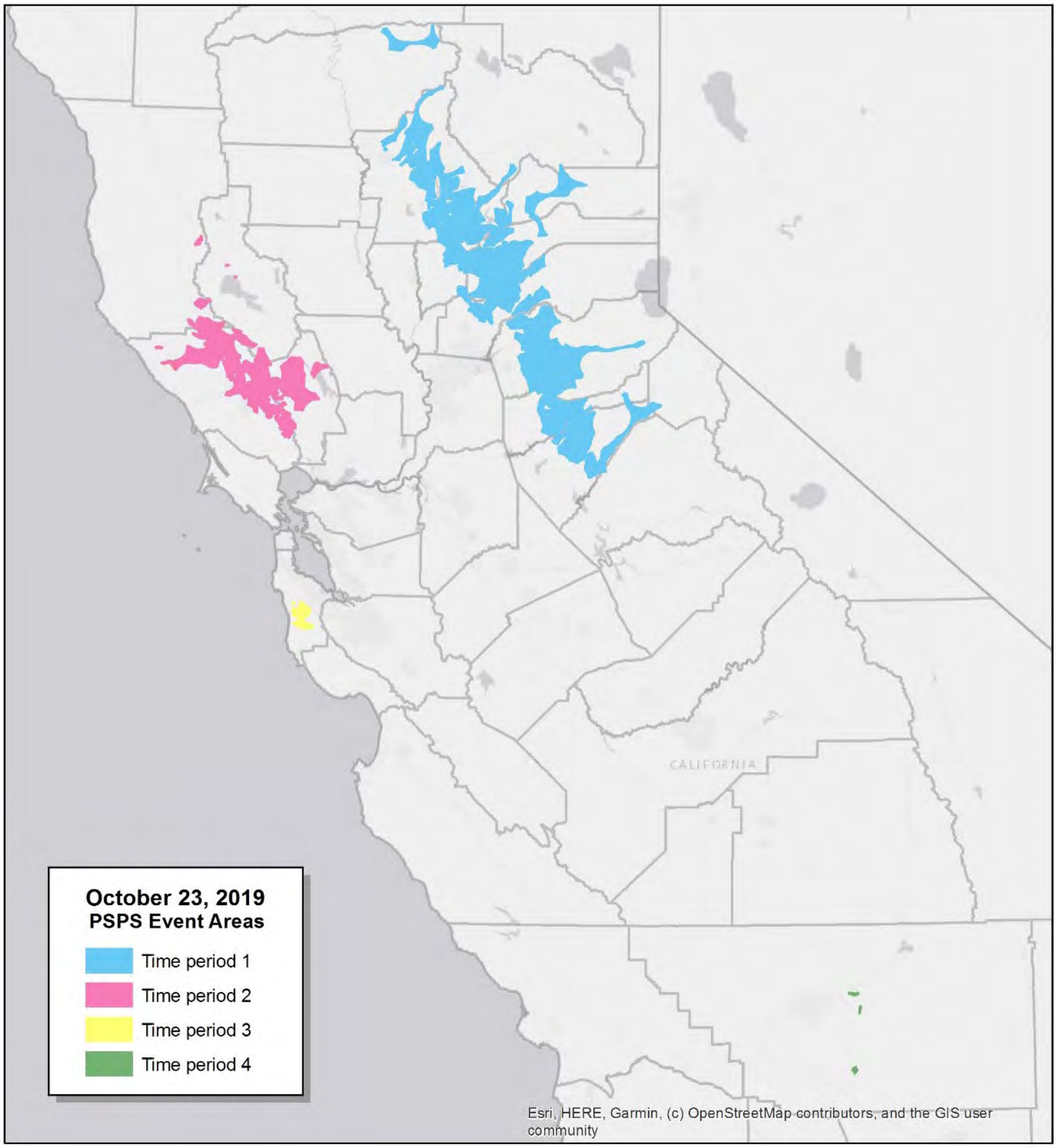
Table 4. October 23-25, 2019 PSPS event phases and times

De-Energization Time Period	Region	Start Time	Restoration Completed
1	Sierra Foothills	10/23/2019 13:54	10/25/2019 15:51
2	North Bay / Mendocino	10/23/2019 14:15	10/25/2019 18:20
3	San Mateo County	10/24/2019 01:00	10/24/2019 15:00
4	Kern County	10/24/2019 01:12	10/25/2019 14:30

The following map shows the areas affected by the PSPS event during this time period. A detailed description of the event can be obtained from the CPUC web site at:

https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/News_Room/NewsUpdates/2019/PGE%20Public%20Safety%20Power%20Shutoff%20Oct.%2023-25,%202019%20Report.pdf

Figure 15. PSPS event areas.



6.2 Analysis of Weather Conditions

6.2.1 Overview

The overall weather pattern for this PSPS event was characterized by an upper-level trough that experienced southward propagation east of California on October 24th, 2019. As this trough propagated south, the upstream ridge amplified over the western US. Atmospheric subsidence in the wake of this trough developed a high-pressure feature over the eastern Great Basin. Very dry air was advected into California by this system. An associated inverted surface trough extended from the Mexican Plateau into central California and facilitated a strong surface pressure gradient across the Sierra Nevada crest. The cross-barrier surface pressure gradient was well forecasted and is a key component for the development of downslope windstorms in northern California.

Surface winds did intensify across California, but in general winds were topographically localized during this event. Most locations in the lower elevations did not experience impacts of the wind event while mid-level elevations and locations at crest height did. Evidence of rotors, indicative of hydraulic jumps, was found in all regional analyses performed. The elevated fire weather risk was confirmed by the ignition of the Kincade Fire in Sonoma County. The fire spread rapidly burning more than 15,000 acres in the first 24 hours. All regions observed minimal to no overnight relative humidity (RH) recoveries with multiple occurrences of single-digit RH observed.

The significance of the event is highlighted by:

- An upper level trough that propagated southward in the eastern region of the Great Basin
- Strong cross-barrier surface pressure gradient development across the Sierra Nevada crest
- Multiple regions likely experienced downslope windstorms with limited low elevation extent
- The lower elevation observations showed evidence of rotors with light and variable winds
- The ignition and blowup of the Kincade fire

Due to the significance of this weather event a detailed description of the event is provided in the next section.

6.2.2 Detailed Weather Description

PG&E released a fact sheet that clearly highlighted the northern Sierras, Coastal Ranges, and Santa Cruz Mountains as the principal regions of impact, and these areas were analyzed separately here as the Sierra region, Sonoma region, and Diablo region (Figure 16). Pine Flat Road observed the strongest wind gust and was subsequently used as a proxy for the peak of the event. This site, depicted in Figure 6, is in the Mayacamas Mountains in the northeast of Sonoma County, California. A time series of sustained wind speed and gusts at Pine Flat Road is shown in Figure 6. Sustained winds remained above twenty knots for approximately eighteen hours. The peak gust was recorded at approximately 0600 UTC 24 October 2019 and will later be referenced as the peak of the event. Event characteristics are analyzed using upper atmosphere analyses, atmospheric soundings, surface analyses, and surface weather station observations.

Figure 16. Surface observation locations are displayed over shaded terrain contours. Marker colors signify the Sierra region (blue), Sonoma region (green), and Diablo region (black). Each region has a site located near crest height (diamonds), in the mid-elevations (squares), and lower elevations (circles). Pine Flat Road is displayed by a ´+´ and is only referenced to identify the peak of the event

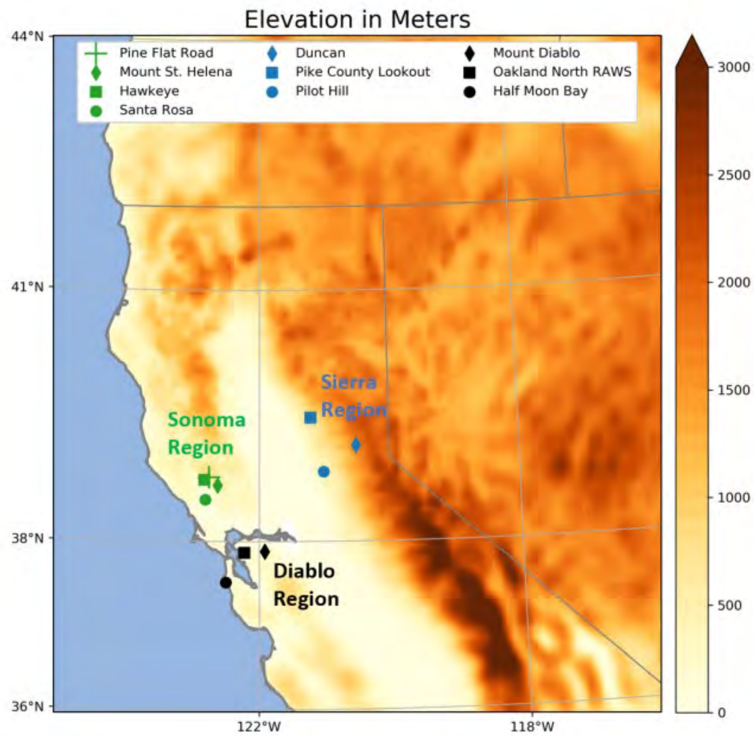
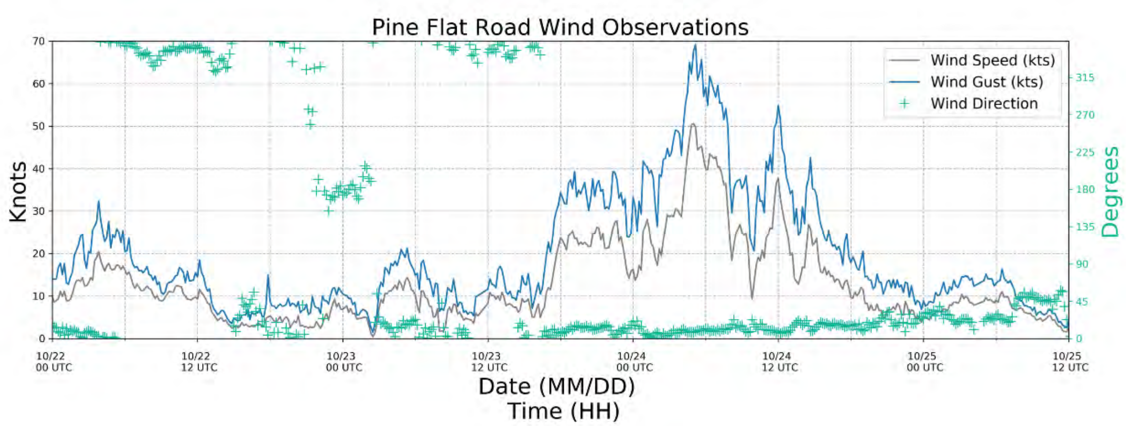


Figure 17. Surface wind observations from Pine Flat Road measured in knots.

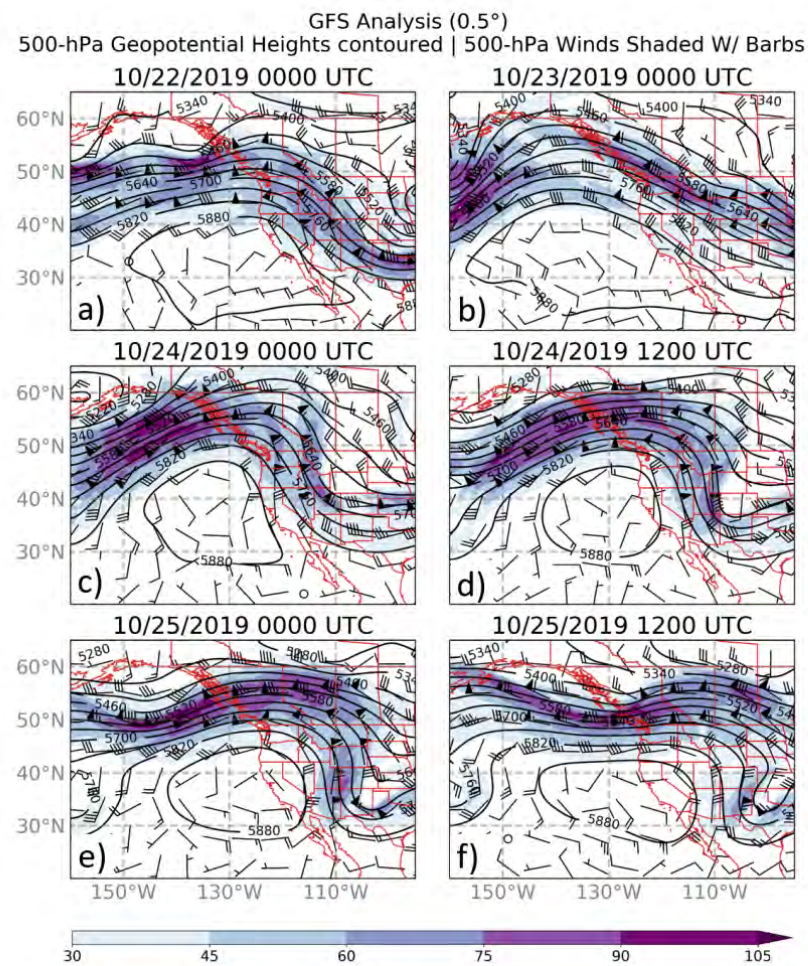


Upper Atmosphere Analysis

The global forecast system (GFS) re-analysis dataset with 0.5° horizontal resolution was used to produce synoptic maps and analyses for this event. Synoptic features responsible for the wind event developed slowly. A shortwave trough, observed off the coast of British Columbia on 0000 UTC 22 October 2019, had to first traverse the upper level ridge that was situated over the western US (Figure 18a). This traverse was completed twenty-four hours later at 0000 UTC 23 October 2019 and signified the start of the southward propagation. As the trough propagated southward, east of California, it coincided with the amplification of the upstream ridge over the western US. By 1200 UTC 24 October, the trough axis was located near the Four Corners region.

Atmospheric profiles are examined next to determine regions of atmospheric stability during the event.

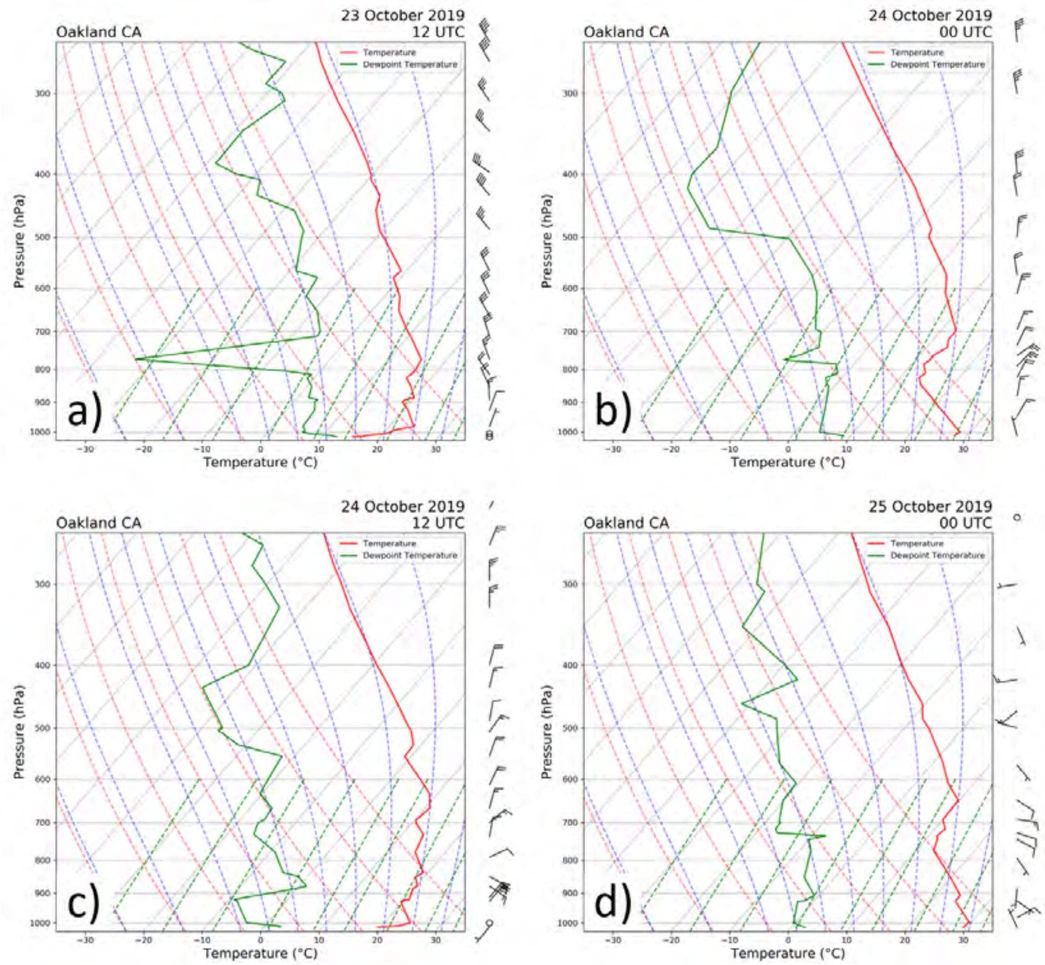
Figure 18. Geopotential heights at 500-hPa are contoured and winds are shaded in knots. Time is labeled in UTC.



Atmospheric Soundings

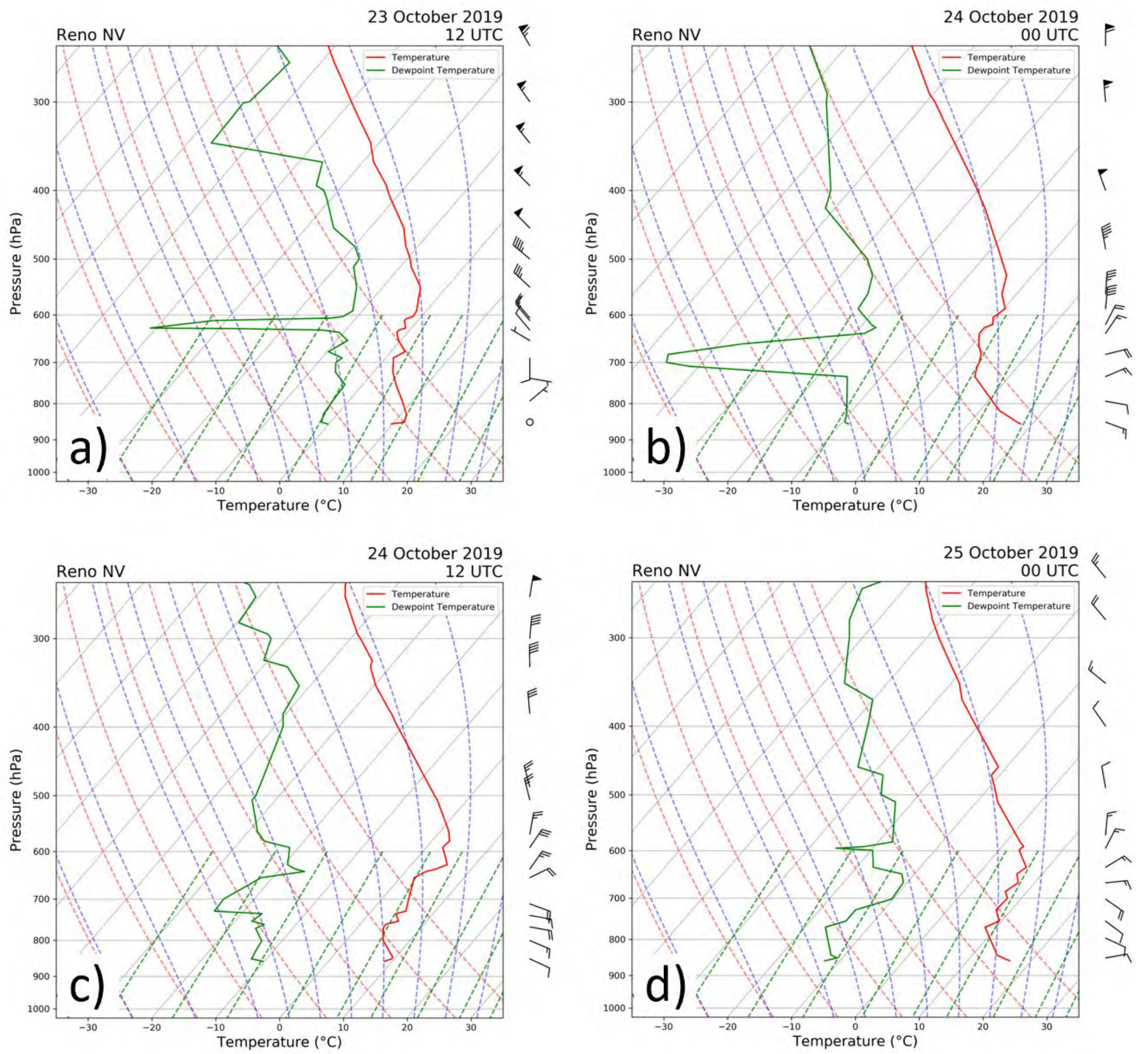
Standard NWS upper-level radiosonde soundings are available every twelve hours at numerous locations in the US. For this event, radiosonde soundings from Oakland, California were used to identify fundamental characteristics necessary for downslope windstorms. The lower elevation of the north bay, Diablo, and Santa Cruz regions are best represented by the atmospheric profiles from Oakland. Atmospheric profiles from Oakland observed cold air advection (CAA) in the lower half of the atmosphere that contributed to a mid-level temperature inversion. This inversion height was approximately 825 hPa at 0000 UTC 24 October and decreased significantly to around 925 hPa by 1200 UTC 24 October (Figure 19b-c). The inversion lowered from 5200 feet to approximately 2600 feet above mean sea level. Both the Sonoma region and the Diablo region observed peak wind speeds when the inversion approached crest height. These observations stress the importance of the stability layer's height and its proximity to crest height. It is the stable layer that forces downward deflection of mountain wave energy as the air flows past the barrier. An analysis was also performed using sounding data from Reno, Nevada which showed a more representative atmospheric profile for the Sierra region.

Figure 19. Atmospheric profiles recorded every twelve hours from Oakland, California (KOAK) are chronologically ordered in panels a though d, starting 12 UTC 23 October 2019 and ending 00 UTC 25 October 2019.



The higher elevations of the Sierra region are best represented by the atmospheric profiles from Reno, Nevada. Skew-t diagrams of the atmospheric profiles collected from Reno are shown in Figure 20. Notable features are backing winds with height, the existence of CAA that contributed to a mid-level inversion, and strong wind shear near the inversion altitude. It was 1200 UTC 23 October 2019 when this inversion was observed near 700 hPa. After twenty-four hours, this inversion descended to approximately 750 hPa which amounted to an altitude change from a height of 11300 feet down to 8500 feet above mean sea level. This descent allowed the inversion to be near crest height of the Sierras and deflection of the channeled winds contributed to the peak of the wind event. The regional analysis showed this at crest height as well, but the winds did not mix down to the mid and lower elevations of the Sierra region.

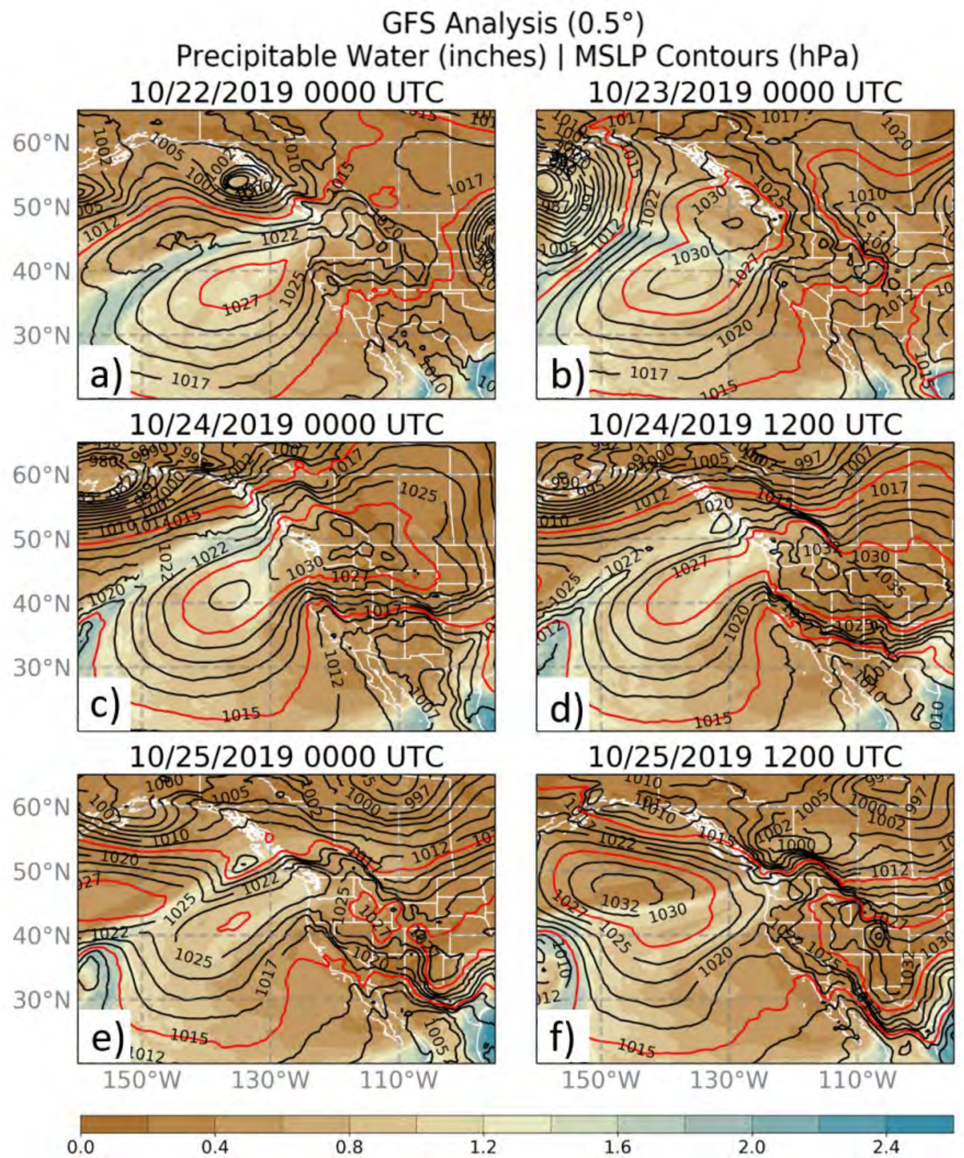
Figure 20. Atmospheric profiles recorded every twelve hours from Reno, Nevada (KREV) are chronologically ordered in panels a though d, starting 12 UTC 23 October 2019 and ending 00 UTC 25 October 2019.



Surface Analysis

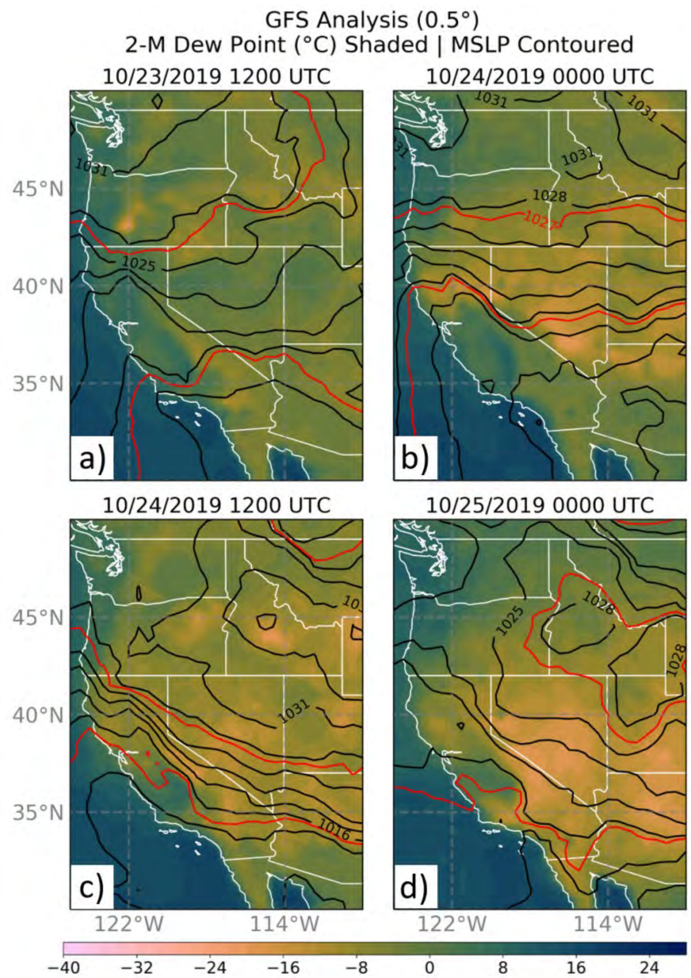
Analyses focused on the surface conditions showed important characteristics associated with this event. An area of high-pressure over the coast of British Columbia was well developed (Figure 21b). This high-pressure area became a robust feature by 0000 UTC 24 October 2019 that expanded continentally and eventually developed a strong pressure gradient along the border of northern California and Oregon. The peak surface winds occurred concurrently as the pressure gradient tightened along the Sierra Nevada crest (Figure 21d). An Inverted surface trough was situated over Southern California when the high pressure reached maximum strength over the eastern Great Basin. Erosion of the surface trough eventually lead to a decrease in surface wind speed. Throughout the entire event, column depth precipitable water was extremely low in California. More localized moisture features were analyzed utilizing 2-m dewpoint temperatures.

Figure 21. Precipitable water shaded (inches) with mean sea level pressure MSLP contoured in black. Red contours are tracers of MSLP at 1015 and 1027 hPa. Time is labeled in UTC



Finer details of the surface pressure gradient and the 2-m dewpoint temperatures are shown in Figure 22. Minimal column depth moisture was observed by precipitable water data, but surface moisture did exist prior to the event. One day before the event peak, at 1200 UTC 23 October 2019, the state of California experienced modest 2-m dew point temperatures. A dry airmass entered northern California as the pressure gradient stacked across the top of the inverted surface trough (Figure 22b). This pressure gradient rotated clockwise and continued to strengthen along the Sierra Nevada Crest. Dewpoint temperatures of roughly -20 °C were observed in Sonoma County with slightly higher values seen in the Sierra foothills and Santa Cruz mountains. The pressure gradient subsided significantly by 0000 UTC 25 October which ended the wind event in northern California. At that time the dry airmass advected over the southern end of the Sierra Nevada and Tehachapi Mountains into Southern California. Regional analyses show more distinct evidence regarding the occurrence of downslope winds on the lee of their local topography.

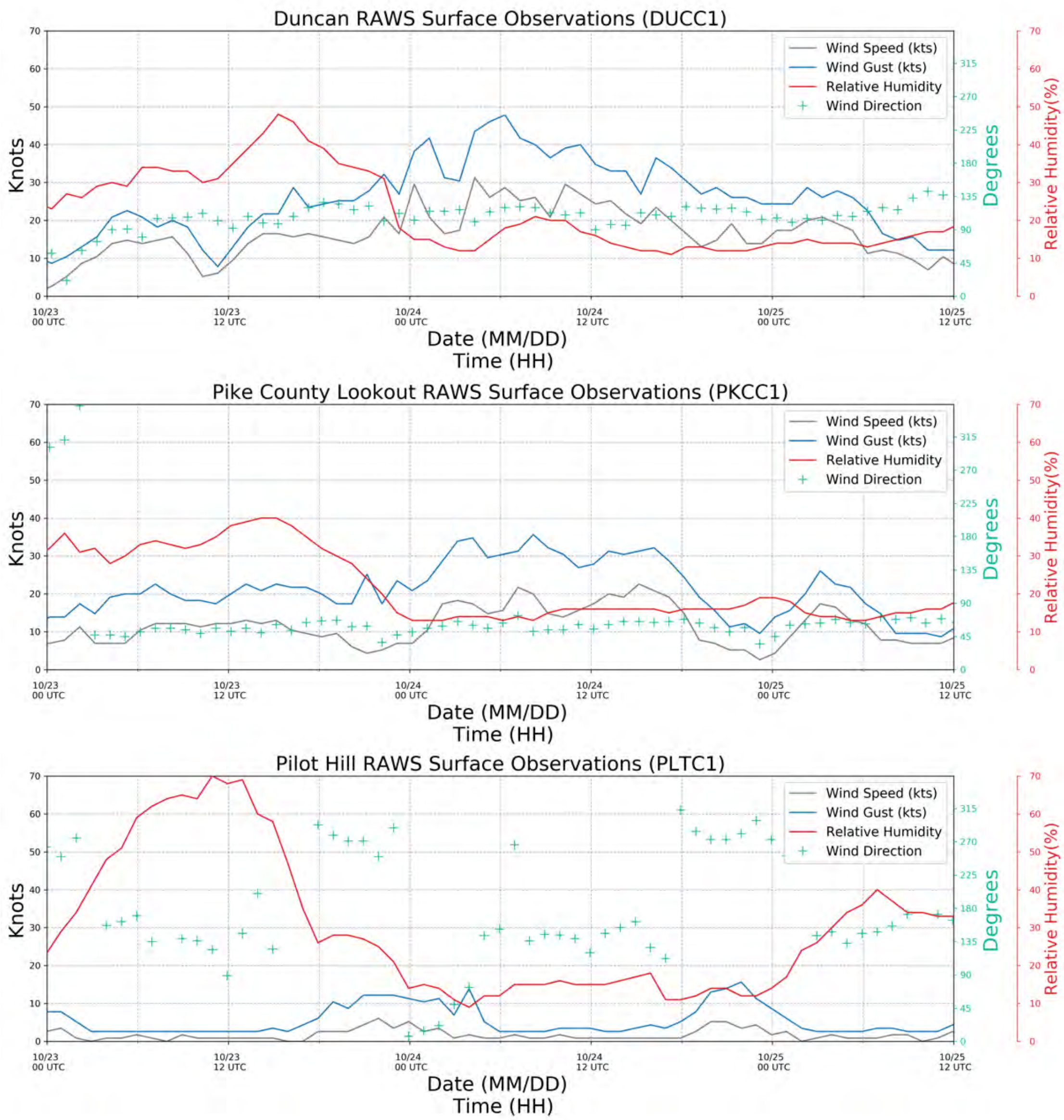
Figure 22. Dewpoint temperatures at two meters (2-m dew point) are shaded (Celsius) whit black contours of MSLP and red tracers at 1015 and 1027 hPa. Time is labeled in UTC.



Regional Analysis

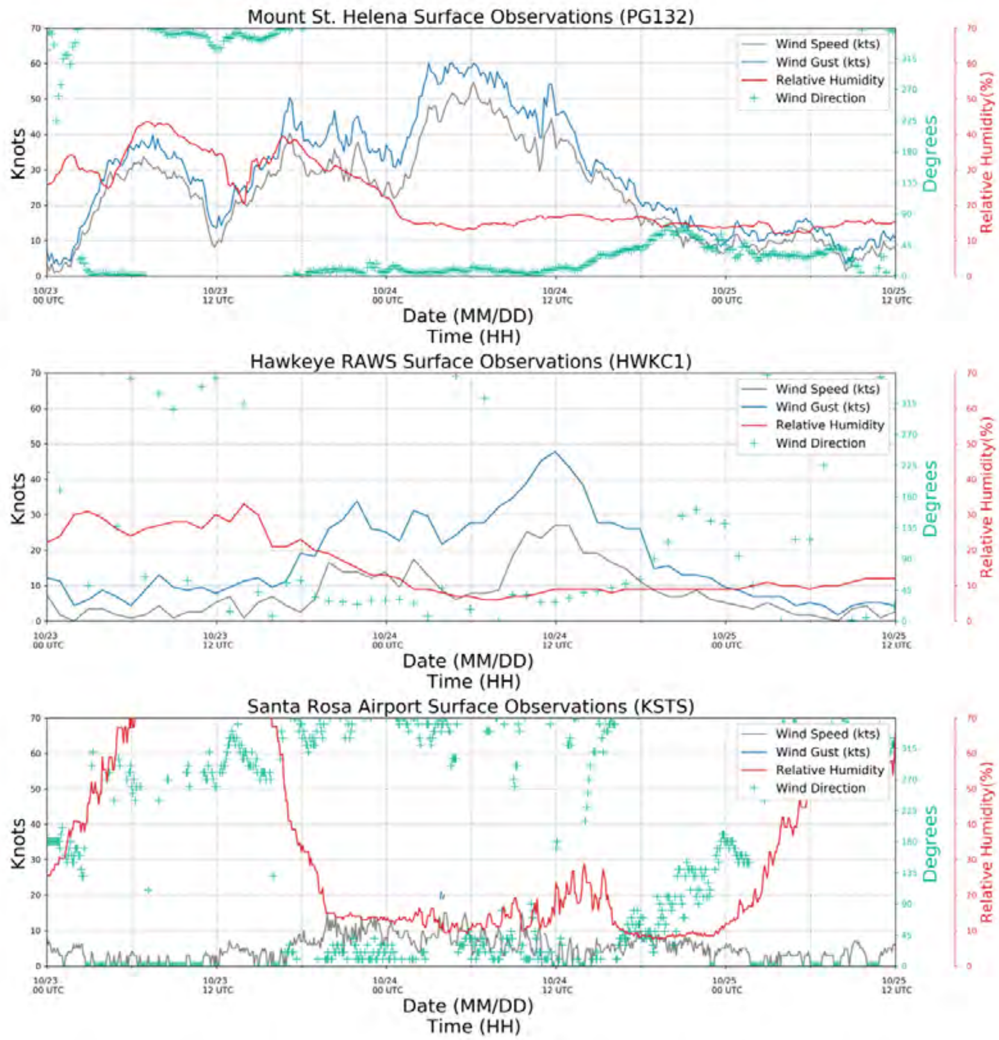
Surface observations are analyzed by region with all stations located on the lee side of the local topography. Each region has one station located near crest height, at a middle elevation, and at the base of the topography. This was chosen in order to better understand the extent of the winds in each region at different altitudes. Surface stations in the Sierra region observed less intense wind speeds than in the Sonoma region, but complex characteristics of downslope windstorms were demonstrated including the existence of a rotor circulation in the low elevations. Multiple observations of west winds were made at the low elevation site (Pilot Hill RAWS) while the sites at higher elevations concurrently observed east winds (Figure 23). Also, the winds observed at the mid-elevation site (Pike County Lookout RAWS) weakened from the east as the west winds increased at the low elevation site. These observations likely indicate that a hydraulic jump feature, with an associated rotor, was situated between the elevations of Pilot Hill RAWS (1249 feet) and Pike County Lookout RAWS (3701 feet). Lastly, Pilot Hill RAWS confirmed downslope winds from the east did not extend to the lowest elevations of the Sierra region. The strongest winds at this site were recorded from the west with gusts below twenty knots. Specific locations and timing of complex events such as downslope windstorms rely heavily on topography and the ambient atmospheric profile which is evident in the Sierra region during this event.

Figure 23. Wind observations (kts) and relative humidity (%) from surface weather stations across the Sierra region The locations are in descending order from highest elevation to lowest starting with Duncan RAWS (top), Pike County Lookout RAWS (middle) and Pilot Hill RAWS(bottom). Each location recorded hourly surface observations



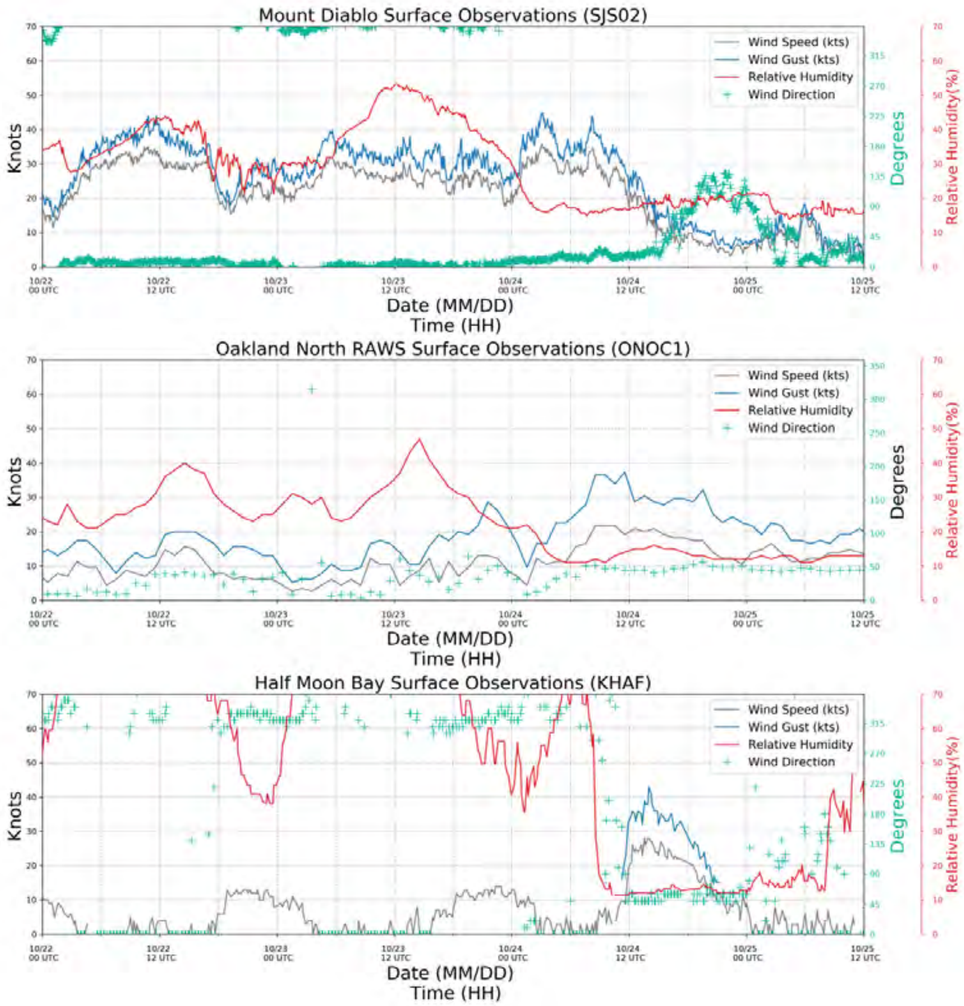
Peak surface winds were observed in the Sonoma region, and similarly to the Sierra region this occurred only near crest height and at middle elevations. Figure 24 shows strong long-lived winds at crest height observed at Mount St. Helena. The mid-elevation site (Hawkeye RAWS) observed a much narrower window of increased wind speeds. Santa Rosa airport, at the base of the topography, observed very dry air but higher wind speeds were absent. Rather, Santa Rosa observed light and variable winds when gusts at Hawkeye RAWS peaked. These variable winds also observed a brief direction reversal, downstream of Hawkeye RAWS, indicative of an atmospheric rotor. Strong winds were accompanied by very dry air which was observed by Hawkeye RAWS with RH values as low as 5%.

Figure 24. Wind observations (kts) and relative humidity (%) from surface weather stations across the Sonoma region The locations are in descending order from highest elevation to lowest starting with Mount St. Helena (top), Hawkeye RAWS (middle) and Santa Rosa Airport (bottom). Santa Rosa recorded five minute observations, Mount St. Helena recorded ten minute observations, and Hawkeye RAWS recorded hourly observations.



The Diablo region similarly experienced evidence of downslope winds. Mount Diablo, the most prominent peak in the area, experienced strong and gusty winds out of the north for more than forty-eight hours. It was not until the inversion forced the winds to mix down to lower elevations. The Oakland North RAWS, located in the intermediate elevations on the lee of the Diablo range, experienced increase wind activity just as the winds began to subside at Mount Diablo (Figure 25). Further, the winds mixed down around the same time that the temperature inversion descended towards crest height. Oakland Airport did not observe significant winds from this event (not shown), indicating that the winds failed to mix to the lowest elevations in the Diablo region. However, Half Moon Bay which is shown in the bottom panel of Figure 25, observed winds that were similar to a downslope wind event in the Lee of the northern Santa Cruz Mountains. The observation of downslope winds in Half Moon Bay and not Oakland Airport stress the importance of the atmospheric profile during downslope windstorms. Improved spatial and temporal atmospheric vertical profile observations are needed to better understand and forecast when and where the winds will mix to the surface and cause significant impacts to utility infrastructure.

Figure 25. Wind observations (kts) and relative humidity (%) from surface weather stations across the Diablo region The locations are in descending order from highest elevation to lowest starting with Mount Diablo (top), Oakland North RAWS (middle) and Half Moon Bay Airport (bottom).Mount Diablo recorded five minute observations, Oakland North recorded hourly observations, and half Moon Bay recorded fifteen minute observations.



6.2.3 Observed Weather Versus Modeled Conditions

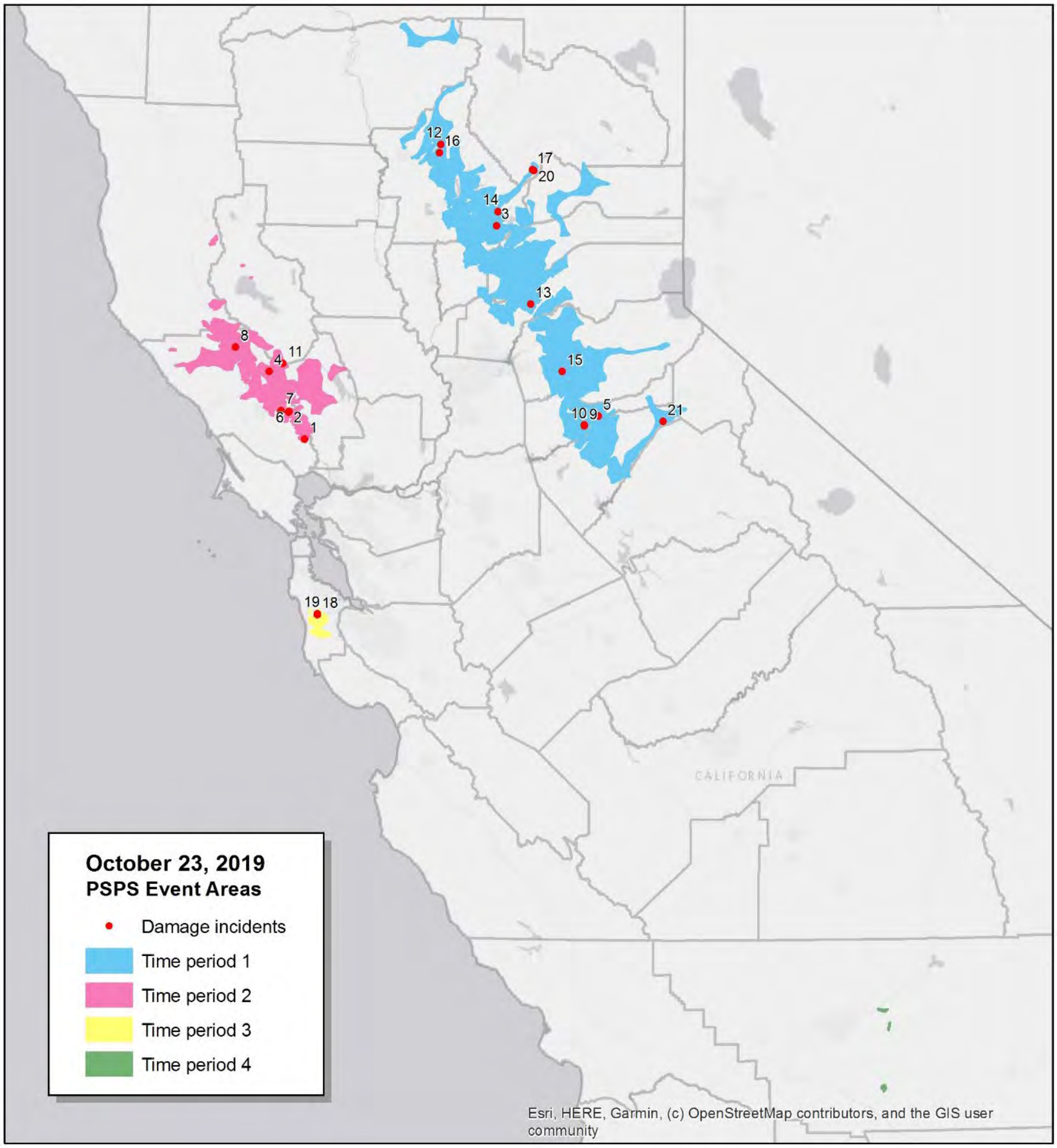
Observed and modeled weather conditions (especially, wind speed and direction) were analyzed and compared for all PSPS damage incidents. Both modelled weather prediction data provided by PG&E, and weather station observations data, were used to conduct the analysis. A comparison between weather data from the nearest weather station to each damage incident and the modeled weather data at both the damage incident ignition point and the modeled weather conditions is provided. Appendix D provides summary weather analysis results for each significant damage incident through two different charts. The first chart shows the comparison between the weather station values and the simulation modeled values at ignition point. The second chart shows the comparison between the weather station values and the modeled weather values at the station coordinates.

Modeled wind direction data is for the most part consistent with weather station at the same geographical point (modeled wind) and ignition point (simulation wind) in almost all damage incident simulations, reflecting that this input is consistent to model potential fire behavior and progression. However, interestingly, differences were identified between modeled wind speed data, simulation and the nearest weather station. Some simulations have higher modeled wind speed than in the nearest weather station (see Appendix D). Also, simulation winds are usually higher than station and modeled winds. This finding may explain the damage incident locations with higher wind speeds. Our analysis has found that it is not surprising for weather station data to deviate from modeled and observed wind conditions at the damage incident locations.

6.3 Summary of Damage Incidents

The analysis relied upon PG&E's assessment of damage incidents for ignition potential. A total of 21 damage incidents were reported by PG&E for the October 23 PSPS event, including the damage location (coordinates) and estimated time of damage. All these damage incidents had the potential to ignite a wildfire through electric arcing according to the detailed report received from PG&E. The following map presents the locations of the damage incidents relative to the PSPS event areas. A unique identification number is provided for each damage incident representing a ranking of population impacted..

Figure 26. Damage incidents relative to PSPS event areas.



6.4 Summary of Analysis Results

6.4.1 Summary of All Damage Incident Simulations

Fire spread simulations were undertaken for all 21 damage incidents using the location of the damage incident as the ignition source, and the date/time estimate for the damage occurring as the start time for the fire simulation. Impacts to buildings affected, population, critical facilities and acres burned were calculated for each fire simulation.

The following table shows the number of buildings and population impacted, and acres burned for all 21 damage incident locations, after averaging 100 fire simulations during a 24 hours fire duration for each incident location, resulting in a total number of 21,600 fire simulations. Almost 4,200 buildings and 5,400 people may have been impacted by simulated fires starting at the damage incidents. Additionally, the fires may have burned approximately 61,000 acres. Note the that all these results do not consider fire suppression.

The variability in fire impact between damage incidents is reflected as the difference between the mean, maximum values and standard deviation. The fire impact deviation was high among incidents and not all fires in the same day would create the same impact, reflecting the need of analyzing all incidents independently.

Table 5. Total expected impact, mean and maximum per fire simulation for all damage incident predictions.

Impact Type	Total	Mean	Maximum	Standard deviation
Population	5,386	256	944	276
Buildings	4,159	198	677	227
Acres Burned (ac)	61,361	2,921	15,290	4,474

6.4.2 Summary of Significant Incidents

Using the criteria described in Section 2.2.4, the most significant simulated fire incidents were identified from the 21 damage incidents. The following table lists these simulations. The IAA is color coded from **Low 1** to **Extreme 5**.

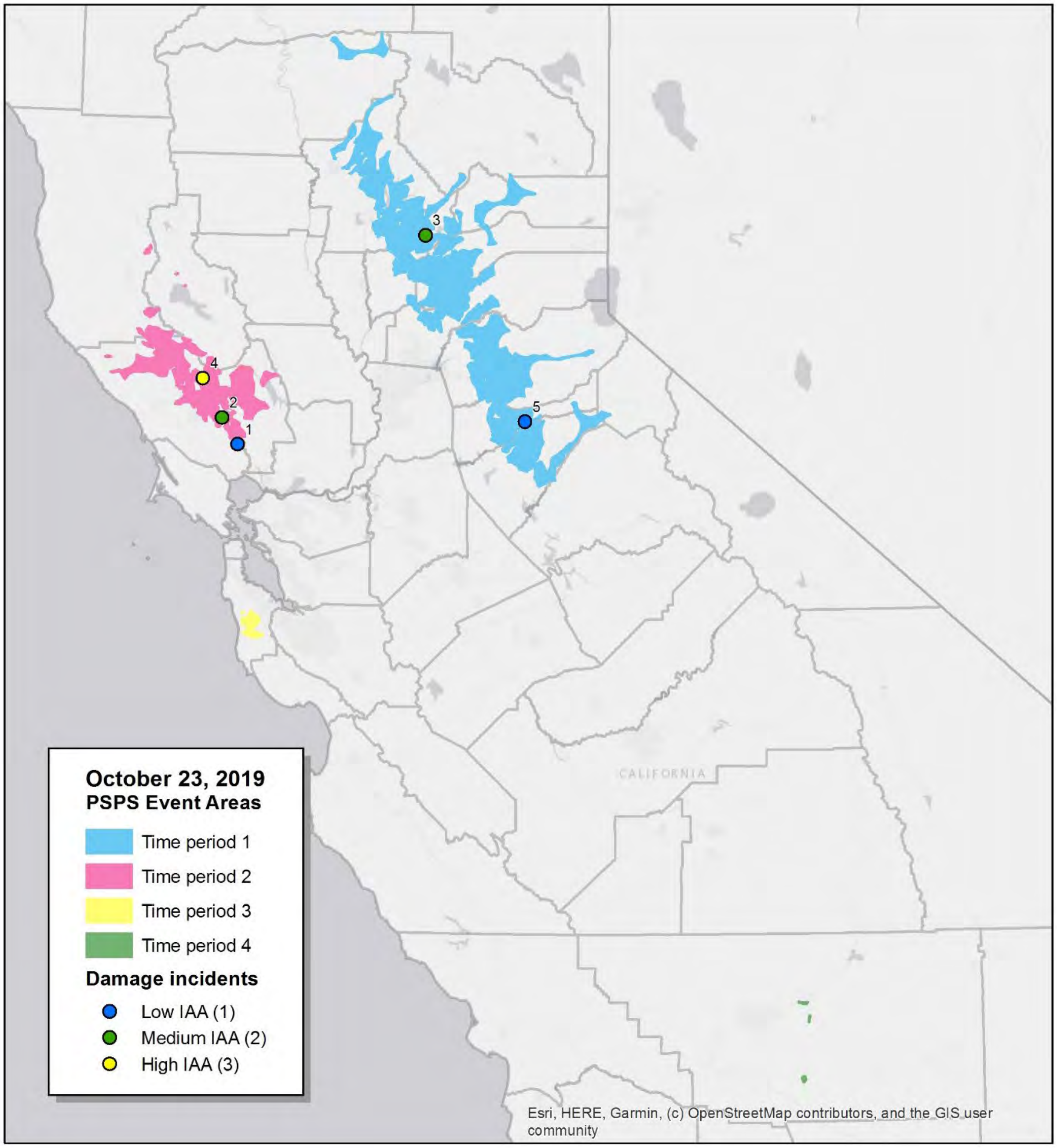
Table 6. List of significant simulated fires for this PSPS event.

Damage Incident	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	Sonoma	944	599	1,054	**1**
2	Sonoma	758	677	4,477	**2**
3	Yuba	595	392	8,593	**2**
4	Sonoma	526	411	15,290	**3**
5	Amador	328	145	937	**1**

Low (1) Moderate (2) High (3) Very High (4) Extreme (5)

The following figure presents a map showing the location of the significant incidents.

Figure 27. Map of the significant damage ignition locations.



Although large fires, in terms of acres burned, usually correlate to higher impacts in terms of buildings and population impacted, the table shown above reveals that smaller fires located near large amounts of buildings and population can also result in large impacts. This is the case of simulation number 1 leading to the highest impact for this PSPS event.

Those fire simulations with an more intense fire behavior (high flame length and high rate of spread) influencing an Initial Attack Assessment Index (IAA) value, had the largest burned areas based on a 24-hour fire simulation (Simulation 4). Obviously, the fire behavior was related to fuel types, complex topography and adverse weather conditions (i.e., low fuel moisture and high wind speed). The IAA index is intended to be used to analyze the fire simulation and the initial attack difficulty and not to analyze potential impacts in terms of buildings of population. As such, some fires with low-moderate IAA values had high impacts.

Figure 28. Summary of population and buildings impacted for the significant incidents.

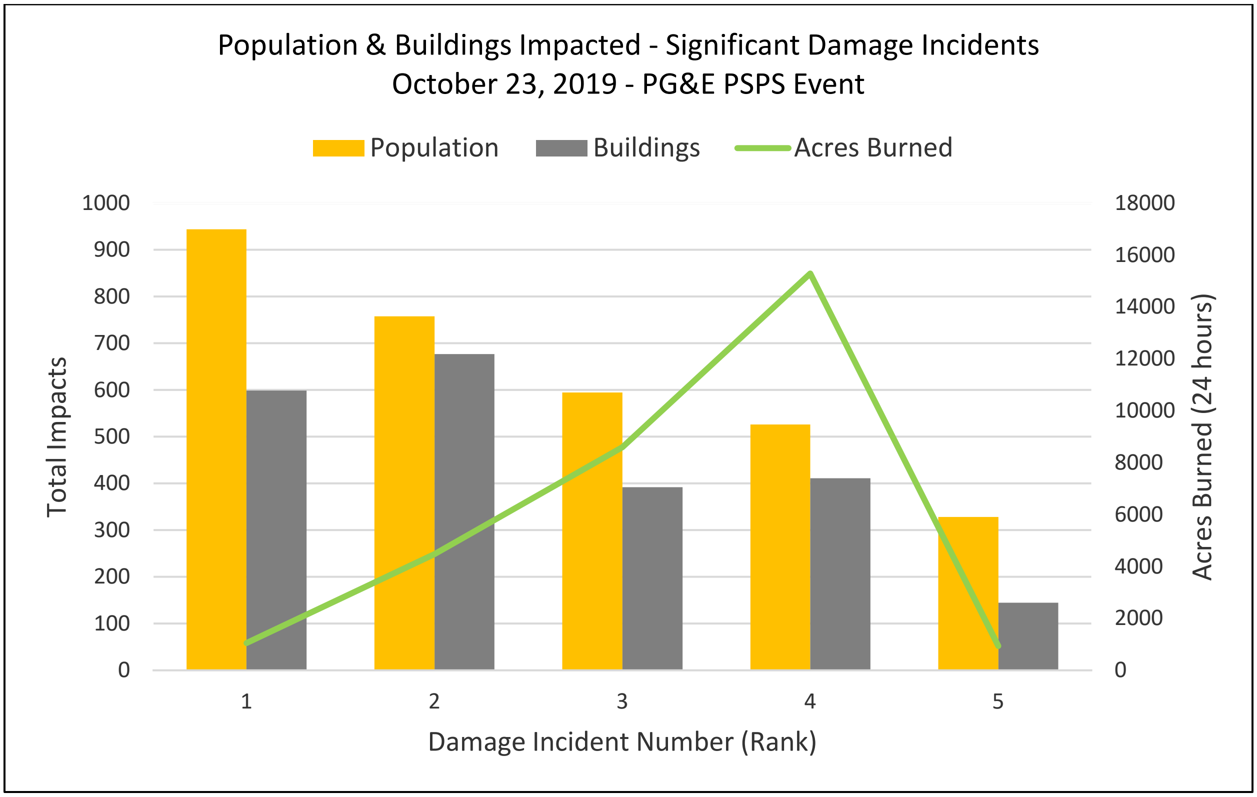
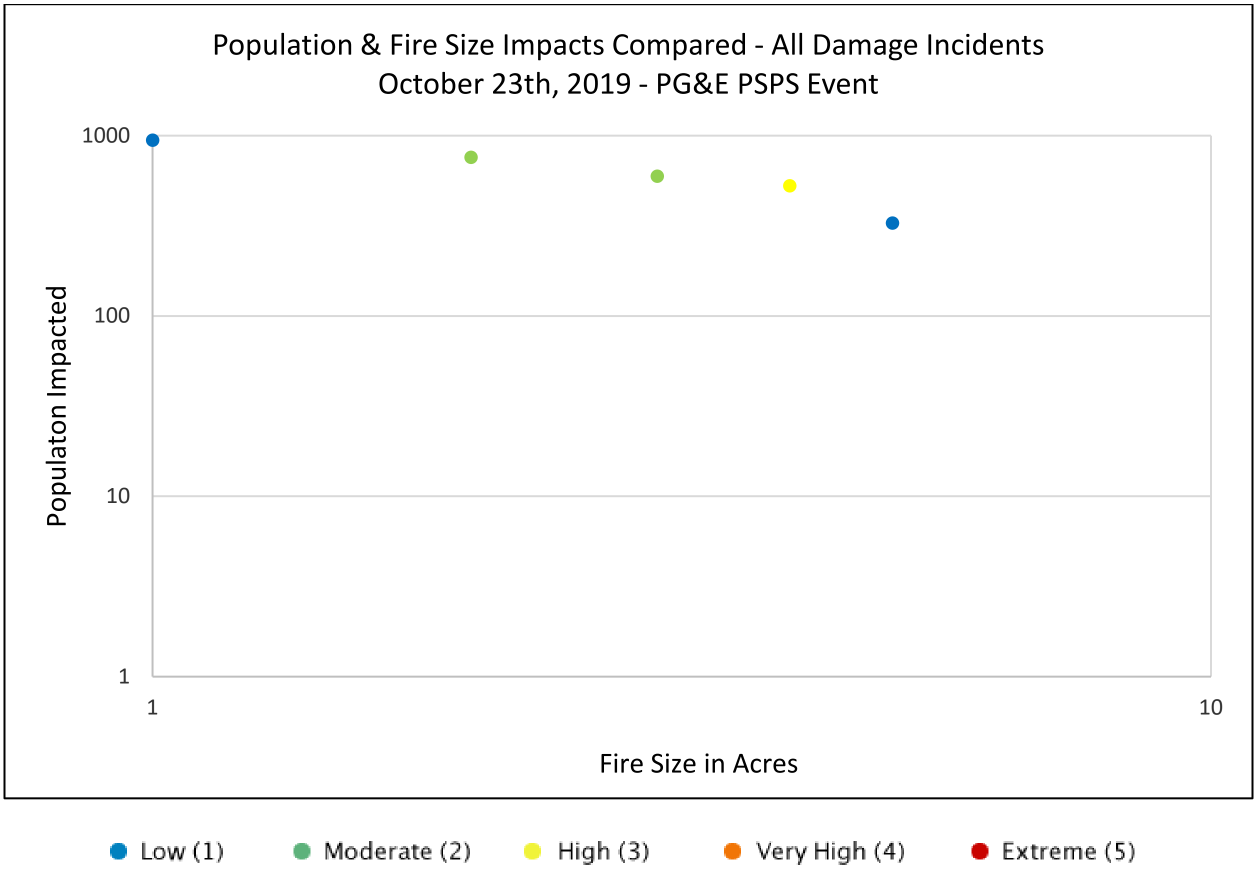


Figure 29 presents the population impacts of each fire simulation as a function of size (acres burned). Fires are color coded by IAA. This chart shows that fire simulations with high IAA index values consistently have large impacts.

Figure 29. Number population impacts as a function of fire size. Colors represents IAA values from low (blue) to extreme (red)



In summary, the following conclusions are reached:

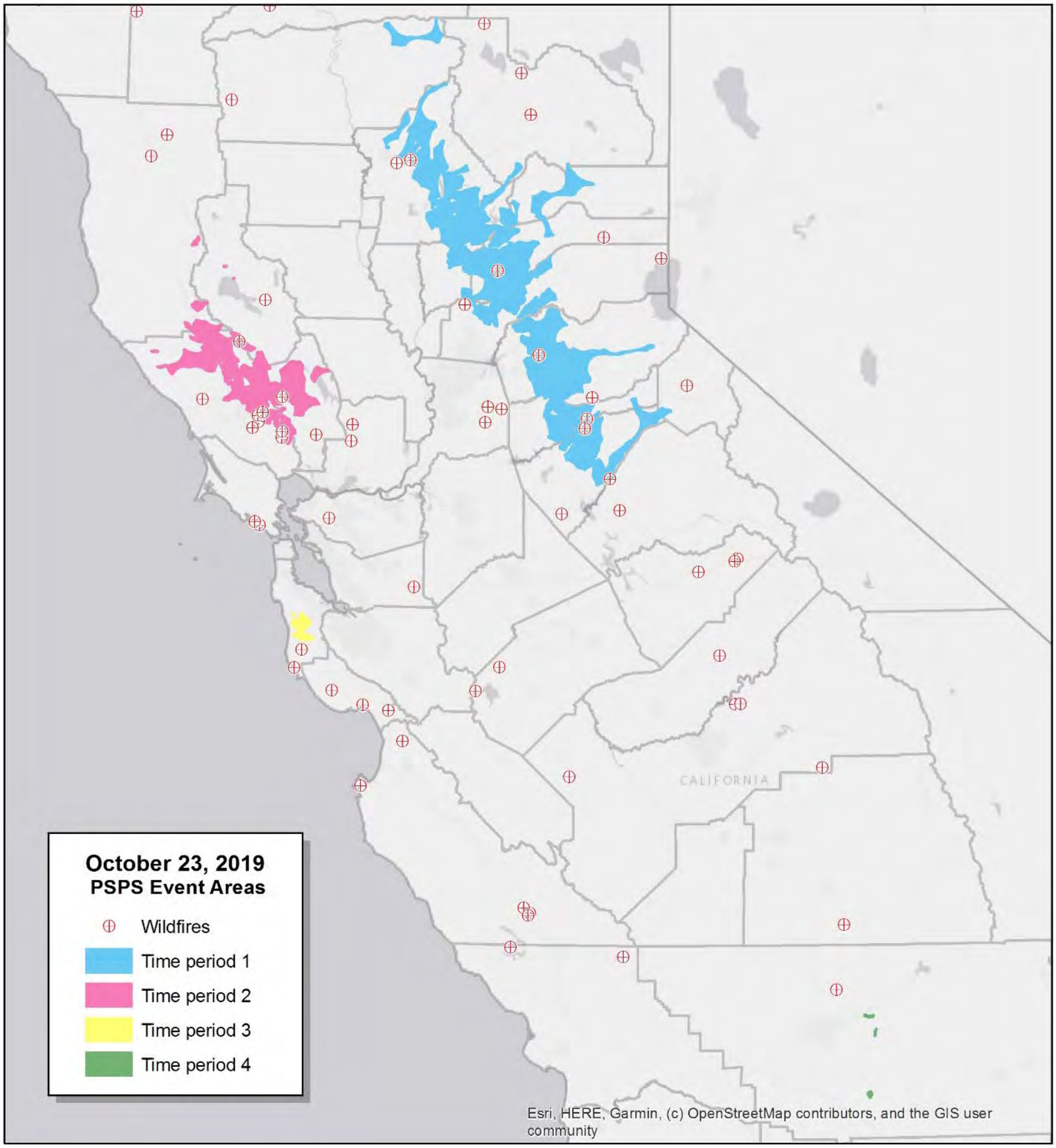
- Moderate size fires can also result in large impacts even though large fires generally result in large impacts
- Many small fires resulted in large impacts due to proximity of buildings and people
- Fires with the highest IAA had larger burned areas but not necessarily more impact on population and buildings.
- Many locations resulted in low or null impacts to population. Therefore, our results highlighted that some areas would not be worthwhile for shutoff.

6.5 Summary of Active Wildfires During the PSPS Event

One hundred and forty seven (147) fire incidents were recorded in the IRWIN system from October 23 to 26, 2019.[19] Eleven (11) of the fires are located in the PGE PSPS event boundaries, including the Kincade Fire (77,758 acres). Figure 30 shows the location of these wildfires.

[19] The IRWIN system records wildfires in California through integration with CAL FIRE, all federal agencies and LA County. Wildfires in other local responsibility areas are not recorded in IRWIN or shown on this map.

Figure 30. Wildfires occurring during this PSPS event.



6.6 Event Conclusions

- Damages sustained to de-energized PG&E facilities during the October 23, 2019 PSPS events could have a moderate fire impact on buildings (4,200), population (5,400), and acres burned (61,000 acres) for all damage incident locations compared to other 2019 PSPS events. However, note that these values were significantly lower due to lesser number of incident damage locations; 21 compared to 114 for the October 9th event and 422 for October 26th event.

- This analysis also shows that the summary of active wildfires during the PSPS event should be considered to evaluate the decision to shutoff power. Although the fire impact derived from damage incident locations was moderate, there were a high number of active wildfires, including three large wildfires.
- The weather observations recorded by weather stations near the potential fire incidents reflect high input data uncertainty (especially in terms of wind speed) in some of the selected fire simulations. Local winds are difficult to predict accurately and weather stations are often too far to be representative. Therefore, it is really important to consider probabilistic approaches to estimate the potential impact of fires. Due to the high level of input data uncertainty, it is required to stochastically analyze all simulations leading to potential fire impacts. Thus, the probabilistic outputs provided in this analysis (i.e. potential fire progression and impacts) are necessary to analyze potential fire impacts.

7. PSPS EVENT ANALYSIS FOR NOVEMBER 20-21, 2019

7.1 Overview

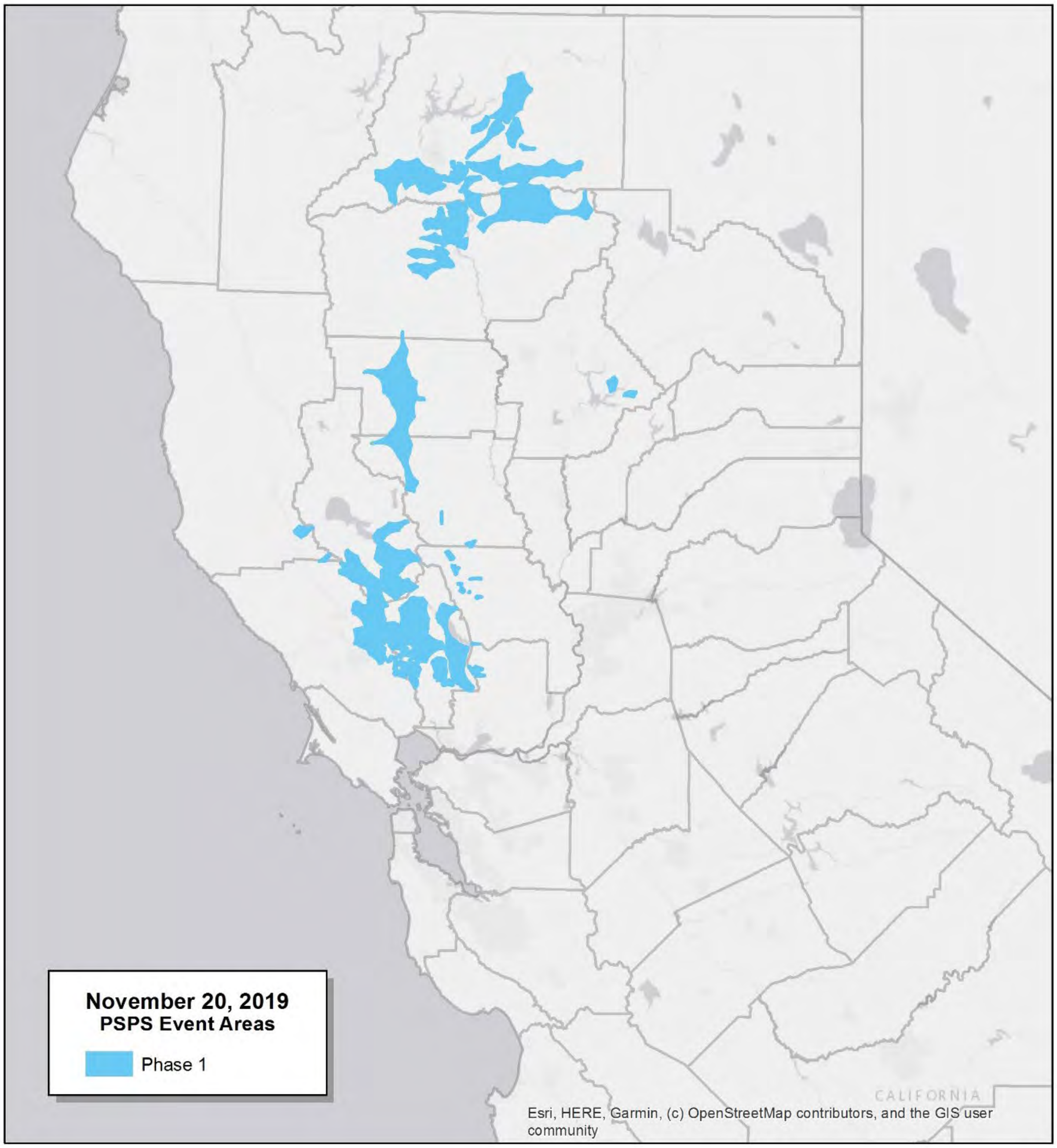
On November 20th, 2019 lasting through November 21st, 2019, PG&E implemented a PSPS event in order to mitigate catastrophic wildfire risk presented by significant offshore wind events combined with low humidity levels and critically dry fuels. Within this event, PG&E planned de-energization times specific to different geographic areas based on their unique weather timing to minimize outage durations. In total, approximately 49,000 customer accounts were impacted.

PG&E considers many factors in weighing the risk of catastrophic wildfire against the impacts of de-energization. These factors include meteorological forecasts and wildfire risk data to determine the scope and scale of an event, the customer and community impacts of de-energizing that scope, as well as the efficacy of possible alternatives and mitigations prior to the potential de-energization. This decision-making process is PG&E's standard procedure used in all PSPS events and is described below.

The following map shows the areas affected by the PSPS event. A detailed description of the event, including time periods and locations for de-energization footprints, can be obtained from the CPUC web site at:

https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/News_Room/NewsUpdates/2019/PGE%20Public%20Safety%20Power%20Shutoff%20Nov.%2020-21%202019%20Report.pdf

Figure 31. PSPS event areas.



7.2 Analysis of Weather Conditions

7.2.1 Overview

The overall weather pattern for the PSPS event was dominated by a shortwave trough that developed into a cutoff low on November 20th, 2019.[20] The cutoff low development allowed increased southward propagation along the California coast before it situated over central and southern California and persisted there for days.[21] An associated surface cold front developed out ahead of the upper-level low. This cold front brought precipitation to select locations, primarily concentrated in the central coast, with nominal amounts of measurable precipitation. The precipitation was not widespread and significant impacts to fuel moistures were not likely. In addition to this front was a high-pressure feature that advected into northern Nevada. This high-pressure feature was accompanied by an inverted surface trough over central and northern California.[22] These meteorological features resulted in a strong surface pressure gradient along the crest of the Sierra Nevada which are known to develop strong downslope windstorms in Northern California.

Strong surface winds were observed to be widespread over northern California with sustained winds of 20-35 knots (23-40 mph) among the incident damage locations identified. The highest wind measurements were recorded in Sonoma County and were associated with gusts up to 65 knots (75 mph). The decrease in atmospheric moisture associated with this event provides further evidence that downslope winds may have occurred. The minimum relative humidity observed by the surface weather stations analyzed ranged from 20 to 35%.

The significance of the event in California is highlighted by:

- The upper-level trough produced dry offshore flow across California.
- A strong pressure gradient over the region stimulated strong downslope winds.
- Insignificant precipitation preceded moderately dry atmospheric conditions.
- Widespread surface wind measurements of 20-35 knots (23-40 mph) sustained and gusts upwards of 65 knots (75 mph) were recorded.

7.2.2 Observed Weather Versus Modeled Conditions

Observed and modeled weather conditions (especially, wind speed and direction) were analyzed and compared for all PSPS damage incidents. Both modelled weather prediction data provided by PG&E, and weather station observations data, were used to conduct the analysis. A comparison between weather data from the nearest weather station to each damage incident and the modeled weather data at both the damage incident ignition point and the modeled weather conditions is provided. Appendix E provides summary weather analysis results for each significant damage incident through two different charts. The first chart shows the comparison between the weather station values and the simulation modeled values at ignition point. The second chart shows the comparison between the weather station values and the modeled weather values at the station coordinates.

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[20] A trough is an elongated region of relatively low atmospheric pressure often associated with weather fronts.

[21] A cutoff low is a closed upper-level low which has become completely displaced from basic westerly current and moves independently of that current.

[22] An inverted surface trough is an atmospheric trough which is oriented opposite to most troughs of the mid-latitudes.

Modeled wind direction data is for the most part consistent with weather station at the same geographical point (modeled wind) and ignition point (simulation wind) in almost all damage incident simulations, reflecting that this input is consistent to model potential fire behavior and progression. However, interestingly, differences were identified between modeled wind speed data, simulation and the nearest weather station. Some simulations have higher modeled wind speed than in the nearest weather station (see Appendix E). Also, simulation winds are usually higher than station and modeled winds. This finding may explain the damage incident locations with higher wind speeds. Our analysis has found that it is not surprising for weather station data to deviate from modeled and observed wind conditions at the damage incident locations.

7.3 Summary of Damage Incidents

The analysis relied upon PG&E's assessment of damage incidents for ignition potential. A total of 9 damage incidents were reported by PG&E for the November 20th, 2019 PSPS event, including the damage location (coordinates) and estimated time of damage. Figure 32 presents the locations of the damage incidents relative to the PSPS event areas. All these damage incidents were considered with potential to ignite a wildfire through electric arcing according to the detailed report received from PG&E and field inspections. A unique identification number is provided for each damage incident representing a ranking of population impacted.

7.4 Summary of Analysis Results

7.4.1 Summary of All Damage Incident Simulations

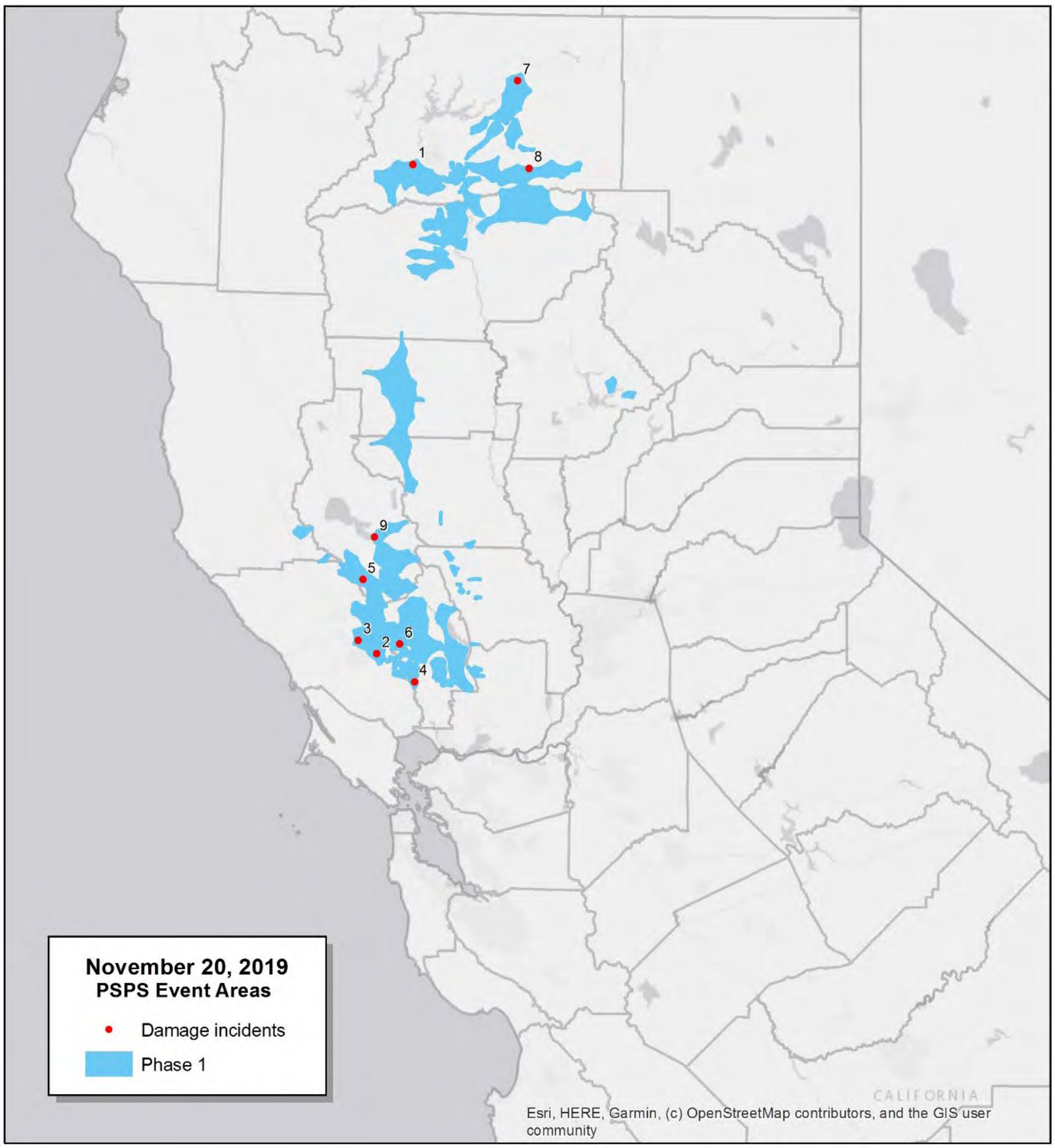
Fire spread simulations were undertaken for all 9 damage incidents using the location of the damage incident as the ignition source, and the date/time estimate for the damage occurring as the start time for the fire prediction. The simulations were run for a 24-hour duration. Impacts to buildings affected, population, critical facilities and acres burned were calculated for each simulation.

Table 7 shows the number of buildings and population impacted, and acres burned for all 9 damage incident locations located inside PSPS boundaries, after averaging 100 fire simulations during a 24 hours fire duration for each incident location. The fire impacts were moderate to high considering that the number of damage incidents was low (9). More than 1,300 buildings and 1,700 people may have been impacted by simulated fires starting at the damage incident locations. Additionally, the fires may have burned almost 21,000 acres. Note the that all these results do not consider fire suppression. The fire impact deviation was high among incidents and not all fires in the same day would create the same impact, reflecting the need of analyzing all incidents independently to evaluate PG&E's decision to shutoff power.

Table 7. Total expected impact, mean and maximum per fire simulation for all damage incidents.

Impact Type	Total	Mean	Maximum	Standard deviation
Population	1,769	196	975	311
Buildings	1,324	147	549	175
Acres Burned (ac)	20,682	2,298	7,110	2,745

Figure 32. Damage incidents relative to PSPS event areas.



7.4.2 Summary of Significant Incidents

Using the criteria described in Section 2.2.4, the most significant fire incidents was identified from the 9 damage incidents. The following table lists and summarizes the population and buildings impacted for the most significant damage incident simulations.

Table 8. List of significant simulated fires for this PSPS event (sorted by population impacted).

Damage Incident	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	Shasta	975	549	7,110	**1**
2	Sonoma	345	198	641	**2**

● Low (1) ● Moderate (2) ● High (3) ● Very High (4) ● Extreme (5)

The following figure presents a map showing the location of the significant incidents identified in Table 8.

Figure 33. Map of the significant damage ignition locations.

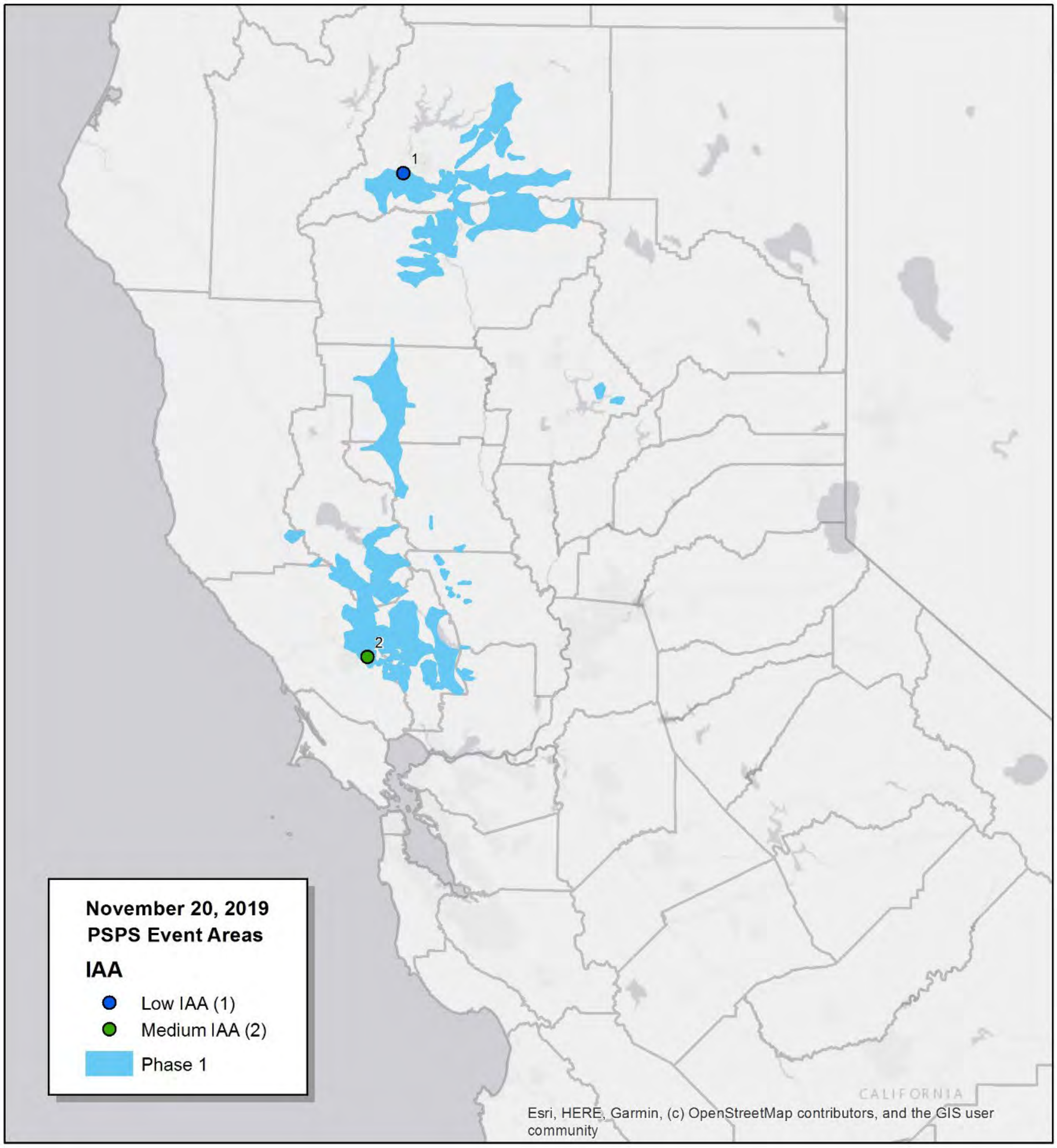


Figure 34. Summary of population and buildings impacted for the significant incidents.

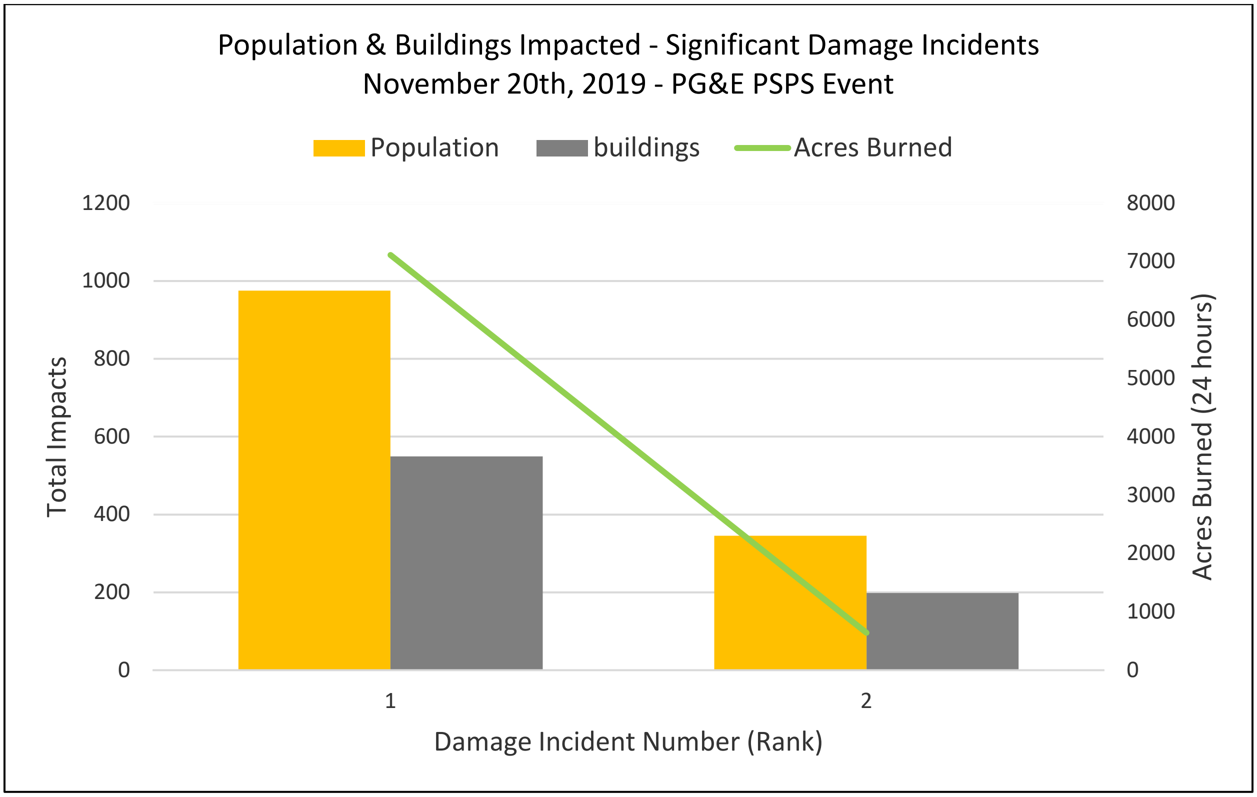
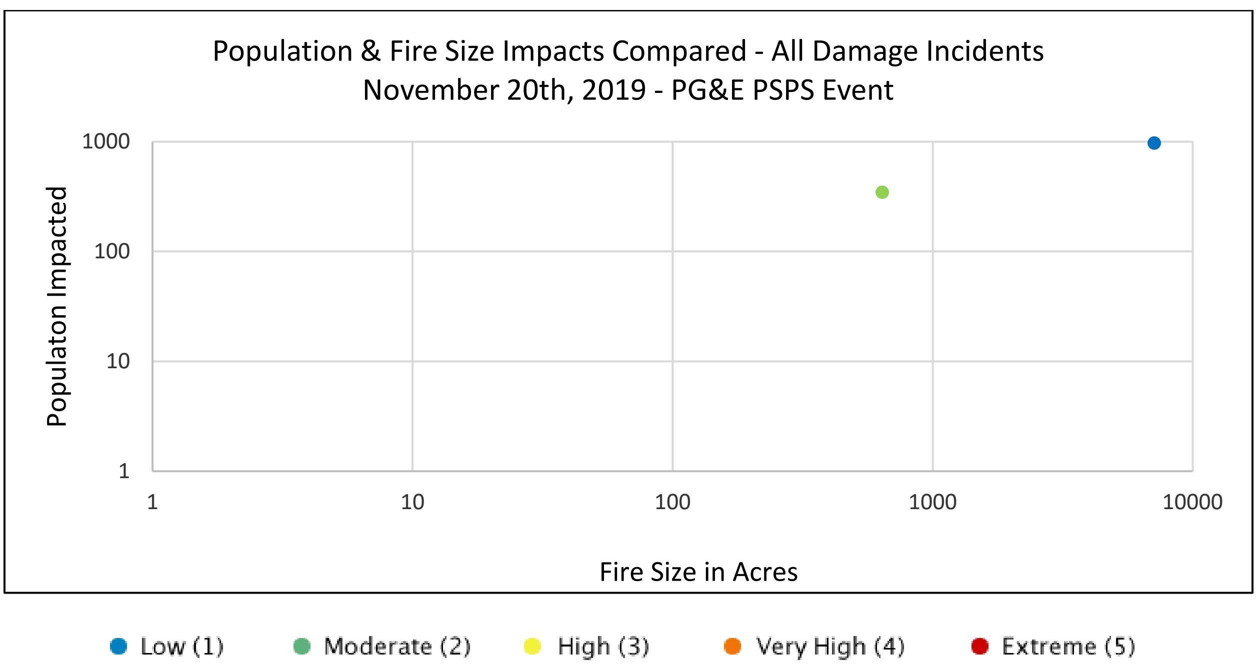


Figure 29 presents the population impacts of each fire simulation as a function of size (acres burned). Fires are color coded by IAA. This chart shows that fire simulations with high IAA index values consistently have large impacts. These fire simulations are significant from the start and are likely to escape initial attack.

Figure 35. Number population impacts as a function of fire size. Colors represents IAA values from low (blue) to extreme (red)



7.5 Summary of Active Wildfires During The PSPS Event

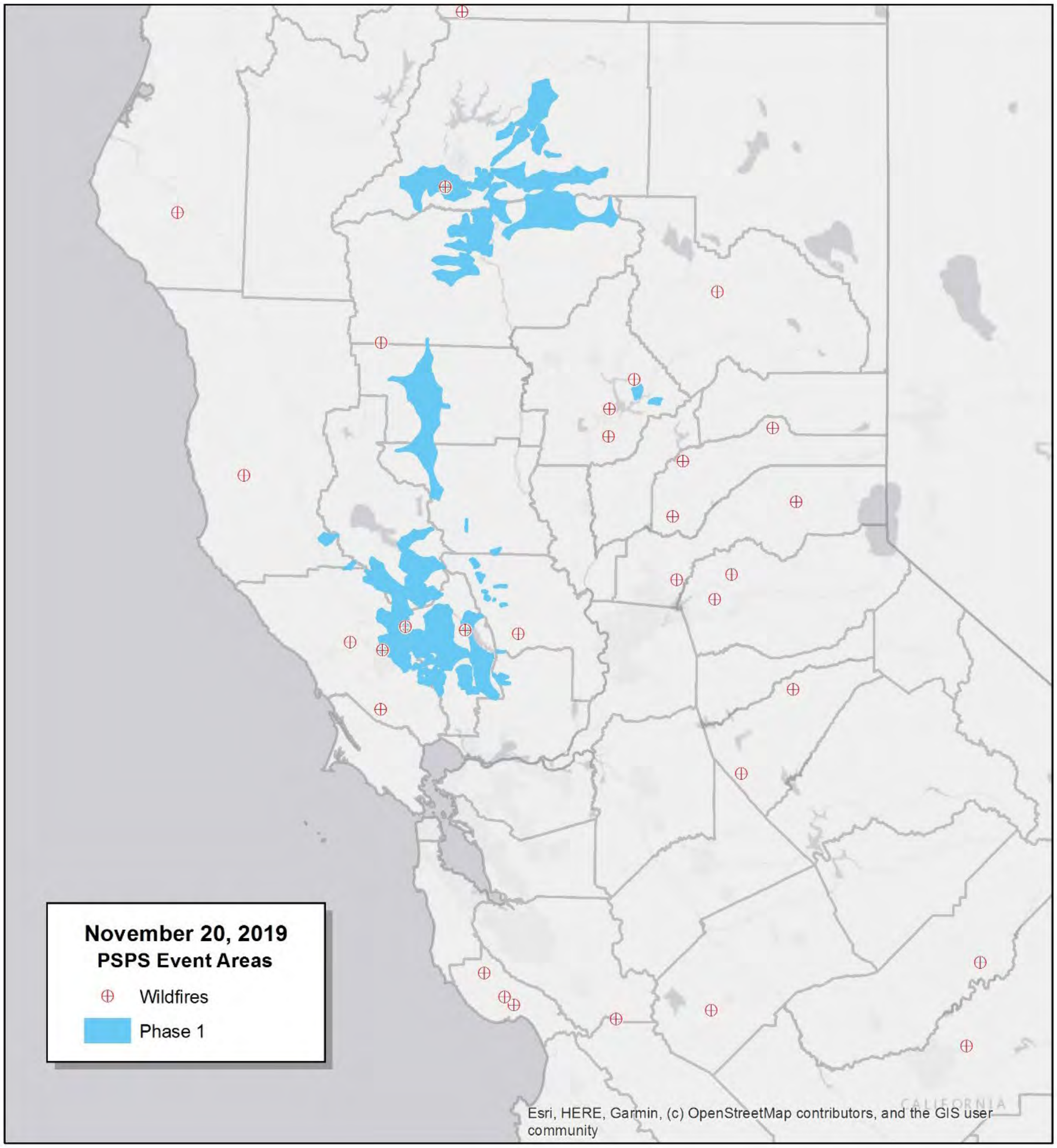
Fifty-one (51) fire incidents were recorded in the IRWIN system from November 20th to 23rd, 2019.[23] Additionally, only four (4) of the fires are located inside the PSPS event boundaries, all less than one acre in size. Figure 36 presents the fires.

7.6 Event Conclusions

- Damages sustained to de-energized PG&E facilities during the November 20, 2019 PSPS event would have low fire impacts in terms of burned area (21,000 acres), buildings (1,300) and population (1,700) compared to the other 2019 PSPS events, due to a lower number of reported damage incidents (9). Note the that all these results do not consider fire suppression. However, fire behavior in some simulations could be moderate-high with high rate of spread as shown for significant damage incident number 1.
- The fire activity reflected by IRWIN incidents (51 fires during the November 20-23th) was low-moderate compared to other PSPS events (i.e. 140 for October 26-29th event). All fires recorded by IRWIN were small.
- Although slight differences were identified between modeled wind speed data, simulation and the nearest weather station with some simulations with higher modeled wind speed than in the nearest weather station (see Appendix E for significant damage incidents), these differences were significantly lower than other PSPS events such as the October 9th. The modeled values are reliable to model the fire progression, especially considering the probabilistic simulations executed for this report dealing with weather uncertainty.

[23] The IRWIN system records wildfires in California through integration with CAL FIRE, all federal agencies and LA County. Wildfires in other local responsibility areas are not recorded in IRWIN or shown on this map.

Figure 36. Wildfires occurring during this PSPS event.



8. OVERALL SUMMARY OF EVENTS

This section provides overall conclusions related to all the PSPS events in this report.

8.1 Findings

- The analysis of the five PG&E events in this report identified a generally low number of damage incidents identified, and generally low to moderate impacts from fires that could have occurred from those incidents. The following table summarize the damage incidents and impacts for each PG&E PSPS event. This includes the October 9th and October 26th events as reference although they their analysis is provided in separate reports (shown in *italics*). Note only incidents within PSPS event areas are included.

Table 9. Summary of report PSPS event impacts.

PG&E PSPS Event Start Date	Total Damages Reported	Damages Expected to Ignite a Fire[24]	Total Population Impacted	Total Buildings Impacted	Total Acres Burned
June 7, 2019	5	1	1,412	859	4,741
Sep. 23, 2019	4	4	400	47	2,394
Oct 5, 2019	2	1	0	0	379
Oct 9, 2019	*193*	*116*	*36,015*	*18,819*	*274,977*
Oct 23, 2019	26	21	5,386	4,159	61,361
Oct 26, 2019	*441*	*422*	*421,271*	*257,570*	*3,056,346*
Nov 20, 2019	9	9	1,769	1,324	20,682

- Probabilistic simulations were used for the most significant incidents for each PSPS event to analyze potential fire impacts in consideration of input data uncertainty. In operational settings, these methods are mandatory given the high degree of input data uncertainty, especially in terms of wind speed. Local winds are difficult to predict accurately and weather stations may be too far away to be representative of localized conditions. Therefore, it is important to consider probabilistic approaches to estimate the potential impact of fires. Probabilistic simulations are presented in Appendices A through E.

8.2 Recommendations and Opportunities for Improvement

- This work includes the potential impact of damage incidents on population, building, and the landscape if ignitions were to occur from the damage incurred to de-energized utility facilities during a PSPS event. The selected incidents shown in this report need to be analyzed with caution due to the uncertainty with the input data found during the analysis. Specifically, in the future, the probability of ignition may be evaluated more

[24] Only includes damages incidents within PSPS areas. Some damage incidents were provided that were outside the PSPS areas.

granularly than the binary yes/no assessments used for this analysis to facilitate more detailed future analysis for specific events.

- The data and analysis provided in this report allow analyzing the potential impact of the fires. This can be used to evaluate the power shutoffs. Many locations resulted in low or null impacts to population and, therefore, opportunities to reduce PSPS impacts may be obtained by sectionalizing circuits and segments for analysis and decision-making.
- Additionally, the fire modelling techniques applied in this analysis, using Technosylva's Wildfire Analyst software, can be used for decision-making before the PSPS event leveraging PG&E's rich forecasted weather data. With this preemptive data in hand, de-energizing decisions can be evaluated both temporally and spatially in advance.[25]
- Specific standards for damage incident data collection should be employed in future to facilitate this kind of analysis as a standard method to evaluate PSPS decisions. Recommendations will be provided as a result of this analysis. This will afford an objective method that will quantify potential impacts consistently for all IOUs and PSPS events.
- The ongoing research of the IOUs and Technosylva in wildfire modeling may increase the opportunities for improvement in the analysis with enhanced and more accurate input data, and new analytical methods to analyze fire impacts and consequences.

[25] Note that PG&E currently uses Technosylva's Wildfire Analyst Enterprise product to derive daily risk metrics for overhead assets.

APPENDIX A: JUNE 7-9, 2019 - ANALYSIS OUTPUTS FOR SIGNIFICANT DAMAGE INCIDENTS

This appendix provides a description of the fire spread prediction and impact analysis outputs for the most significant damage incidents matching those summarized in each PSPS event section. Maps are provided for both the deterministic and probabilistic simulations. Building footprints are shown in both maps as reference. In addition, the deterministic boundary is also shown in each probabilistic map as reference. Map scale varies across the maps as they are sized to match simulation extent. Each simulation represents a 24 hour duration.

For each incident, critical input data such as wind speed and direction are analyzed, including fire behavior and impact metrics shown through tables and figures.

Two weather charts are included for each fire simulation, representing hourly wind direction and speed throughout the incident (i.e. 24 hours) for the nearest weather station and modeled winds for the weather station location point and the ignition location of the incident. In this sense, wind data uncertainty is shown both spatially and temporally.

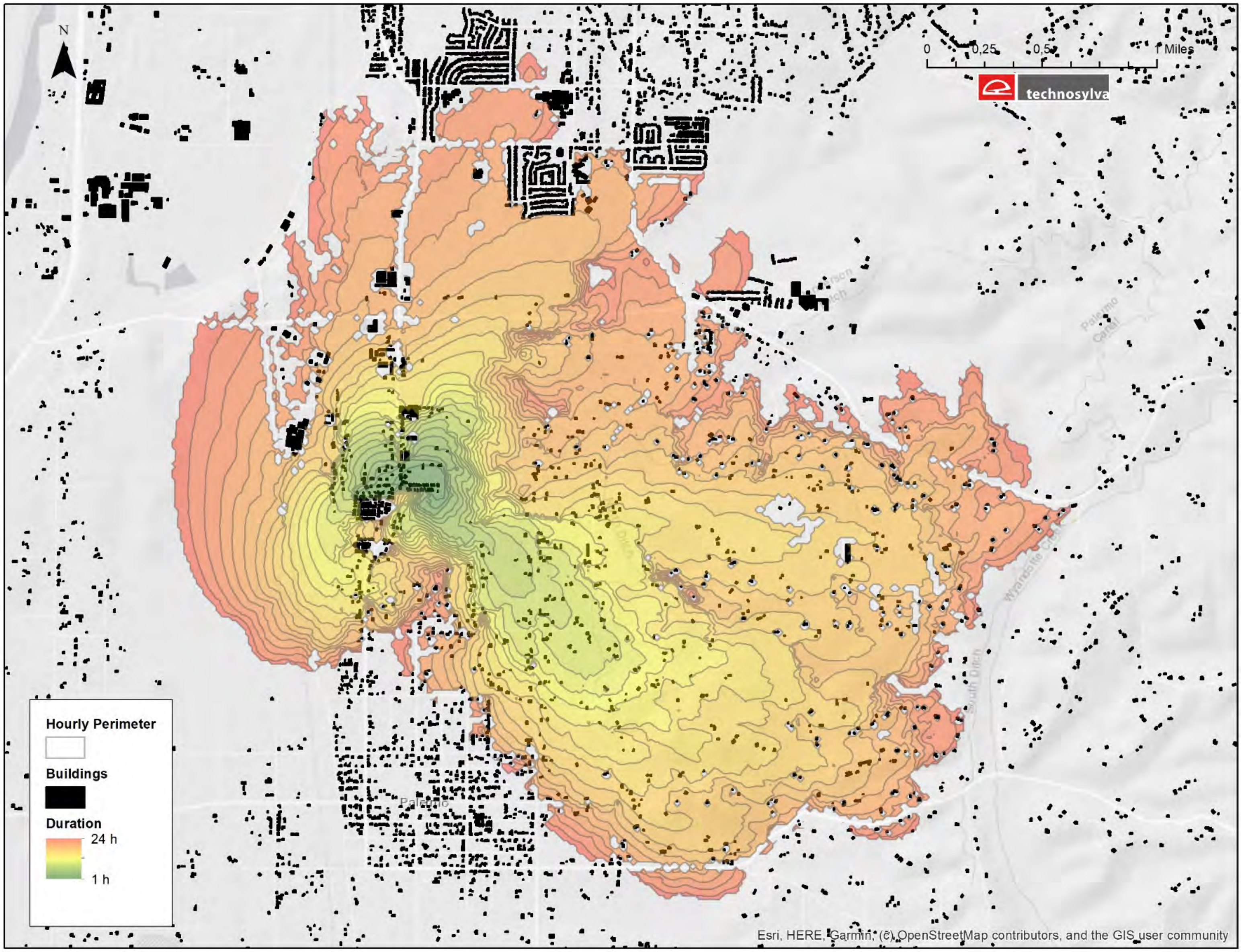
Two charts on fire behavior are included in each simulation to show the rate of spread and flame length (i.e. fire intensity) throughout the fire duration with well-known variable thresholds established in fire science.

DAMAGE INCIDENT – 1

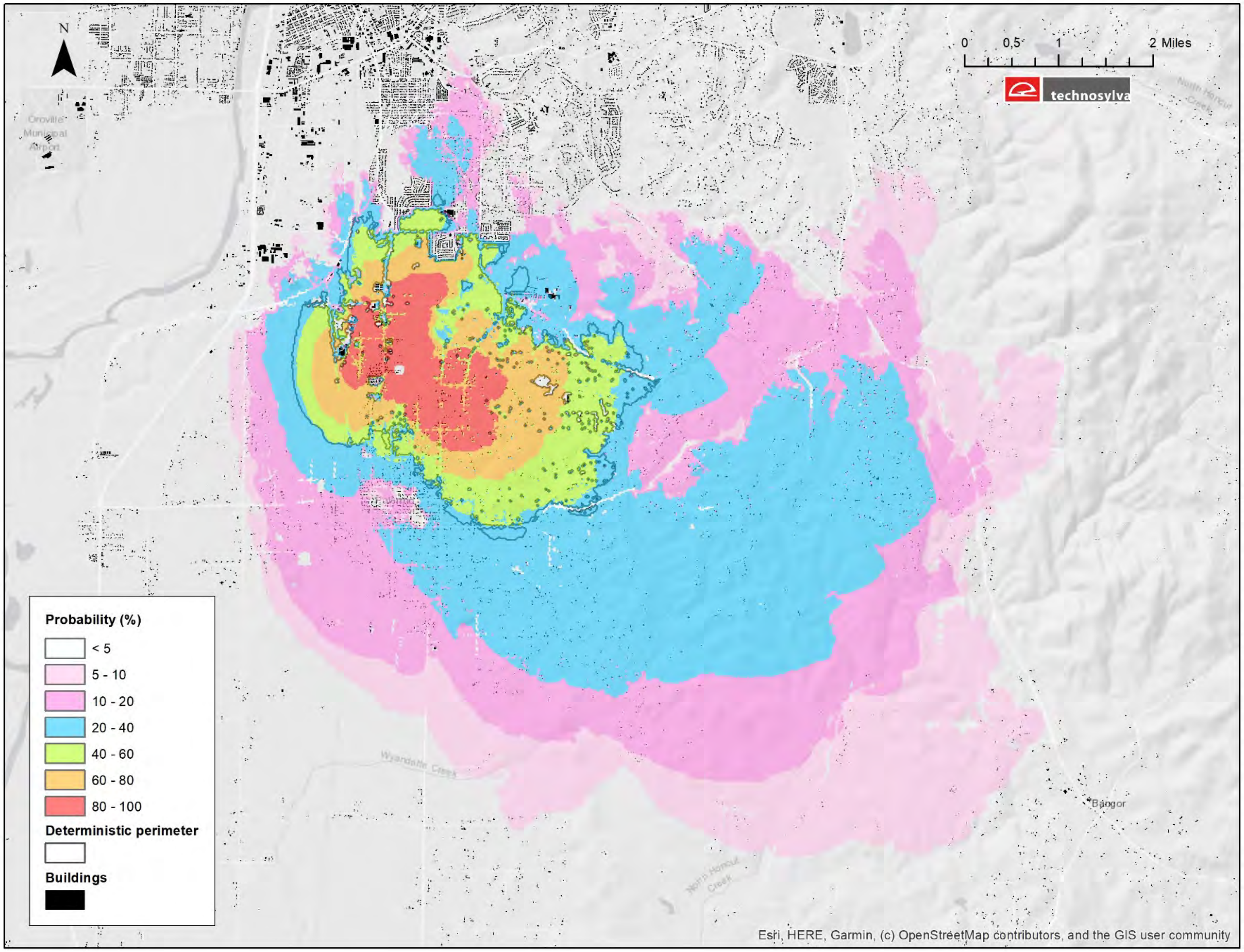
The damage incident is located in Butte County and has the potential to burn more than 4,700 acres, causing an impact of 859 buildings and 1,412 people in 24 hours. However, the fire would start spreading slowly from an urban area with low IAA (1) and rate of spread and may be suppressed in the initial attack by the corresponding fire agency easily. The fire simulation reaches lots of buildings scattered across the landscape with moderate-high rate of spread as shown in the maps and figures below.

INCIDENT SUMMARY	
Start Time	06/08/19 - 22:00
Duration (hrs)	24
Size (ac)	4,741
Initial Attack Assessment	1 – Low
No. of Buildings	859
Total Population	1412
Average ROS	Low-Moderate

DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION



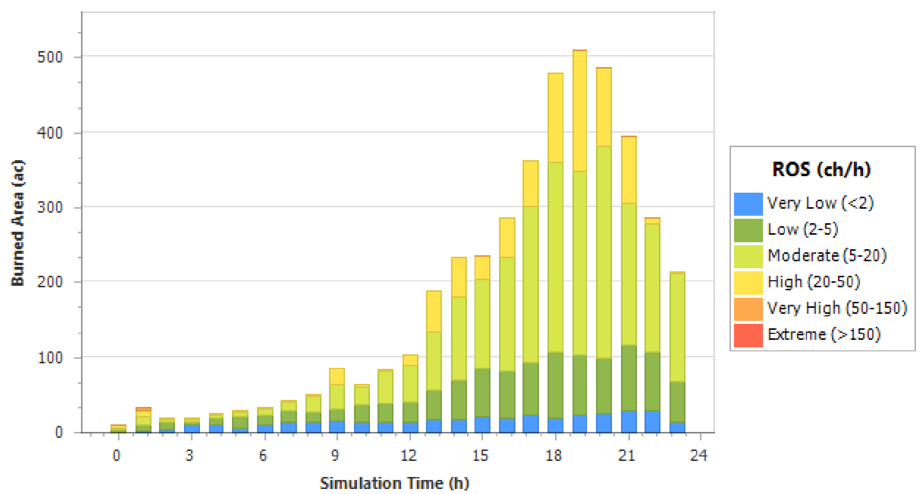
DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION

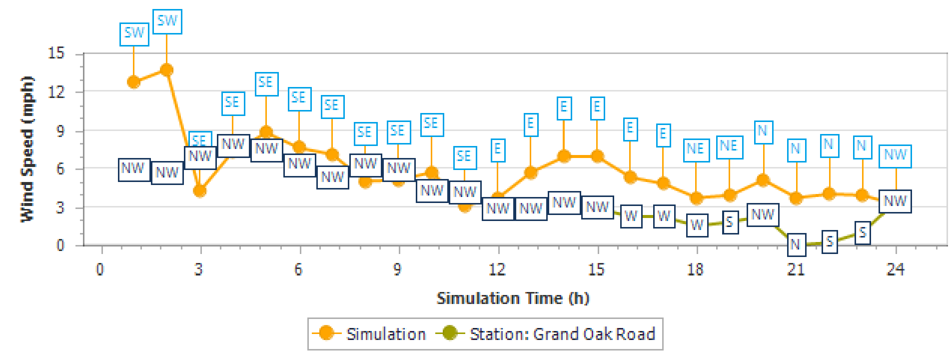


DAMAGE INCIDENT NO. 1

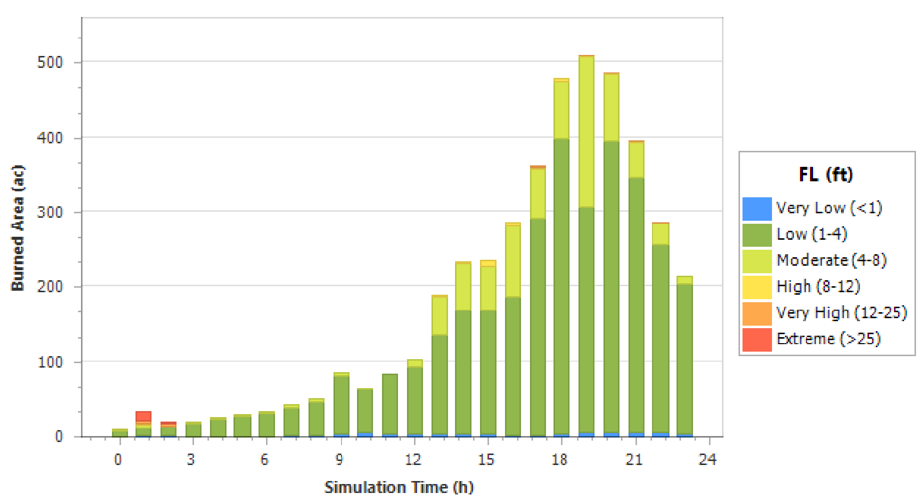
FIRE BEHAVIOR	WEATHER **Nearest Station:** Grand Oak Road
Rate of Spread	Station ID - PG297 Weather station (Wx) elevation - 1585 ft Fire ignition point (IP) elevation - 190 ft Distance between Wx and IP - 8.57 mi

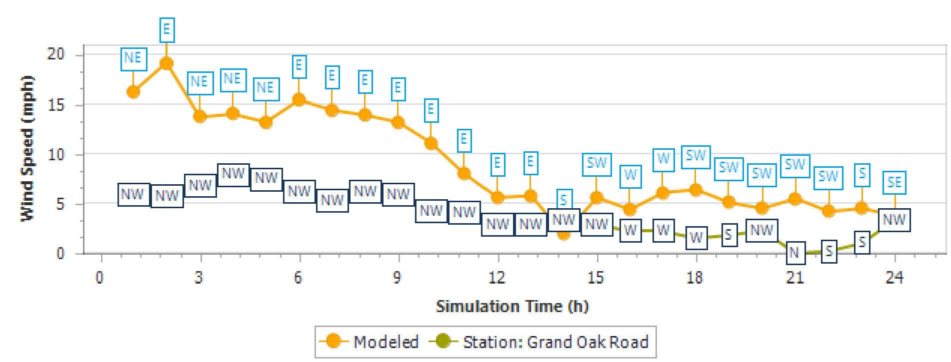
Rate of Spread





Flame Length





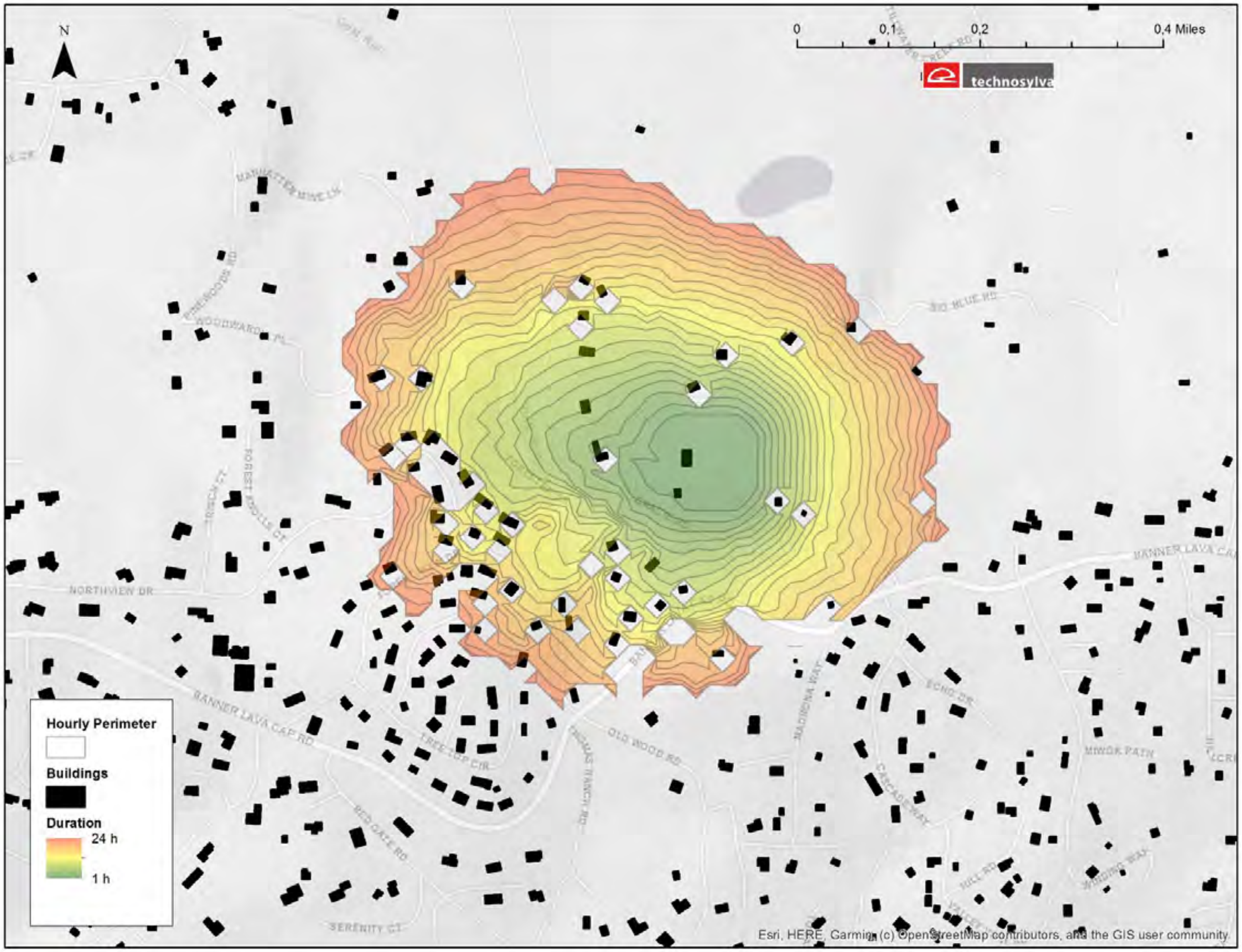
APPENDIX B: SEPTEMBER 23-26, 2019 - ANALYSIS OUTPUTS FOR SIGNIFICANT DAMAGE INCIDENTS

DAMAGE INCIDENT – 1

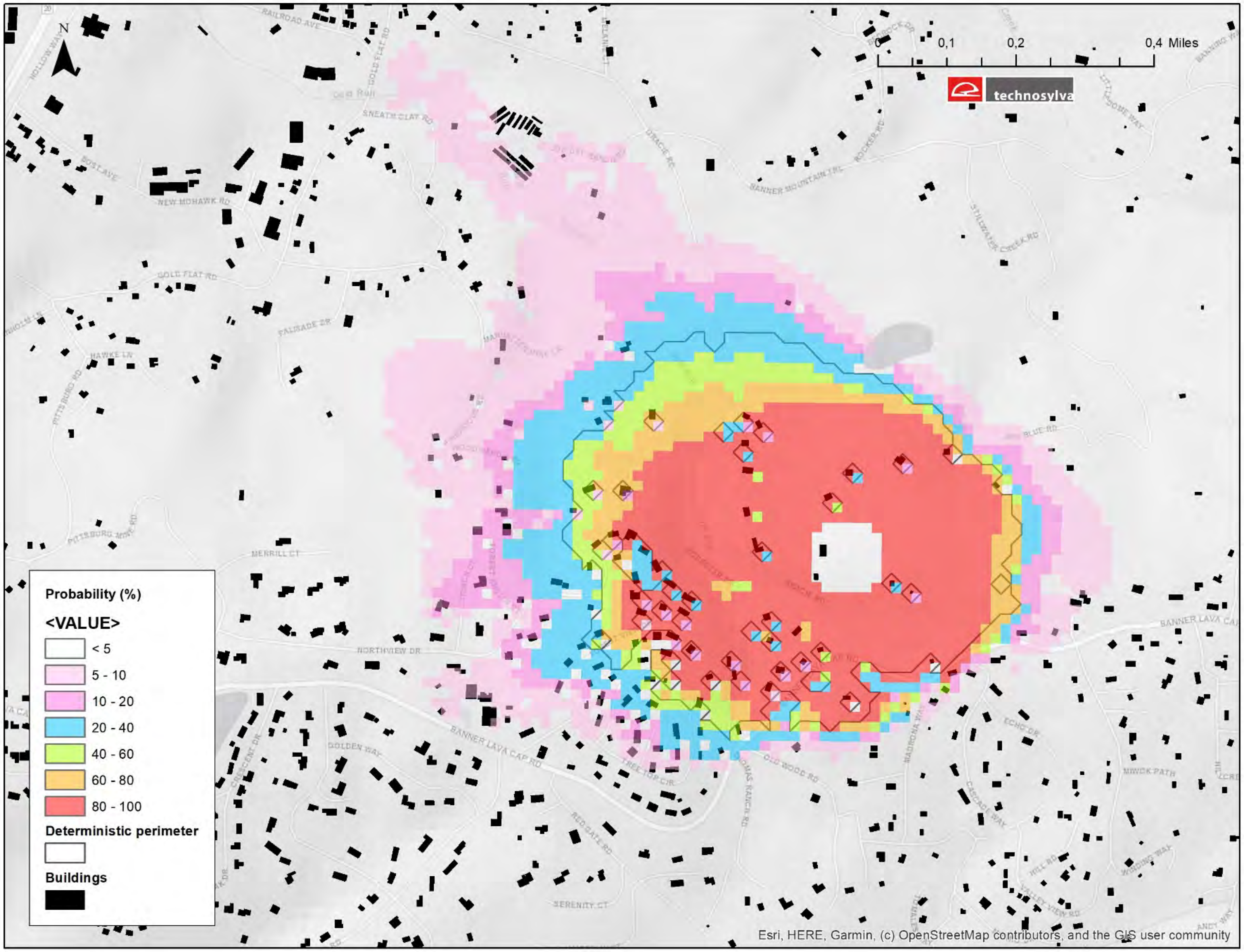
This incident is located in Yuba County, mostly burning timber fuel types near Forest Knolls and Nevada City. The fire would spread slowly in absence of crowning, not predicted during the fire simulation. Both the rate of spread and fire intensity would be low and fire could reach buildings scattered across the landscape. The fire would be expectedly suppressed by the fire agency in the initial attack (IAA = 1). Although it seems in the maps that more than 3 buildings were impacted by fire, note that the fire behavior is very low and would not have enough intensity to totally impact all the buildings. However, it is evident that the fire could threat more than 3 buildings. Historically, lots of fires were recorded in this area according to the FRAP CALFIRE fire dataset.

INCIDENT SUMMARY	
Start Time	09/25/19 - 03:00
Duration (hrs)	24
Size (ac)	172
Initial Attack Assessment	1 - Low
No. of Buildings	3
Total Population	153
Average ROS	Low

DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION



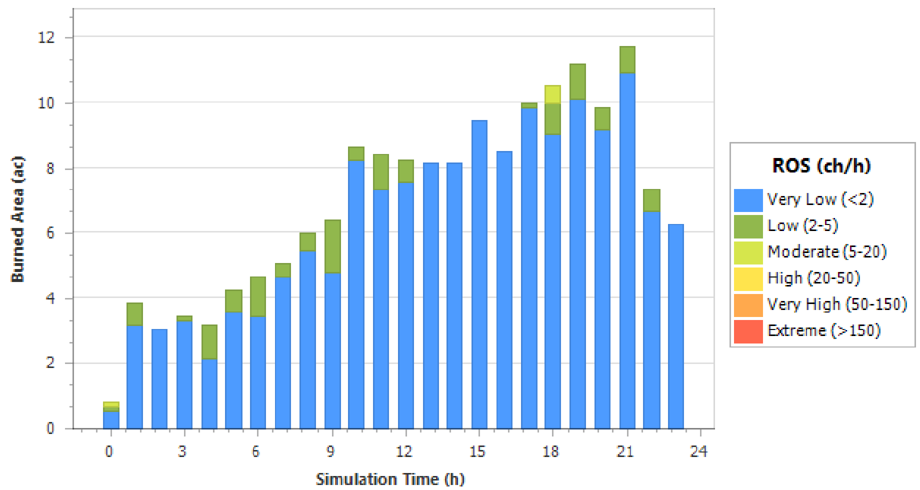
DAMAGE INCIDENT NO. 1

FIRE BEHAVIOR

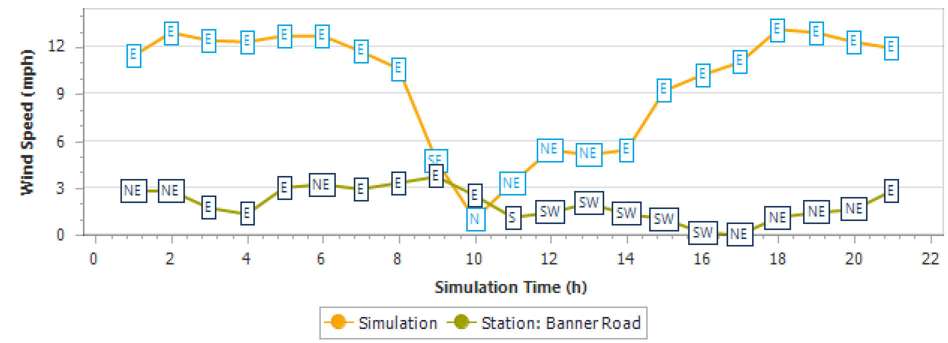
WEATHER

Nearest Station: Banner road

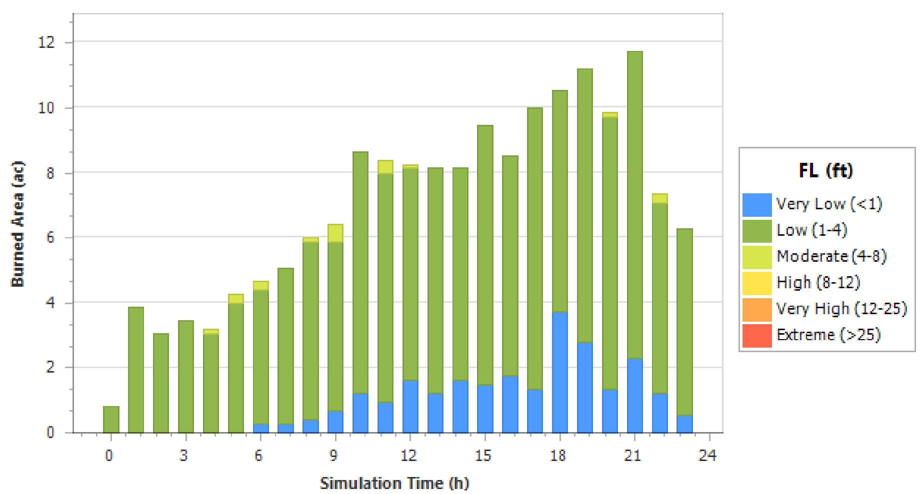
Rate of Spread

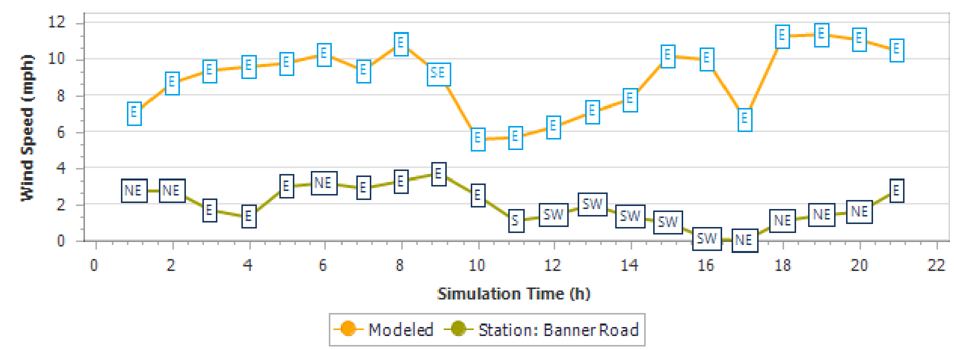


Station ID - PG025
Weather station (Wx) elevation - 3580 ft
Fire ignition point (IP) elevation - 3087 ft
Distance between Wx and IP - 3.11 mi



Flame Length



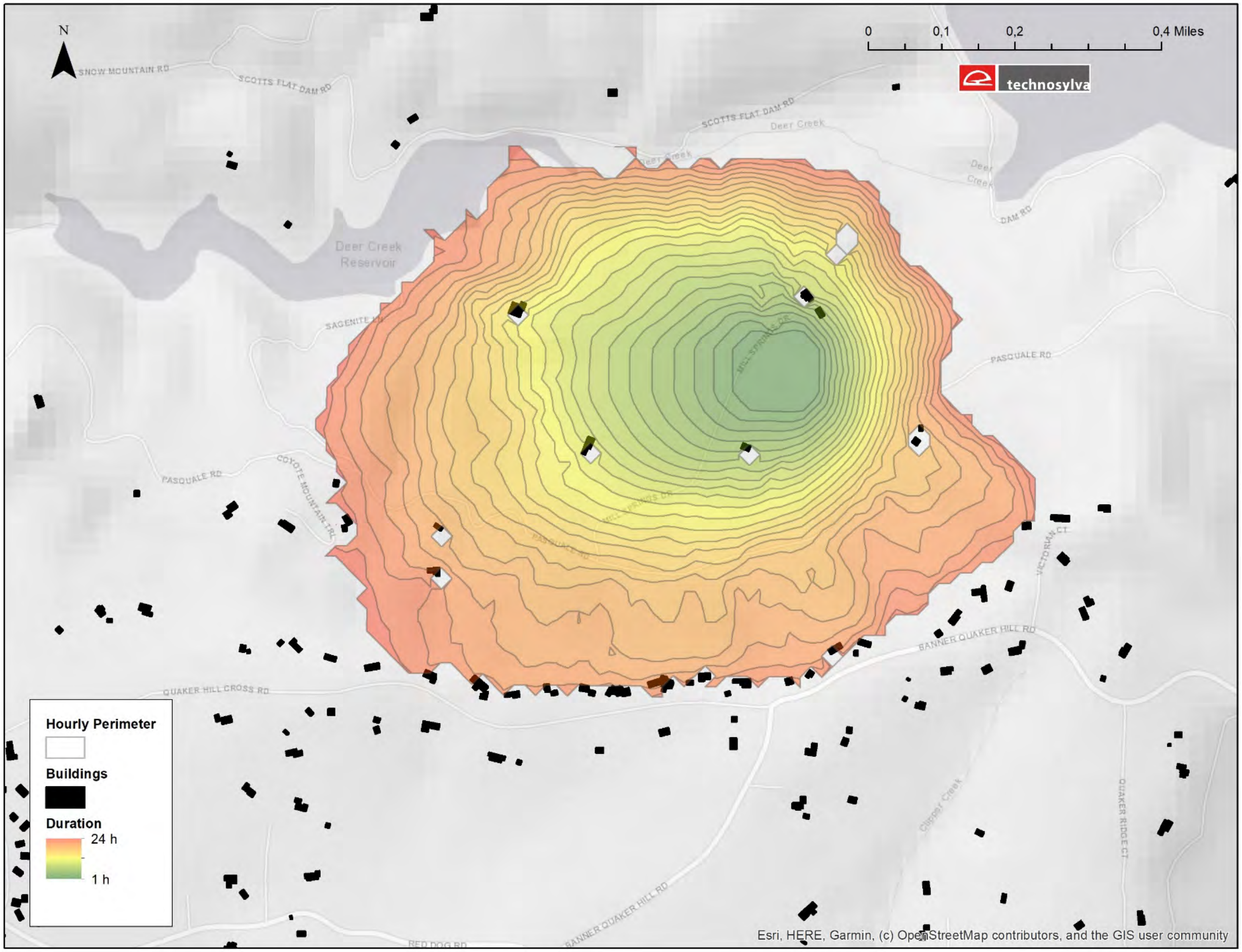


DAMAGE INCIDENT – 2

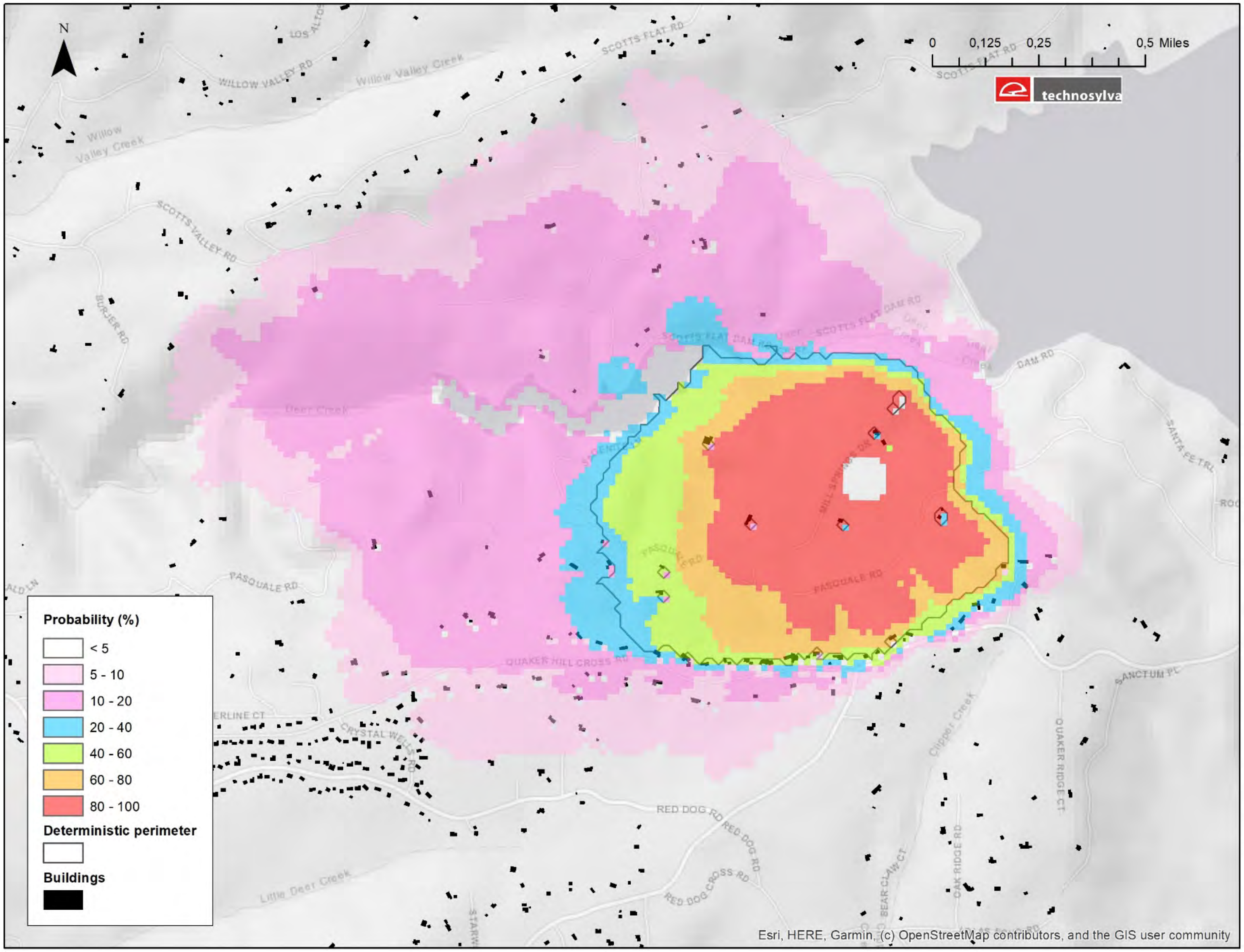
This incident is located in Butte County, mostly burning timber fuel types near the Scotts Flat Reservoir. The fire would spread slowly in absence of crowning, not predicted during the fire simulation. Both the rate of spread and fire intensity would be low and fire could threat isolated buildings across the landscape. The fire would be expectedly suppressed by the fire agency in the initial attack (IAA = 1). Although it seems in the maps that more than 1 buildings were impacted by fire, note that the fire behavior is very low and would not have enough intensity to totally impact all the buildings. However, it is evident that the fire could threat more than 1 building. Historically, lots of fires were recorded in this area according to the FRAP CALFIRE fire dataset.

INCIDENT SUMMARY	
Start Time	09/25/19 - 03:00
Duration (hrs)	24
Size (ac)	352
Initial Attack Assessment	1 - Low
No. of Buildings	1
Total Population	143
Average ROS	Low

DAMAGE INCIDENT NO. 2 : DETERMINISTIC SIMULATION



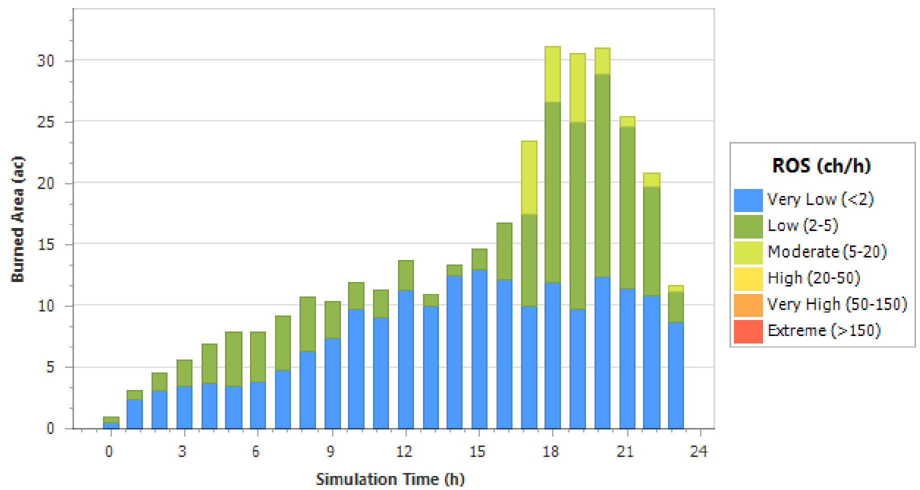
DAMAGE INCIDENT NO. 2 : PROBABILISTIC SIMULATION



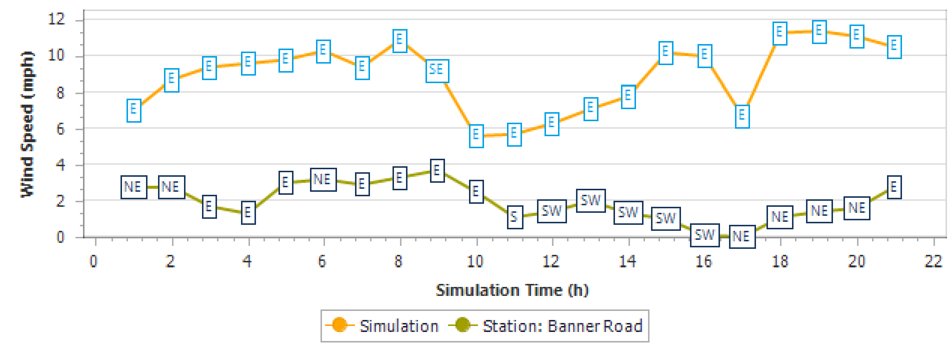
DAMAGE INCIDENT NO. 2

FIRE BEHAVIOR	WEATHER **Nearest Station:** Banner road

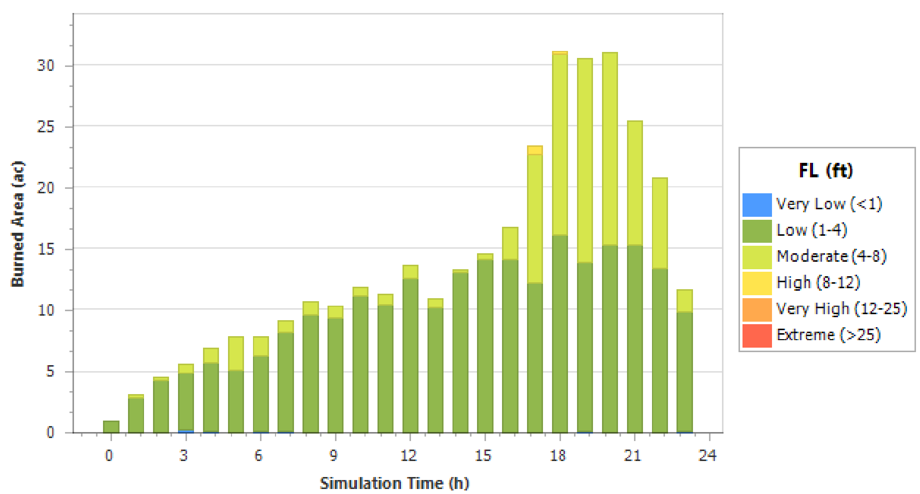
Rate of Spread

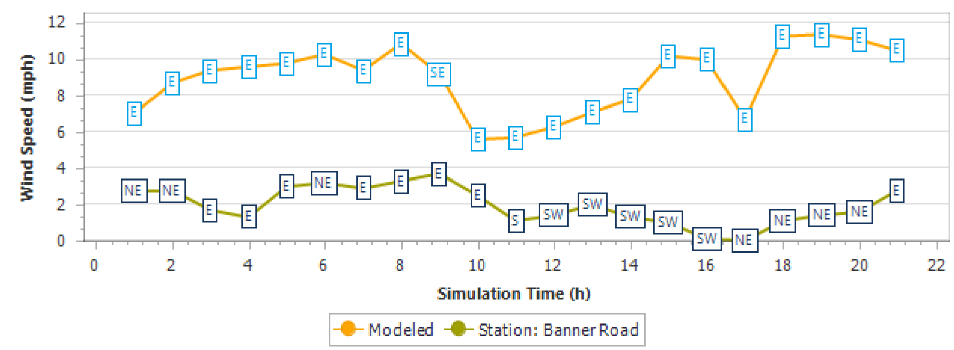


Station ID - PG025
Weather station (Wx) elevation - 3580 ft
Fire ignition point (IP) elevation - 3198 ft
Distance between Wx and IP - 1.06 mi



Flame Length



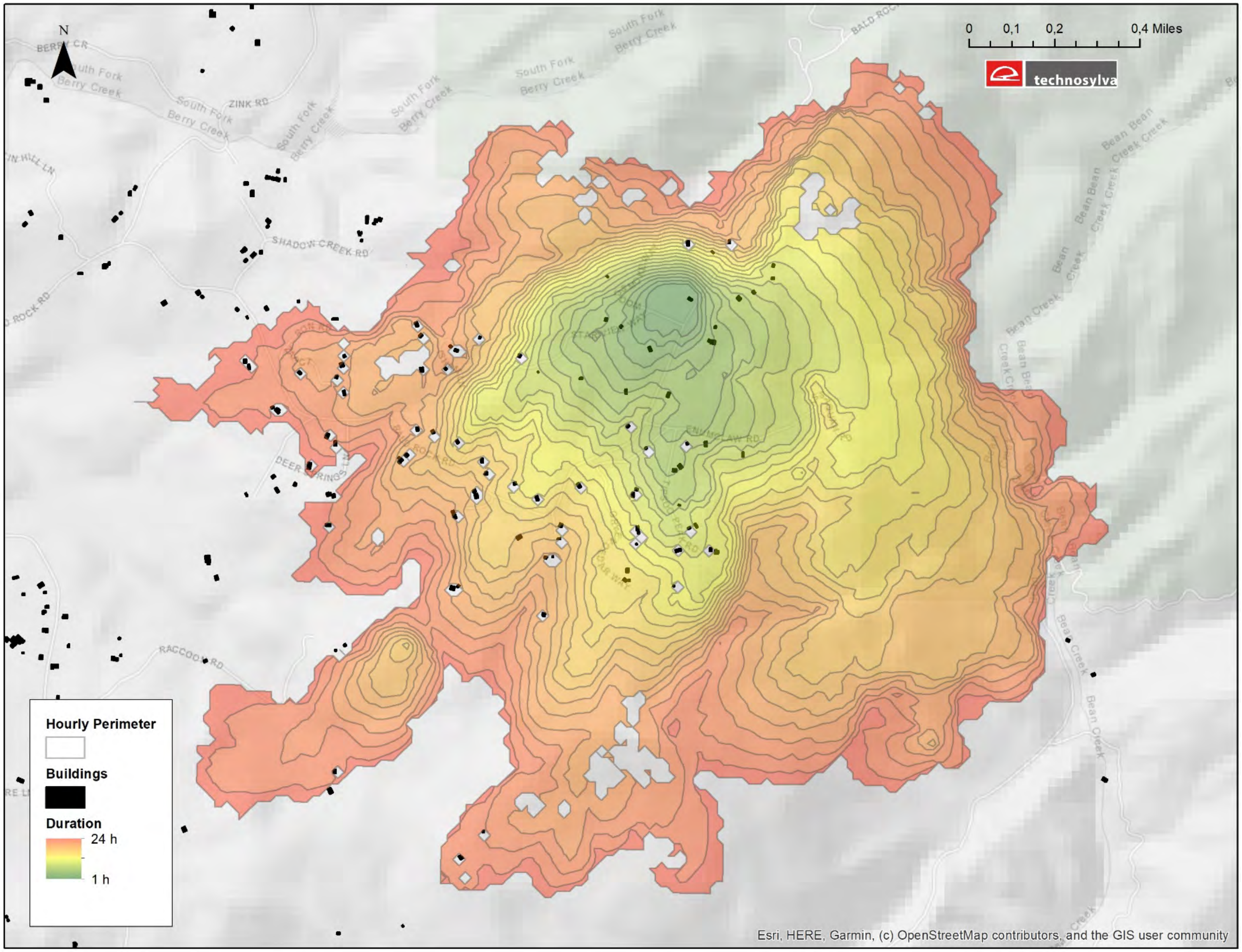


DAMAGE INCIDENT – 3

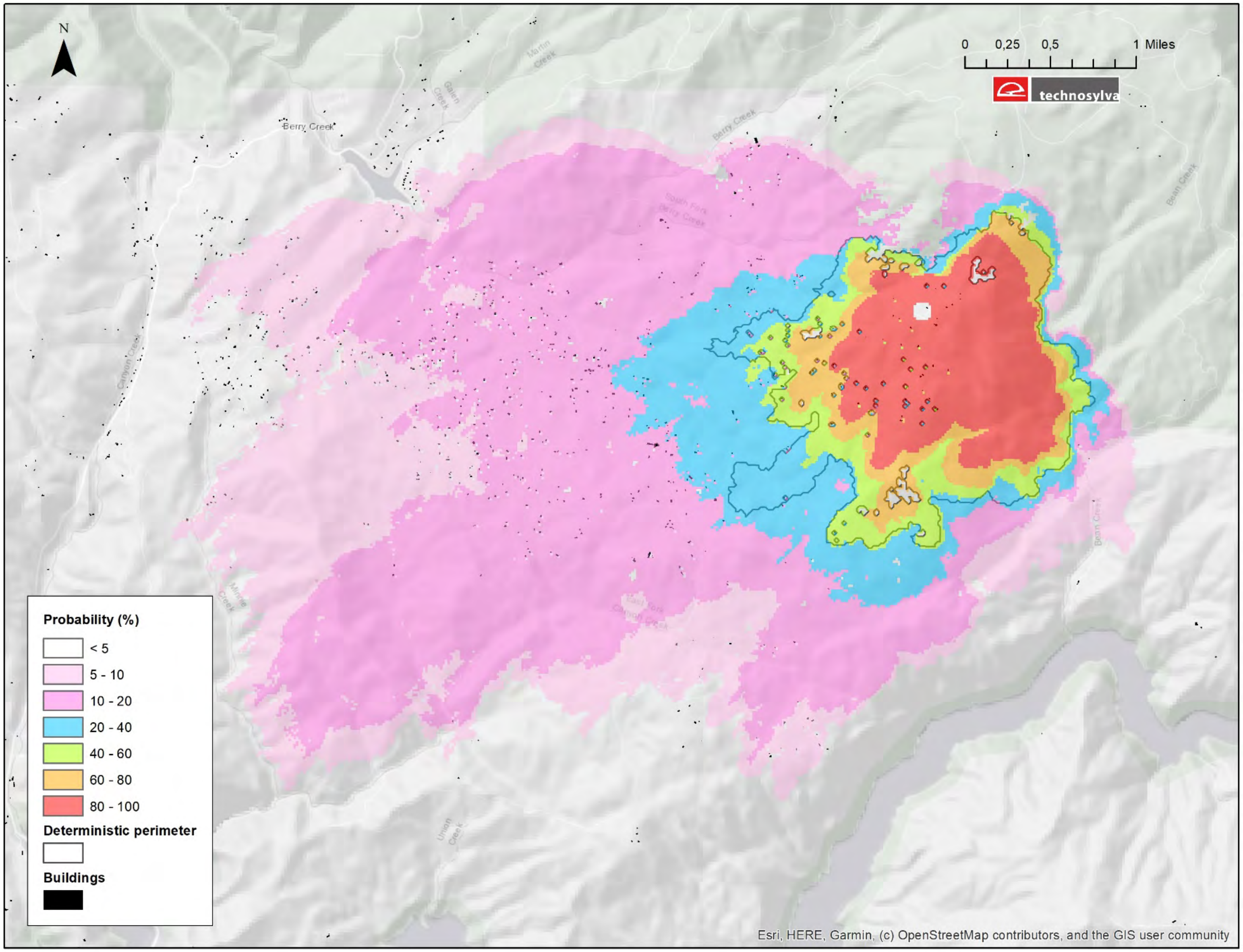
This incident is located in Nevada County, mostly burning timber and shrub fuel types. The fire would spread slowly in absence of crowning, not predicted during the fire simulation. The rate of spread would be generally low but faster than other simulations in this PSPS event giving rise a larger fire. Also, the fire intensity would be higher. However, the fire would be expectedly suppressed by the fire agency in the initial attack (IAA = 1). The fire could impact more than 80 buildings given an increased fire intensity in this incident. Historically, lots of fires were recorded in this area according to the FRAP CALFIRE fire dataset.

INCIDENT SUMMARY	
Start Time	09/24/19 - 06:00
Duration (hrs.)	24
Size (ac)	1,644
Initial Attack Assessment	1 - Low
No. of Buildings	27
Total Population	82
No. of Places	17
Average ROS	Low

DAMAGE INCIDENT NO. 3 : DETERMINISTIC SIMULATION



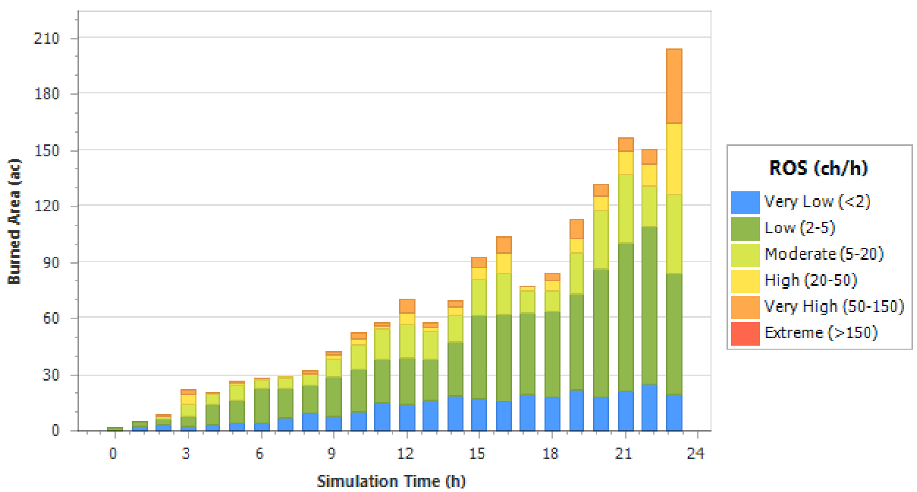
DAMAGE INCIDENT NO. 3 : PROBABILISTIC SIMULATION



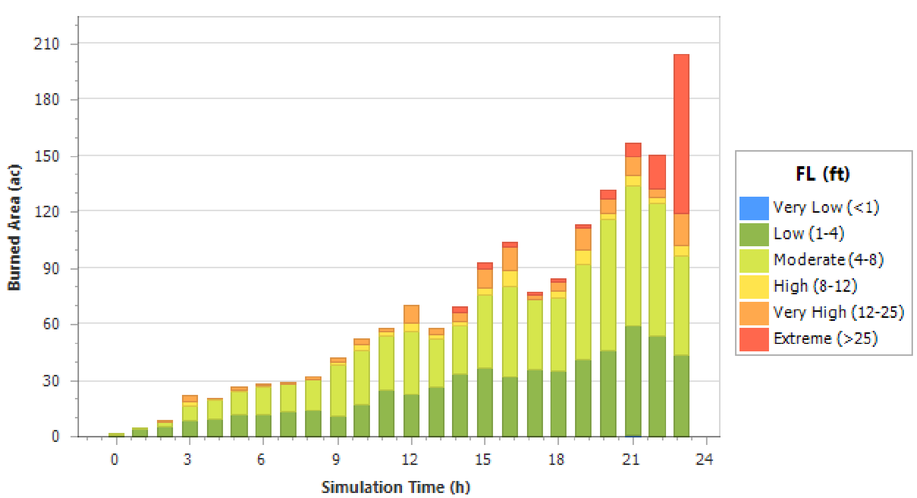
DAMAGE INCIDENT NO. 3

FIRE BEHAVIOR

Rate of Spread



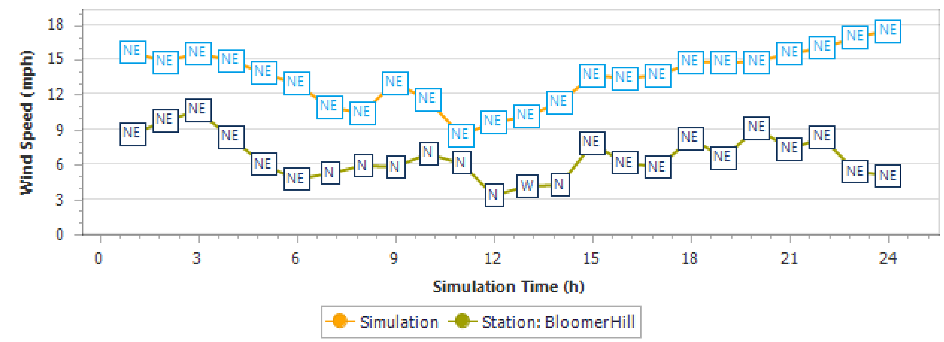
Flame Length

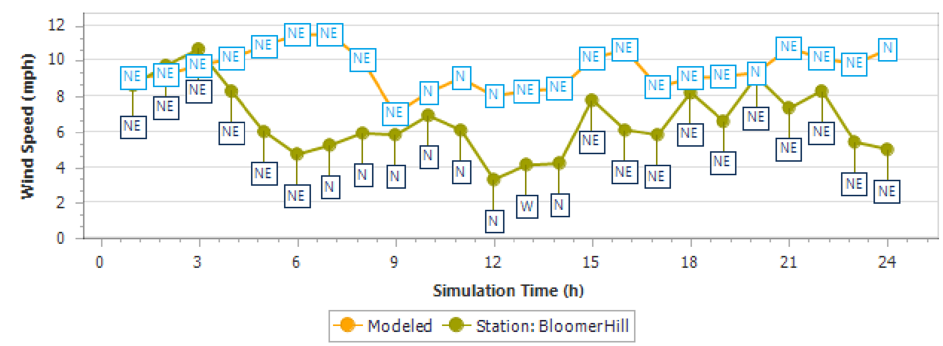


WEATHER

Nearest Station: Bloomer Hill

Station ID - PG264
Weather station (Wx) elevation - 2982 ft
Fire ignition point (IP) elevation - 2972 ft
Distance between Wx and IP - 6.35 mi

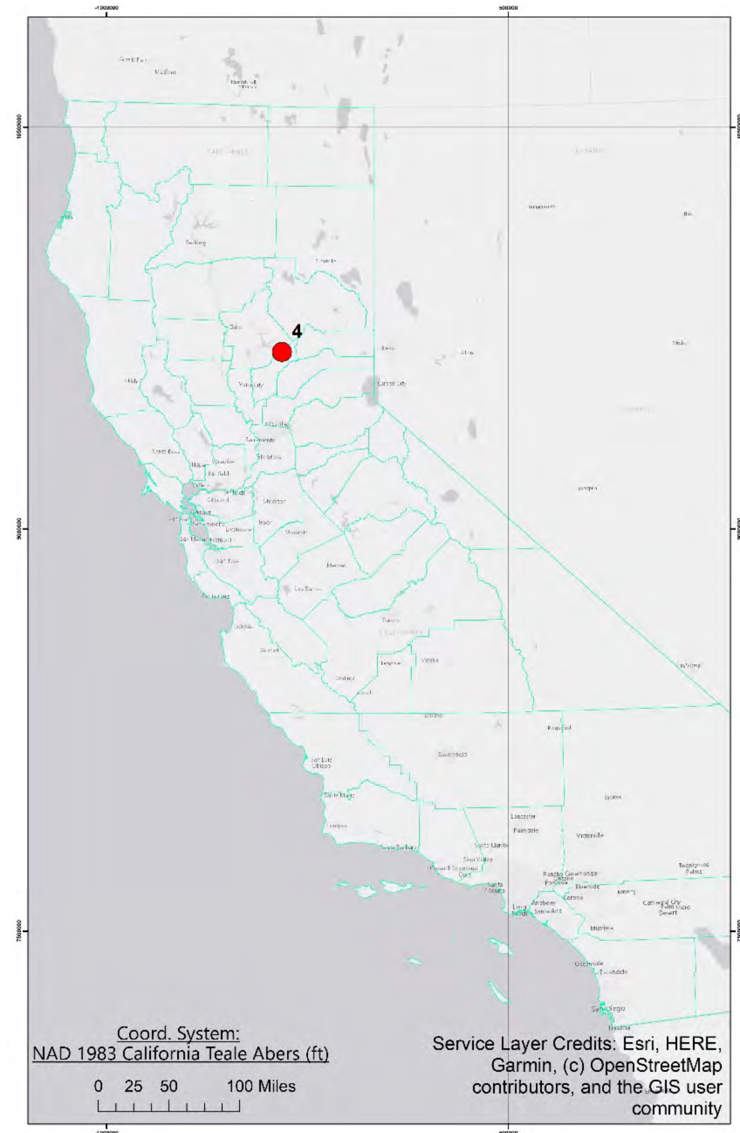




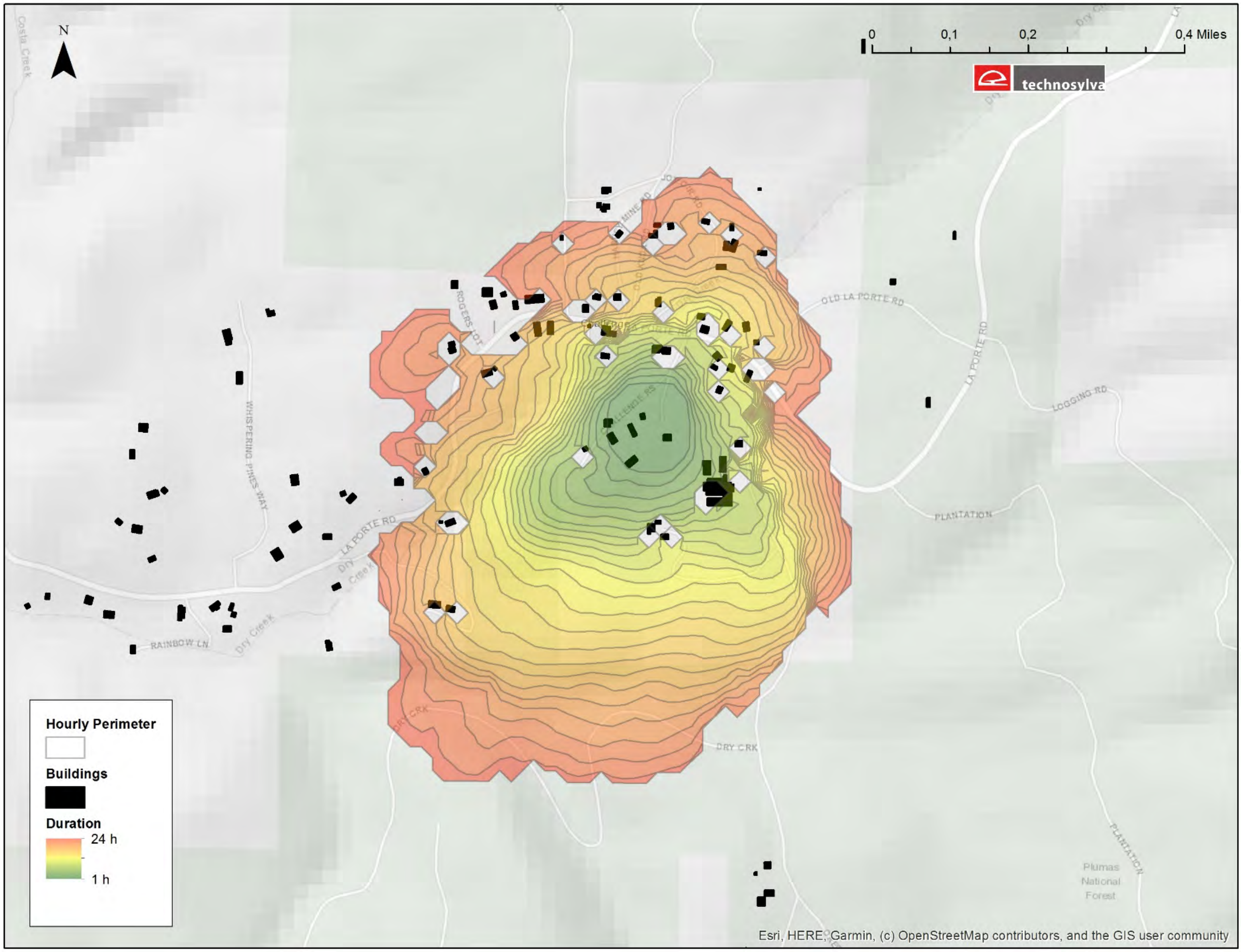
DAMAGE INCIDENT – 4

This incident is located in Nevada County, mostly burning timber fuel types near a scattered Wildland Urban Interface in Challenge. The fire would spread slowly in absence of crowning, not predicted during the fire simulation. Both the rate of spread and fire intensity would be generally low. The fire would be expectedly suppressed by the fire agency in the initial attack (IAA = 1). Although it seems in the maps that more than 16 buildings were impacted by fire, note that the fire behavior is very low and would not have enough intensity to totally impact all the buildings. Historically, lots of fires were recorded in this area according to the FRAP CALFIRE fire dataset.

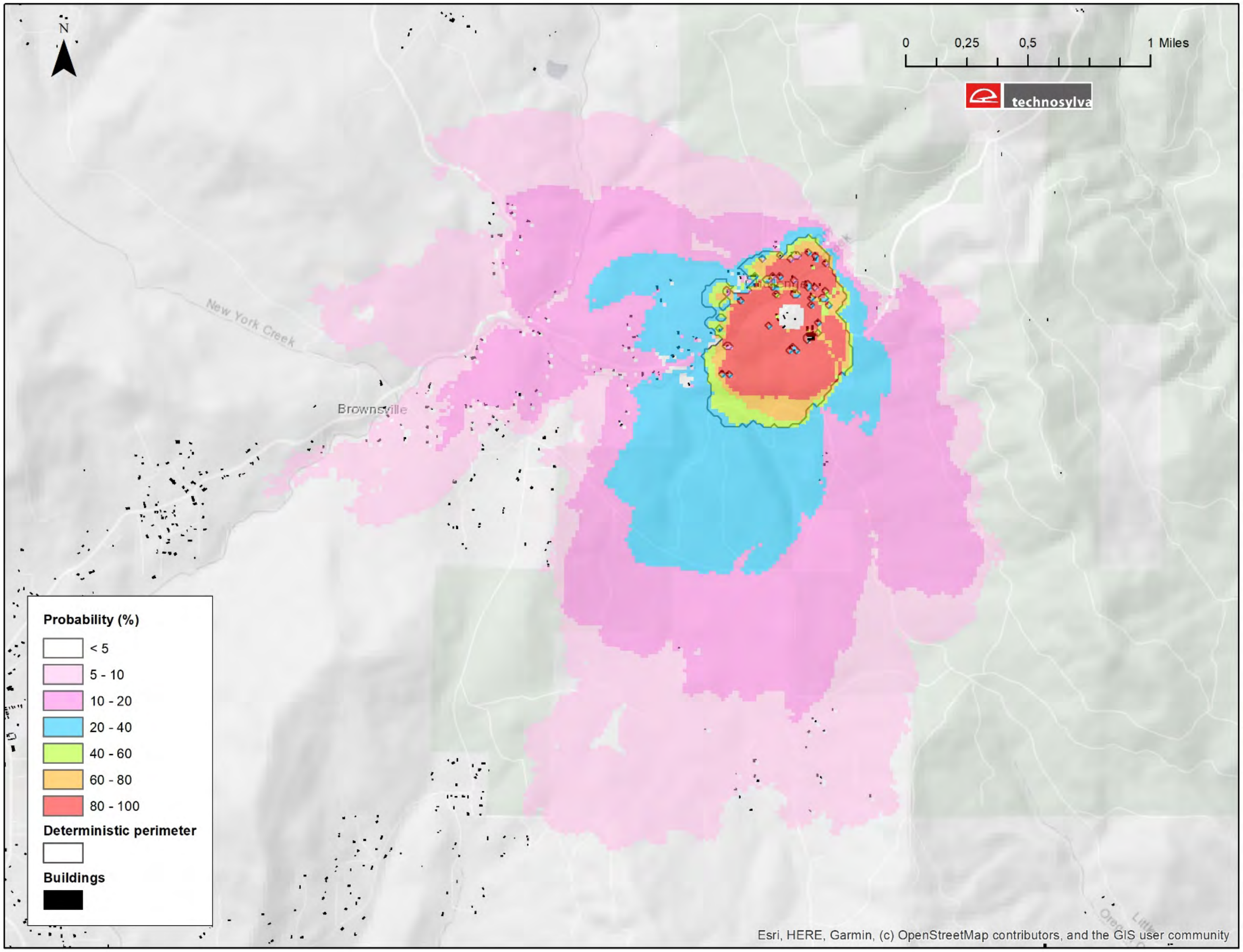
INCIDENT SUMMARY	
Start Time	09/24/19 - 06:00
Duration (hrs)	24
Size (ac)	224
Initial Attack Assessment	1 - Low
No. of Buildings	16
Total Population	22
Average ROS	Low



DAMAGE INCIDENT NO. 4 : DETERMINISTIC SIMULATION



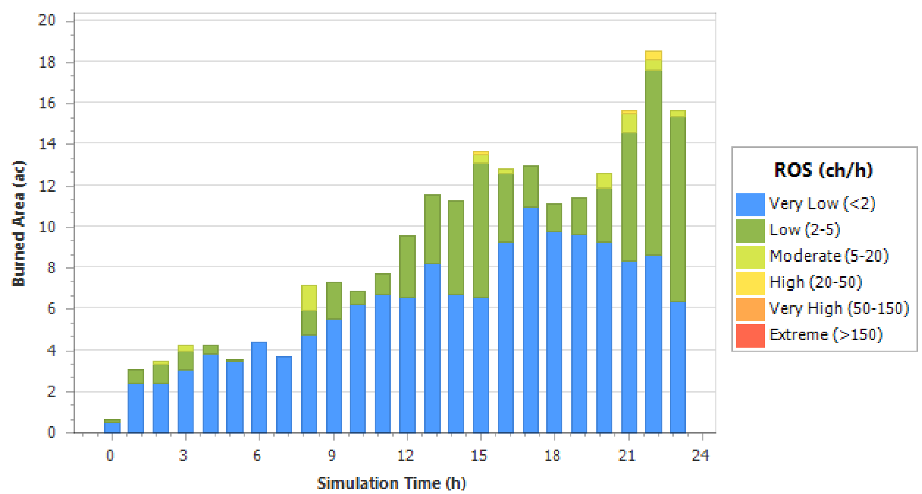
DAMAGE INCIDENT NO. 4 : PROBABILISTIC SIMULATION



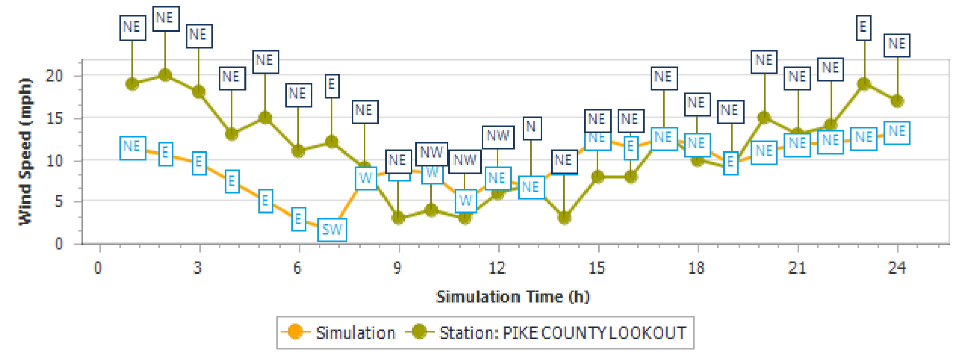
DAMAGE INCIDENT NO. 4

FIRE BEHAVIOR	WEATHER **Nearest Station:** Pike county lookout

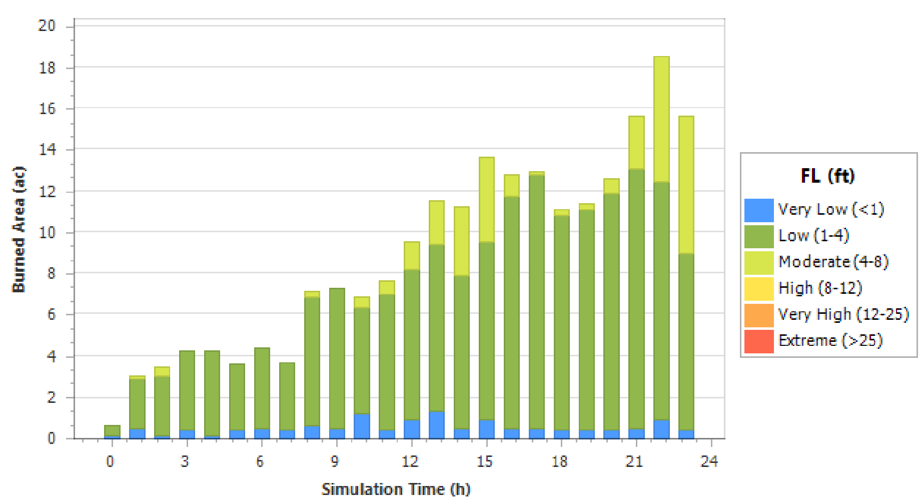
Rate of Spread

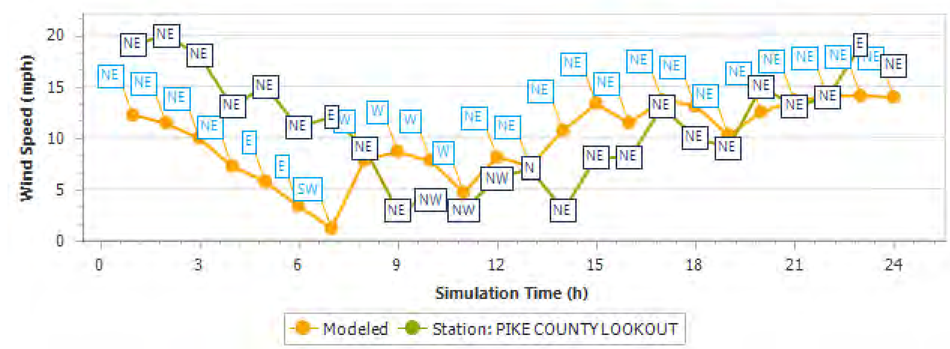


Station ID - PKCC1
Weather station (Wx) elevation - 3701 ft
Fire ignition point (IP) elevation - 2566 ft
Distance between Wx and IP - 1.27 mi



Flame Length





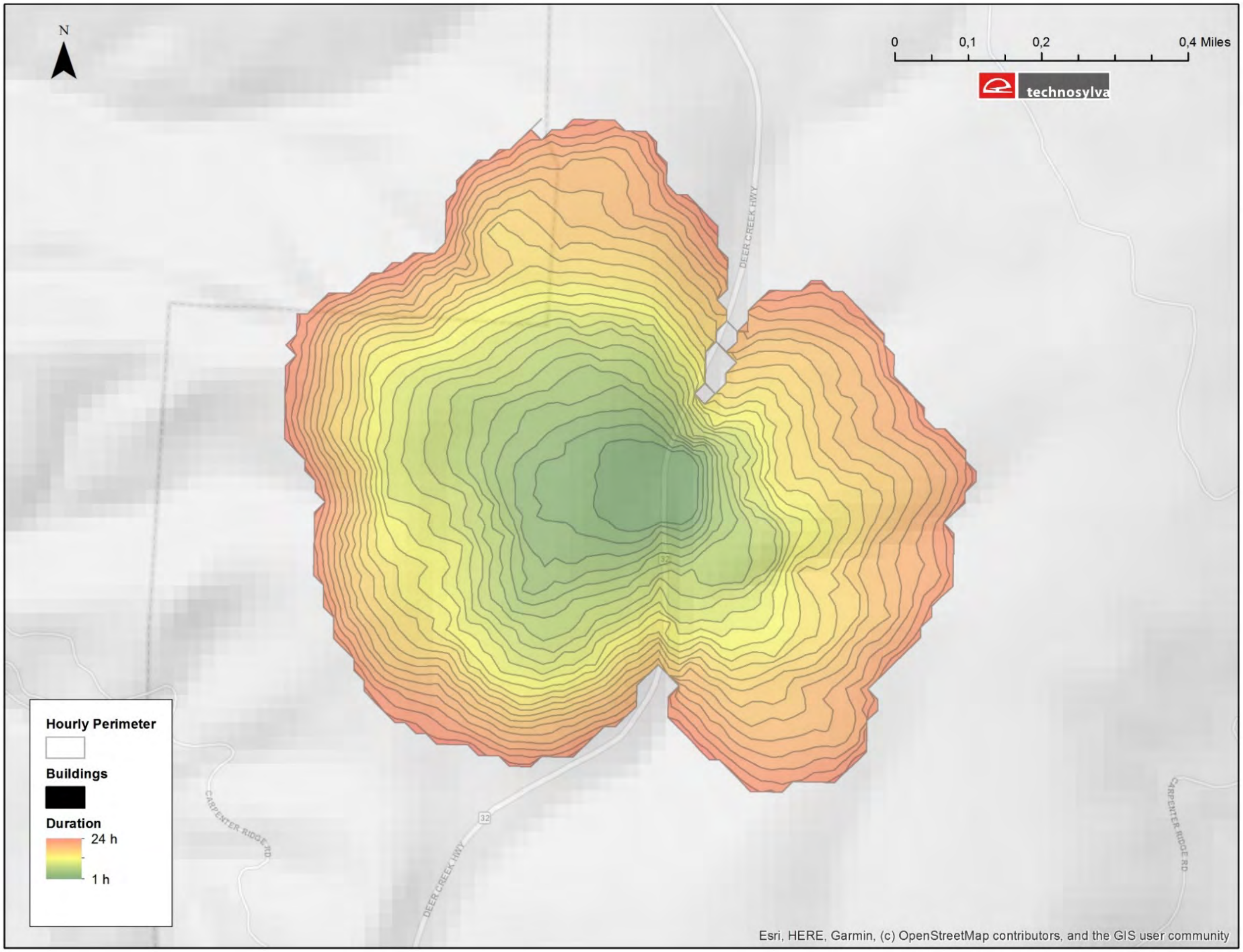
APPENDIX C: OCTOBER 5-6, 2019 - ANALYSIS OUTPUTS FOR SIGNIFICANT DAMAGE INCIDENTS

DAMAGE INCIDENT – 1

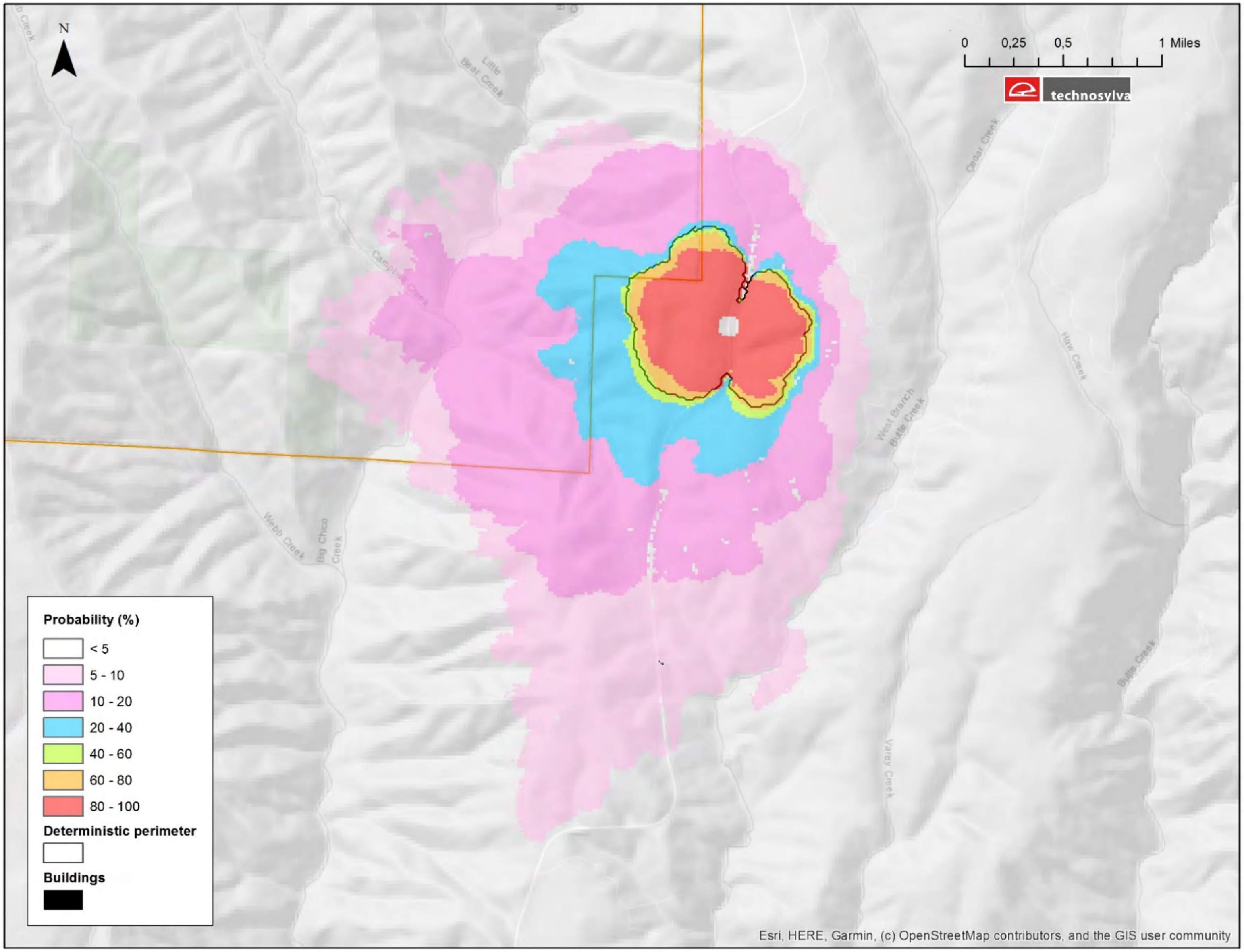
Topography-driven fire starting near a road with a very low rate of spread (< 2ch/h) and flame length (< 2 ft) giving rise a low IAA (1). Low wind speed ranging between 1 and 6 mi/h in the weather station. Modeled wind speed was higher as shown in the weather charts. Therefore, it would be expected that the fire would have suppressed in the initial attack. There were no buildings or population near the ignition point and the expected fire impact on buildings and population would be null.

INCIDENT SUMMARY	
Start Time	10/05/19 - 23:00
Duration (hrs)	24
Size (ac)	379
Initial Attack Assessment	1 - Low
No. of Buildings	0
Total Population	0
Average ROS	< 2 chains/hr

DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION



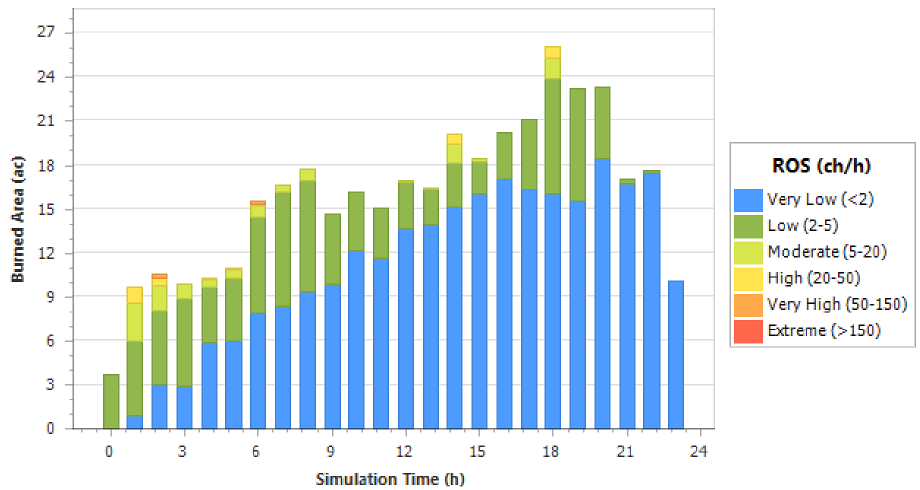
DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION



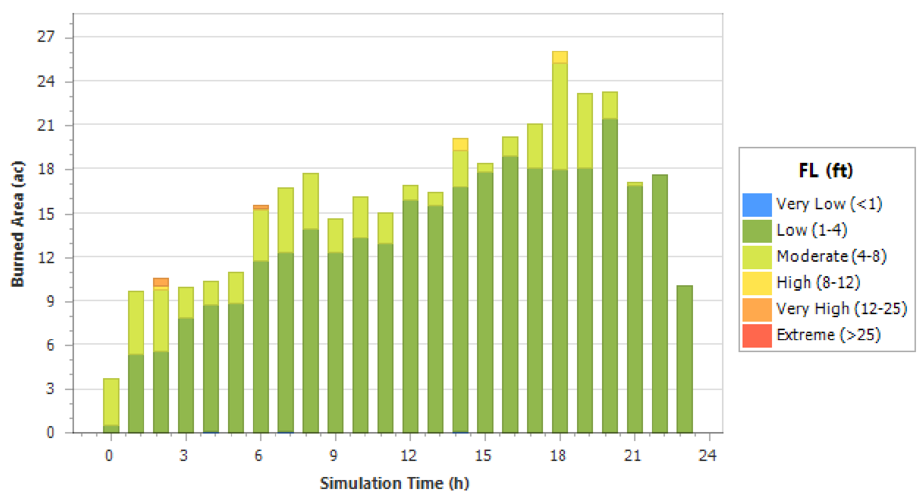
DAMAGE INCIDENT NO. 1

FIRE BEHAVIOR

Rate of Spread



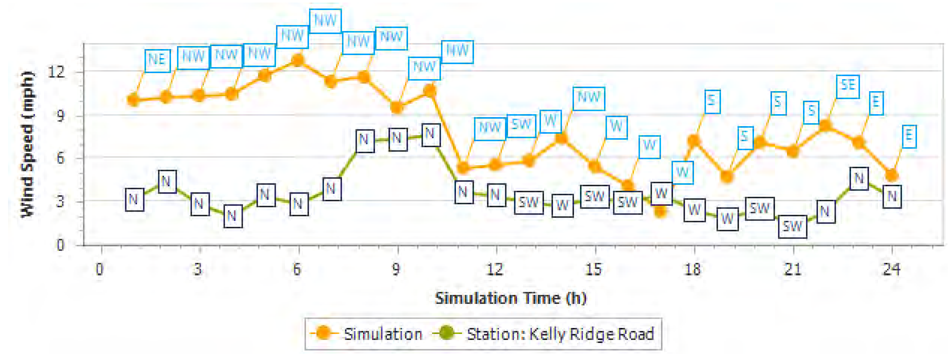
Flame Length

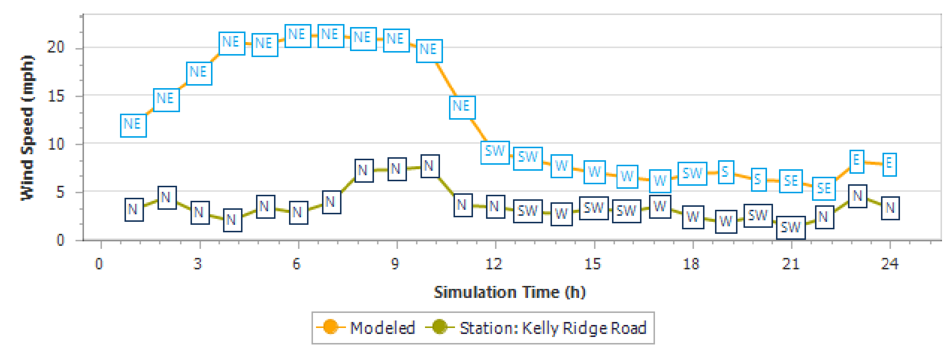


WEATHER

Nearest Station: Blue Sky Road

Station ID - PG366
Weather station (Wx) elevation - 1436 ft
Fire ignition point (IP) elevation - 518 ft
Distance between Wx and IP - 9.43 mi





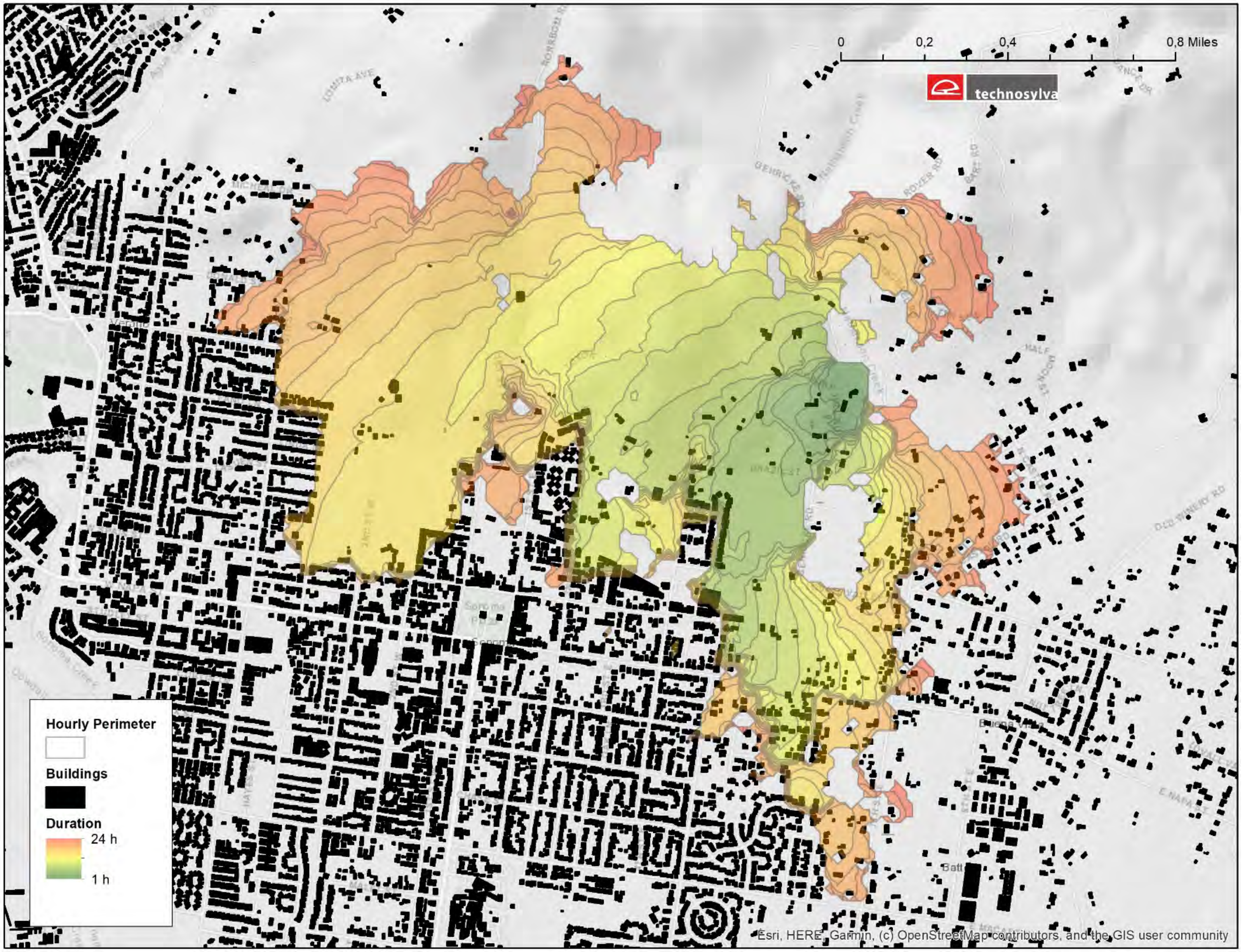
APPENDIX D: OCTOBER 23-25, 2019 - ANALYSIS OUTPUTS FOR SIGNIFICANT DAMAGE INCIDENTS

DAMAGE INCIDENT – 1

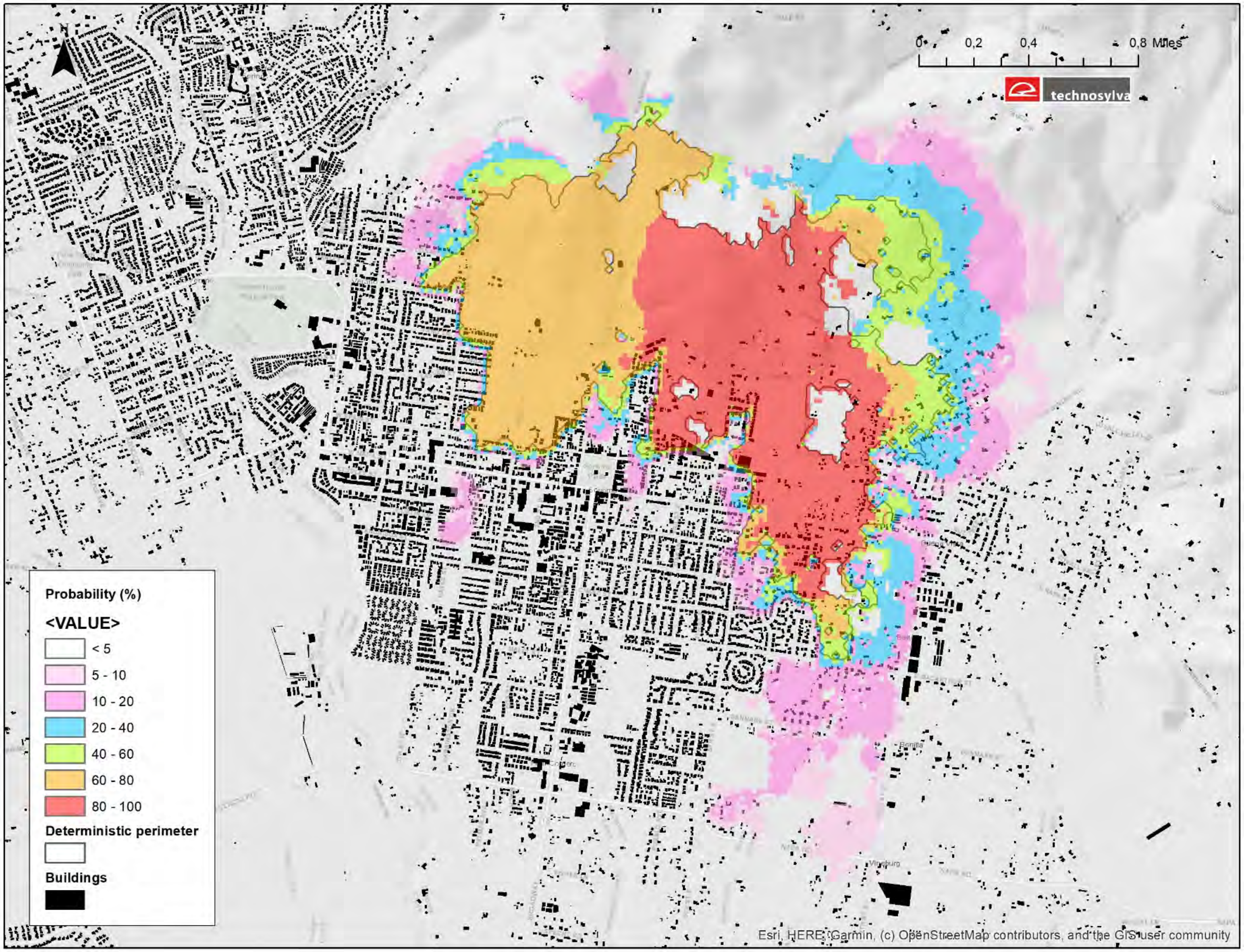
This incident is located in Sonoma County, Northern San Francisco Bay. The fire would generally have low rate of spread and fire intensity, giving rise a low IAA (1). However, the damage incident is near a very populated area with scattered buildings and a dense wildland urban interface with extreme fire behavior in some areas. In this context, the fire would impact almost 1,000 people and 600 buildings. The fire size would be low with 1,000 acres burned in 24 hours. In 2017, the area was threatened by the NUNS fire with a total burned area of 55,797 ac. Modeled wind speed was similar to the weather station at the same coordinates but higher in the ignition simulation point.

INCIDENT SUMMARY	
Start Time	10/23/19 - 15:00
Duration (hrs)	24
Size (ac)	1,054
Initial Attack Assessment	1 - Low
No. of Buildings	599
Total Population	944
Average ROS	Low

DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION



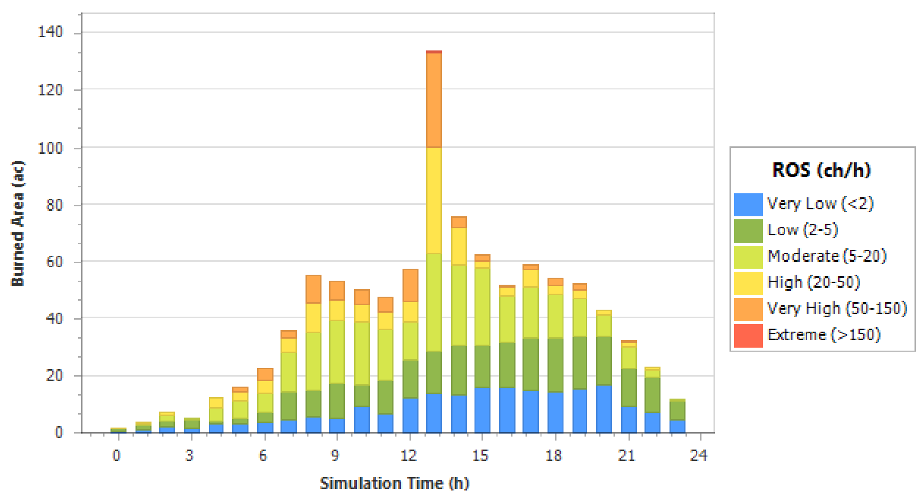
DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION



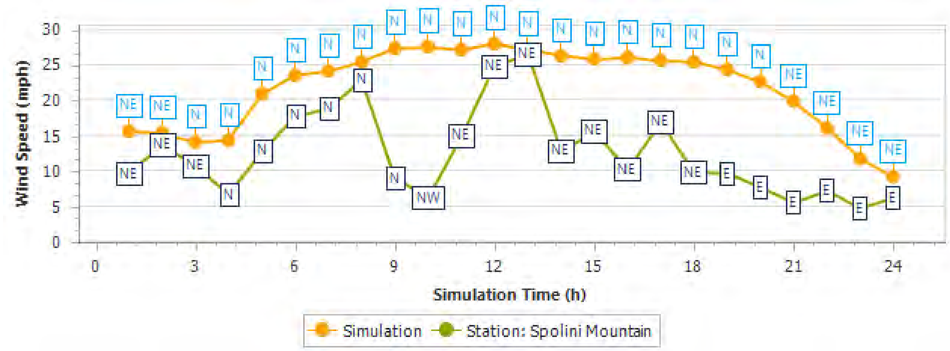
DAMAGE INCIDENT NO. 1

FIRE BEHAVIOR	WEATHER **Nearest Station:** Spolini Mountain

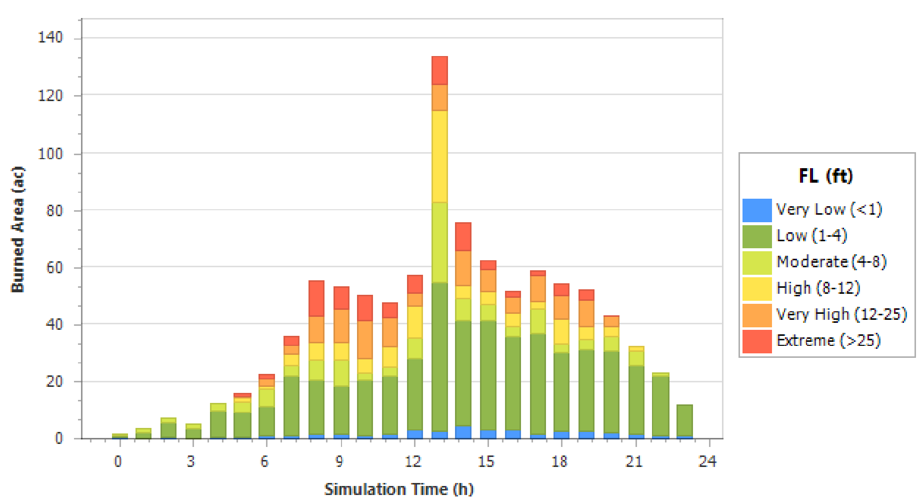
Rate of Spread

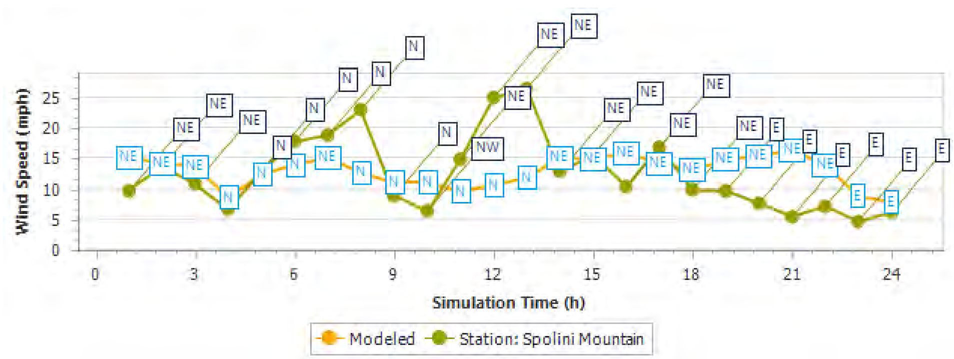


Station ID - PG548
Weather station (Wx) elevation - 825 ft
Fire ignition point (IP) elevation - 156 ft
Distance between Wx and IP - 5.68 mi



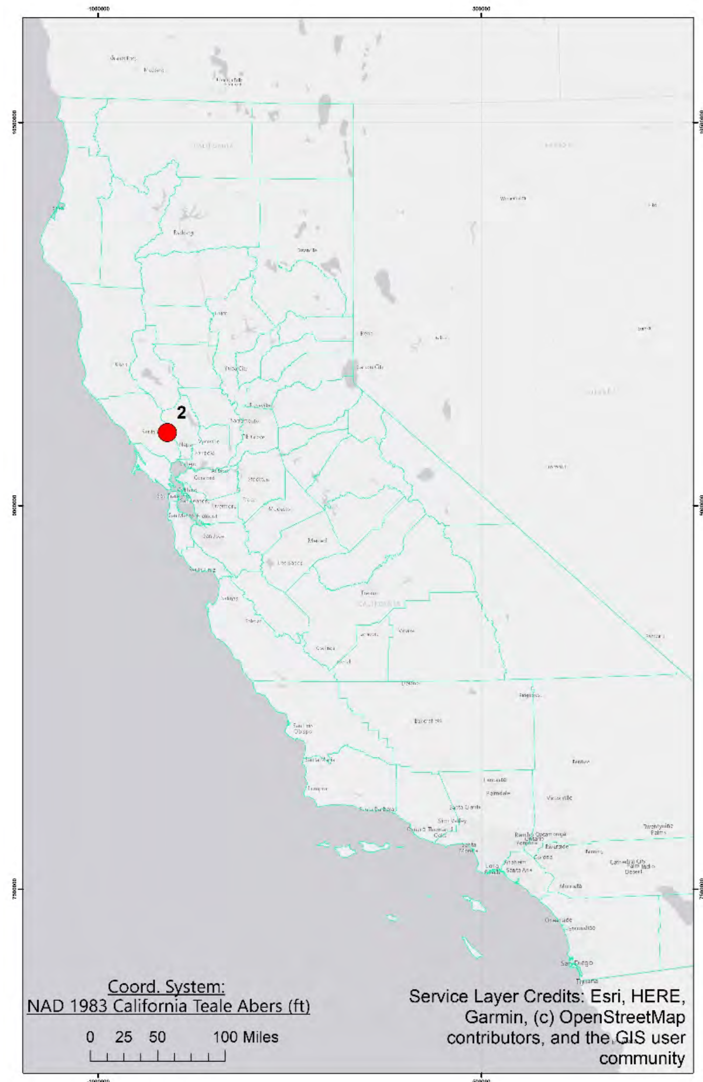
Flame Length





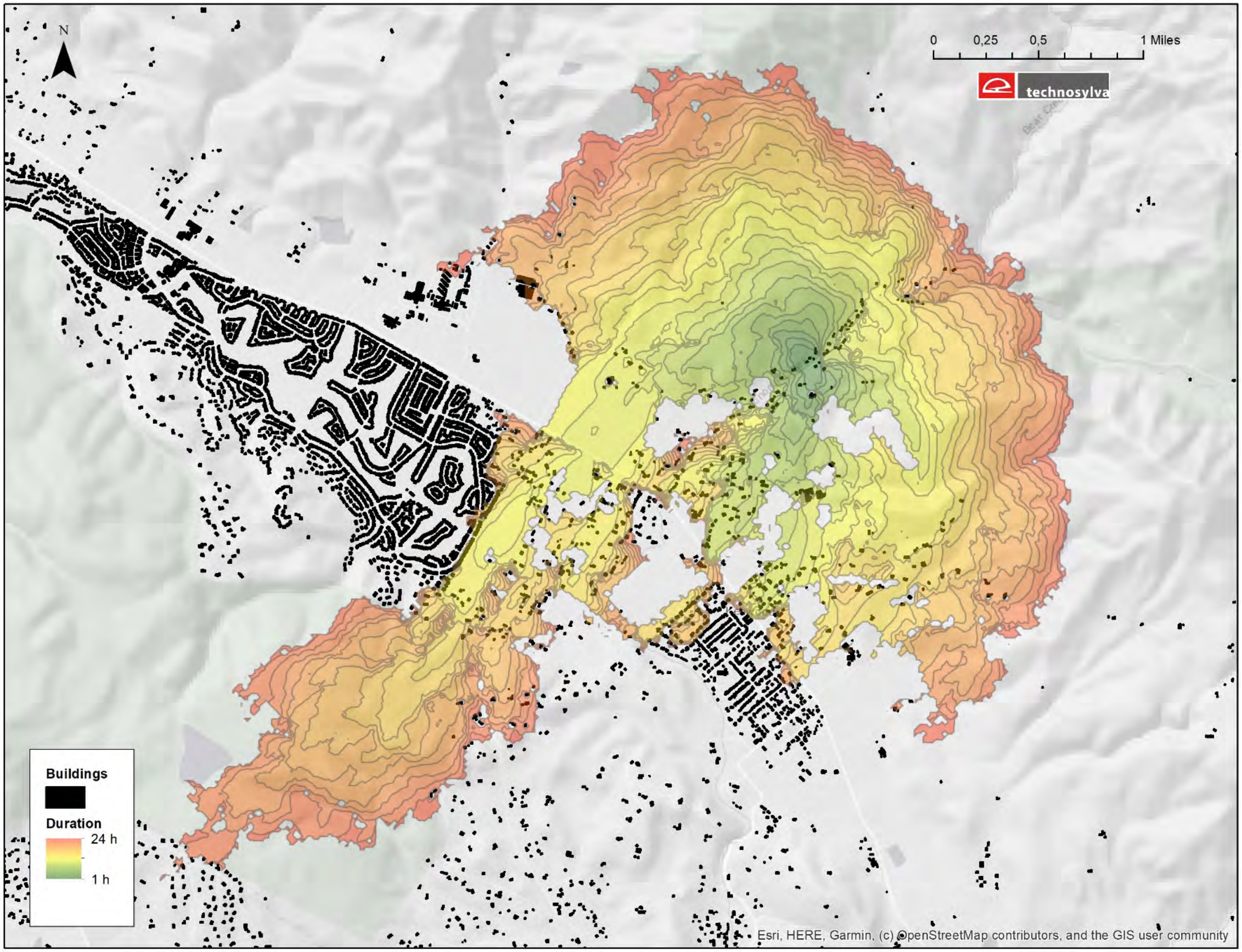
DAMAGE INCIDENT – 2

This incident is located in Sonoma County, Northern San Francisco Bay. The fire would have low rate of spread and fire intensity, giving rise a low IAA (2). However, both the rate of spread and flame length could be high or even very high throughout the fire progression as reflected in the fire behavior charts. The damage incident is near a very populated area with scattered buildings and a dense wildland urban interface in Kenwood. In this context, the fire could impact lots of people and buildings. The fire size would be low with 1,000 acres burned in 24 hours. In 2017, the area was threatened by the NUNS fire with a total burned area of 55,797 ac. Modeled wind speed was similar to the weather station at the same coordinates but higher in the ignition simulation point.

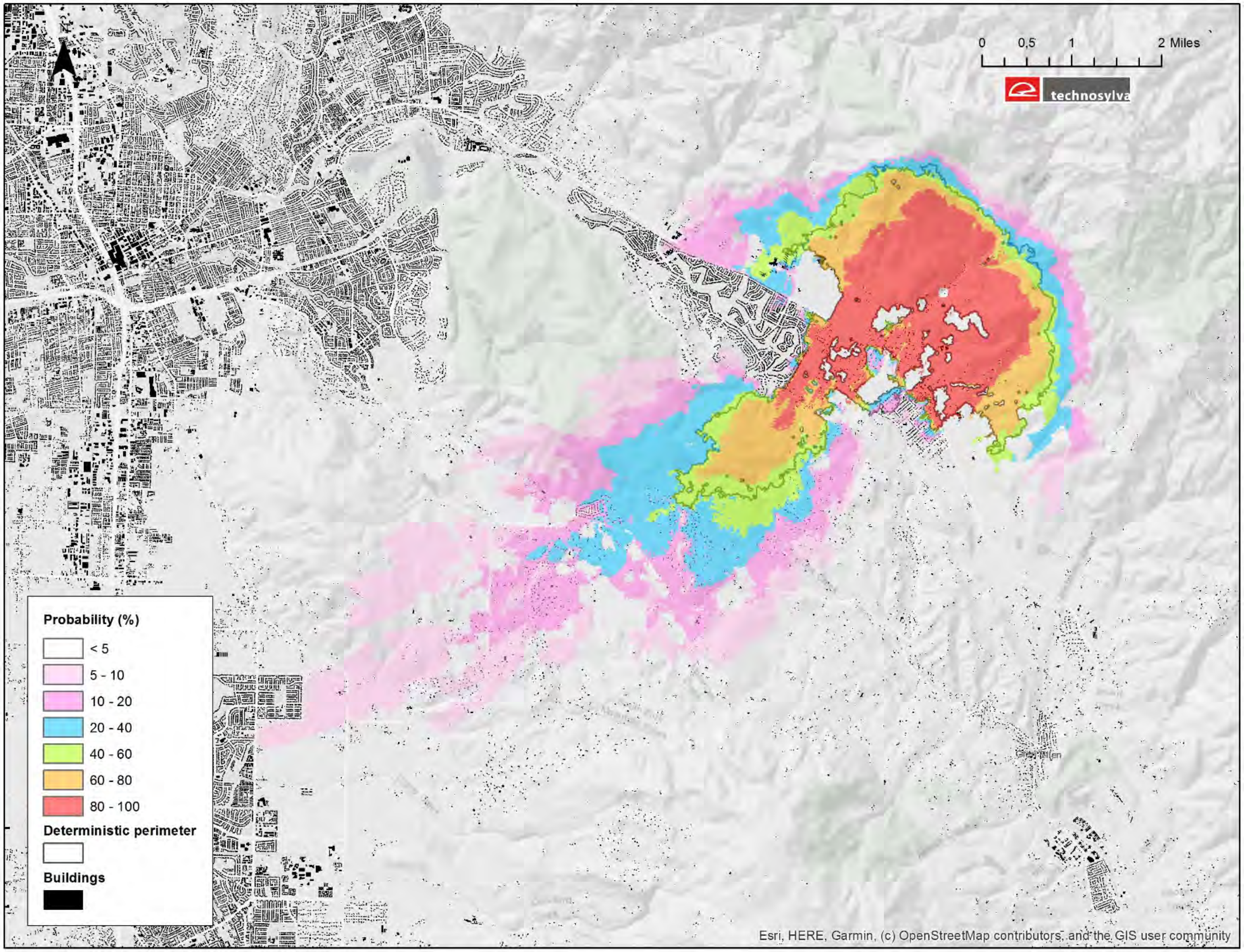


INCIDENT SUMMARY	
Start Time	10/23/19 - 15:00
Duration (hrs)	24
Size (ac)	4,477
Initial Attack Assessment	2 - Moderate
No. of Buildings	677
Total Population	758
Average ROS	Low

DAMAGE INCIDENT NO. 2 : DETERMINISTIC SIMULATION



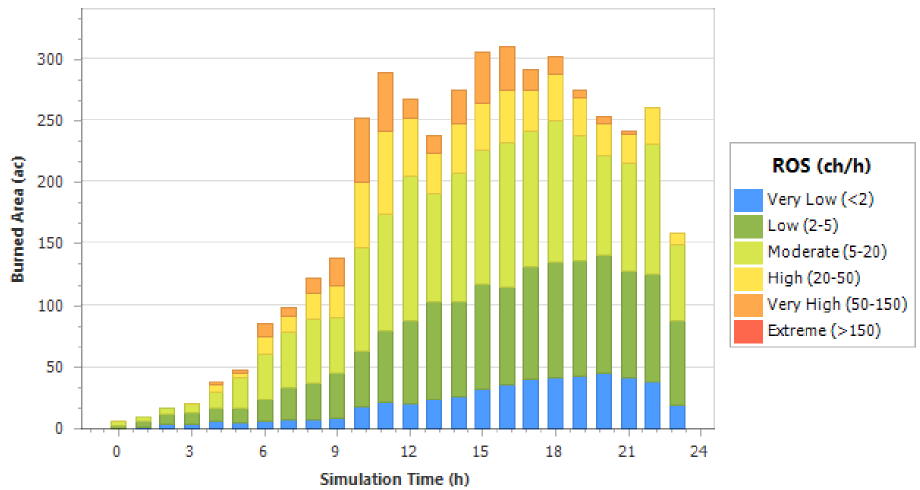
DAMAGE INCIDENT NO. 2 : PROBABILISTIC SIMULATION



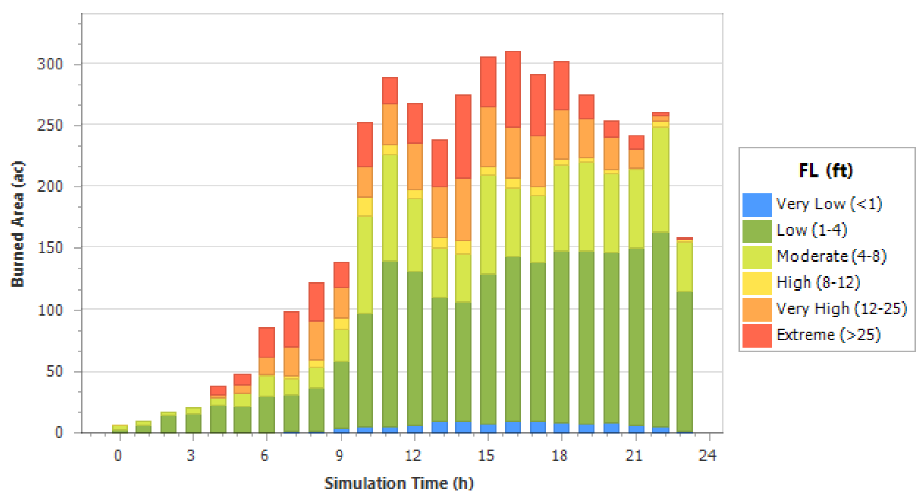
DAMAGE INCIDENT NO. 2

FIRE BEHAVIOR

Rate of Spread

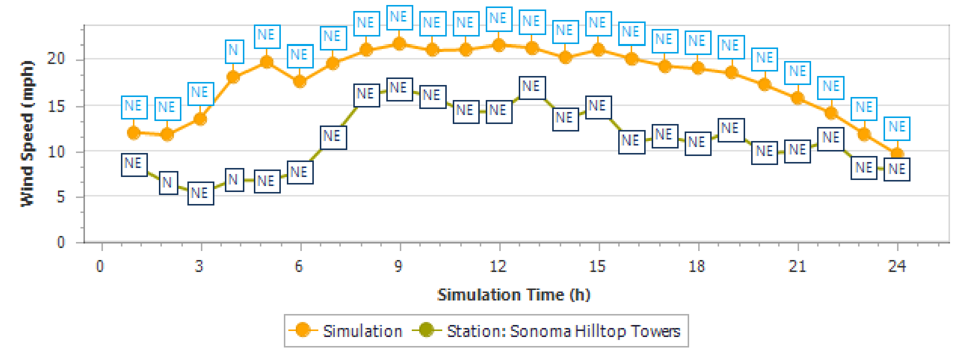


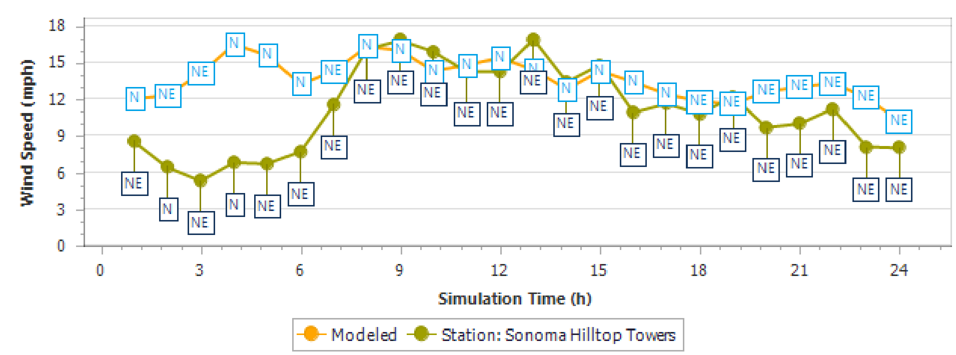
Flame Length



WEATHER **Nearest Station:** Sonoma Hilltop Towers

Station ID - PG593
Weather station (Wx) elevation - 2530 ft
Fire ignition point (IP) elevation - 509 ft
Distance between Wx and IP - 2.28 mi



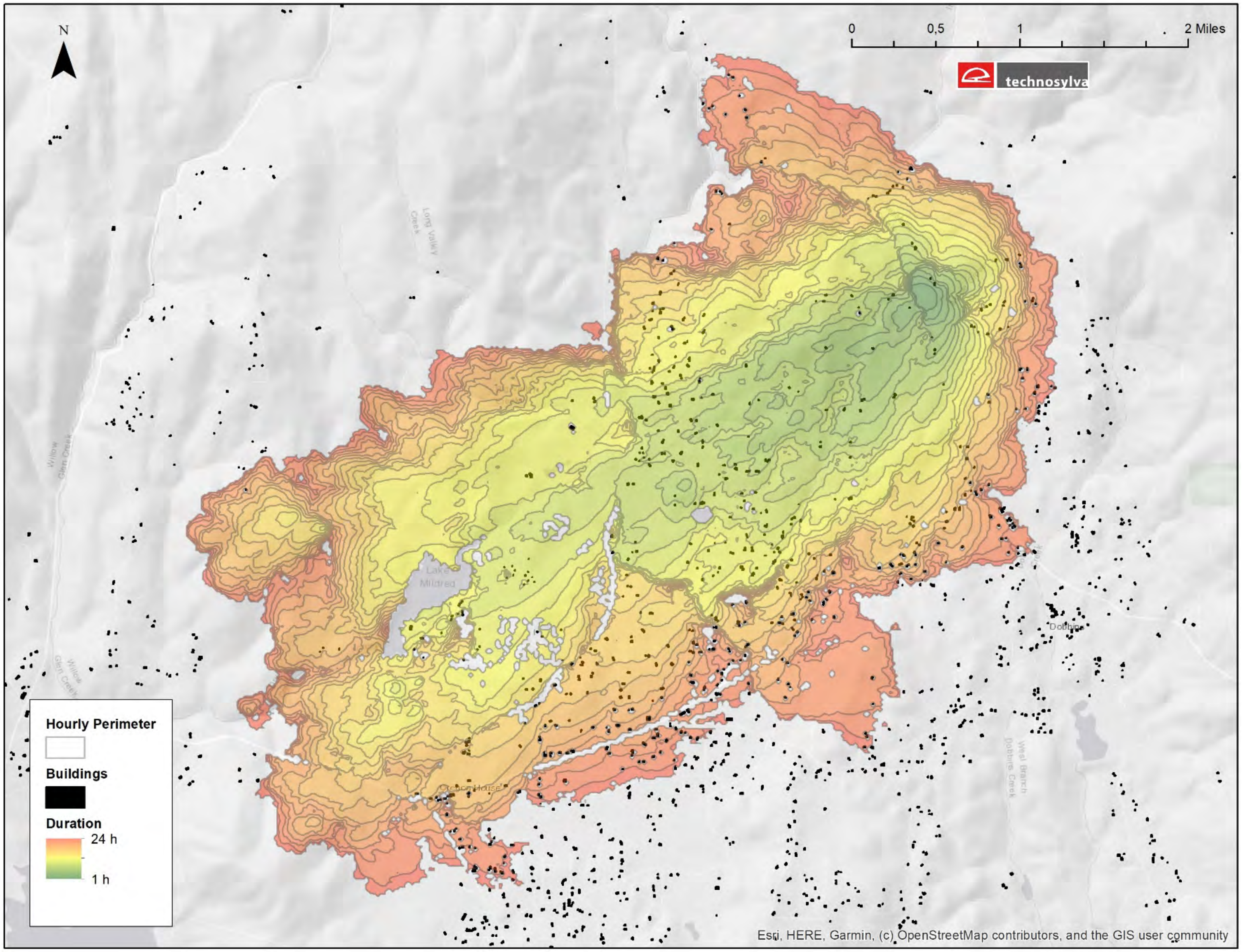


DAMAGE INCIDENT – 3

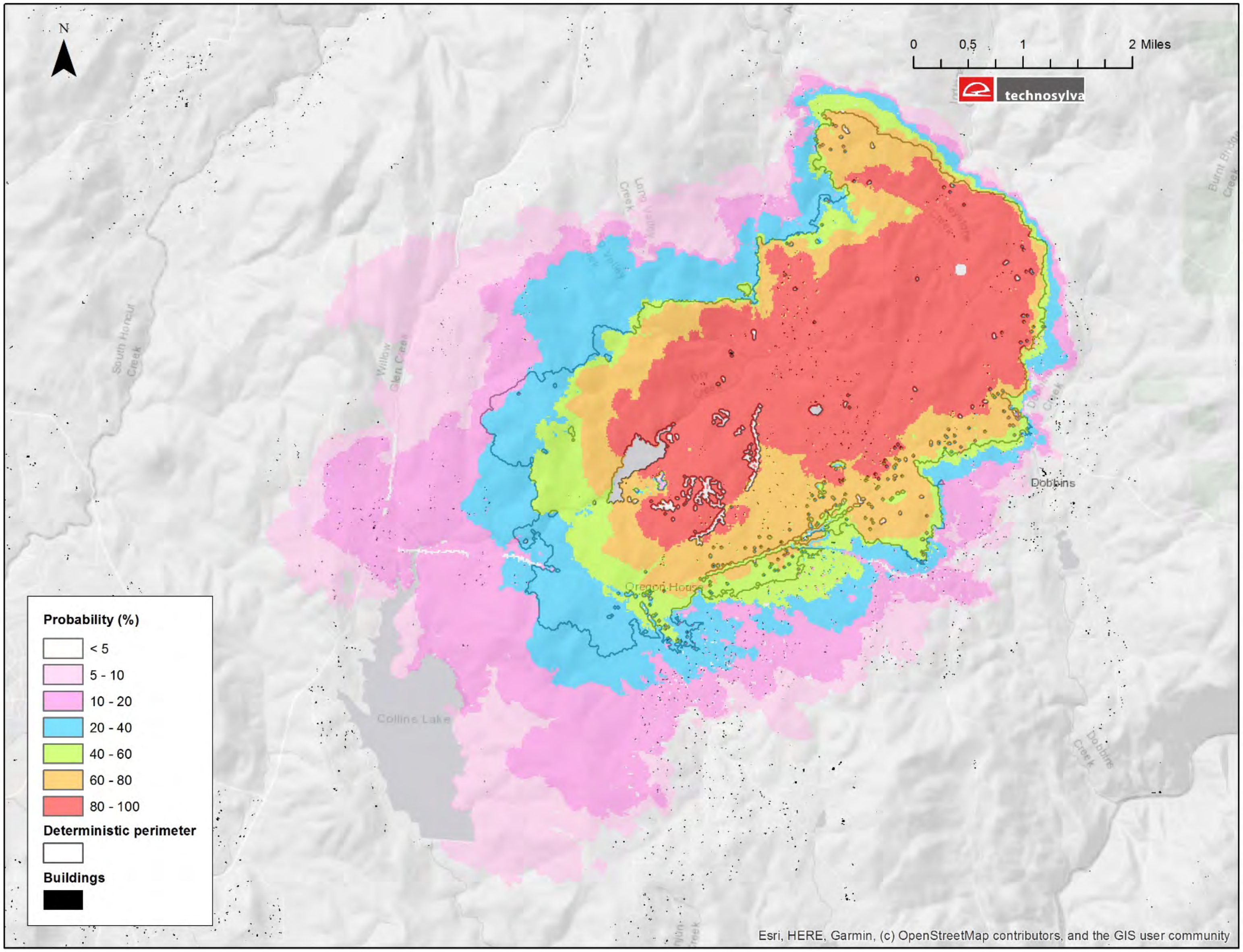
This incident is located in Yuba county. It would be a wind-driven (20 mi/h) on grass-shrub fuels with moderate rate of spread and moderate spotting speeding up the fire propagation. The IAA is moderate (2) but the rate of spread would increase after three hours after the fire start, making difficult the fire suppression activities. The fire impact on population could be very moderate as shown in the summary table given a high ember exposure in all scattered buildings located in all the landscape. The area was burned by many historical wildfires such as the Williams fire in 1997 (5,837 ac). Modeled wind speed was similar to the weather station at the same coordinates and the ignition point.

INCIDENT SUMMARY	
Start Time	10/23/19 - 16:00
Duration (hrs.)	24
Size (ac)	8,593
Initial Attack Assessment	2 - Moderate
No. of Buildings	392
Total Population	595
Average ROS	Moderate

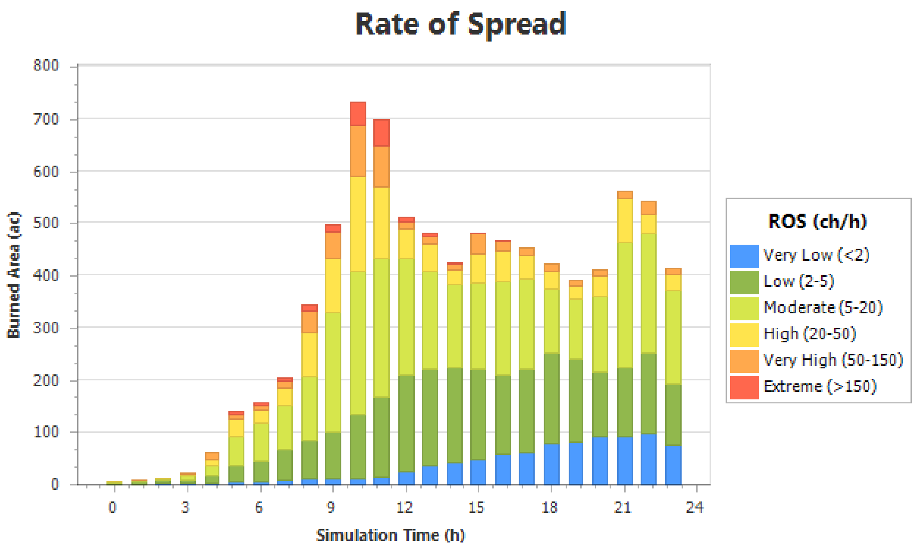
DAMAGE INCIDENT NO. 3 : DETERMINISTIC SIMULATION



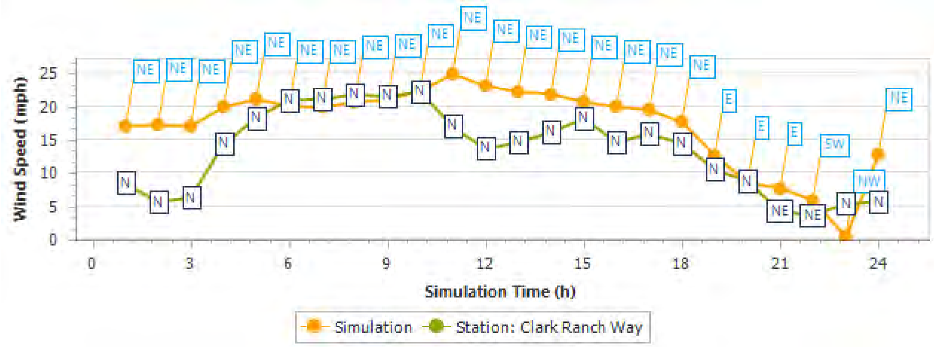
DAMAGE INCIDENT NO. 3 : PROBABILISTIC SIMULATION

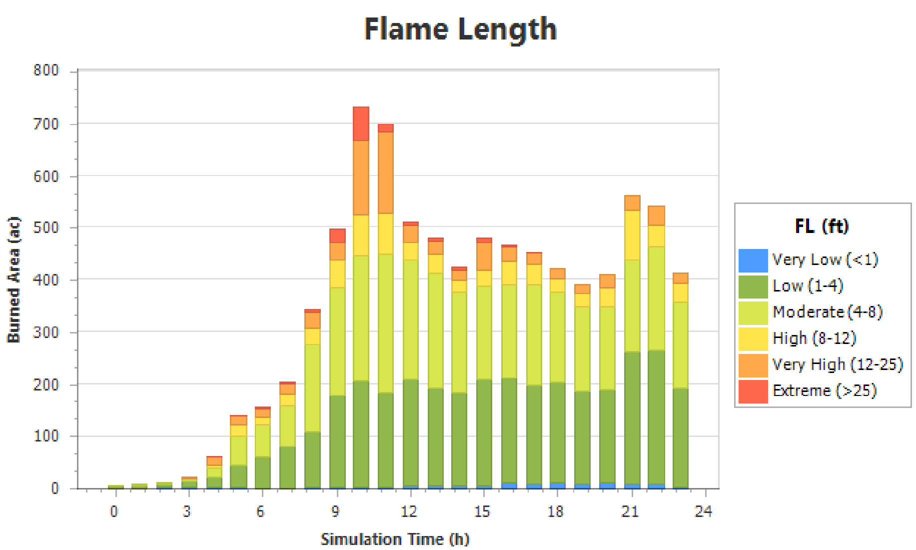


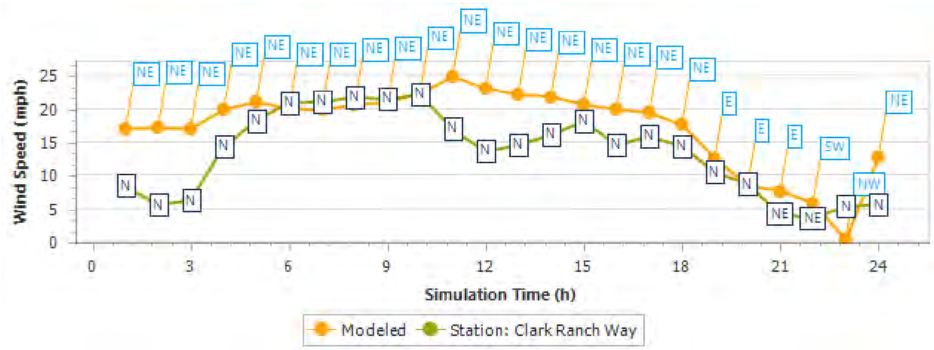
DAMAGE INCIDENT NO. 3	
FIRE BEHAVIOR	**WEATHER** **Nearest Station:** Clark Ranch Way



Station ID - PG593
Weather station (Wx) elevation - 2530 ft
Fire ignition point (IP) elevation - 509 ft
Distance between Wx and IP - 2.28 mi





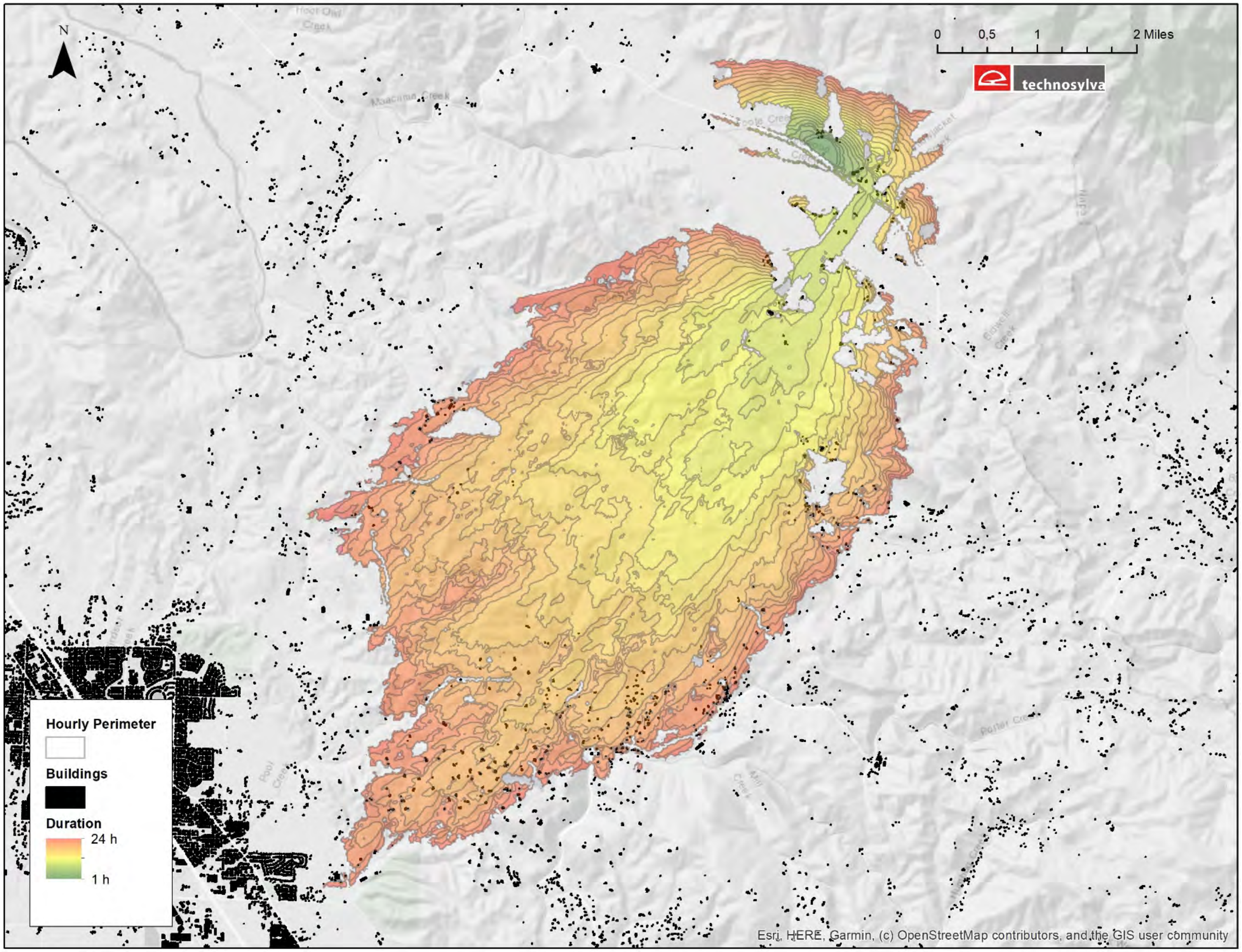


DAMAGE INCIDENT – 4

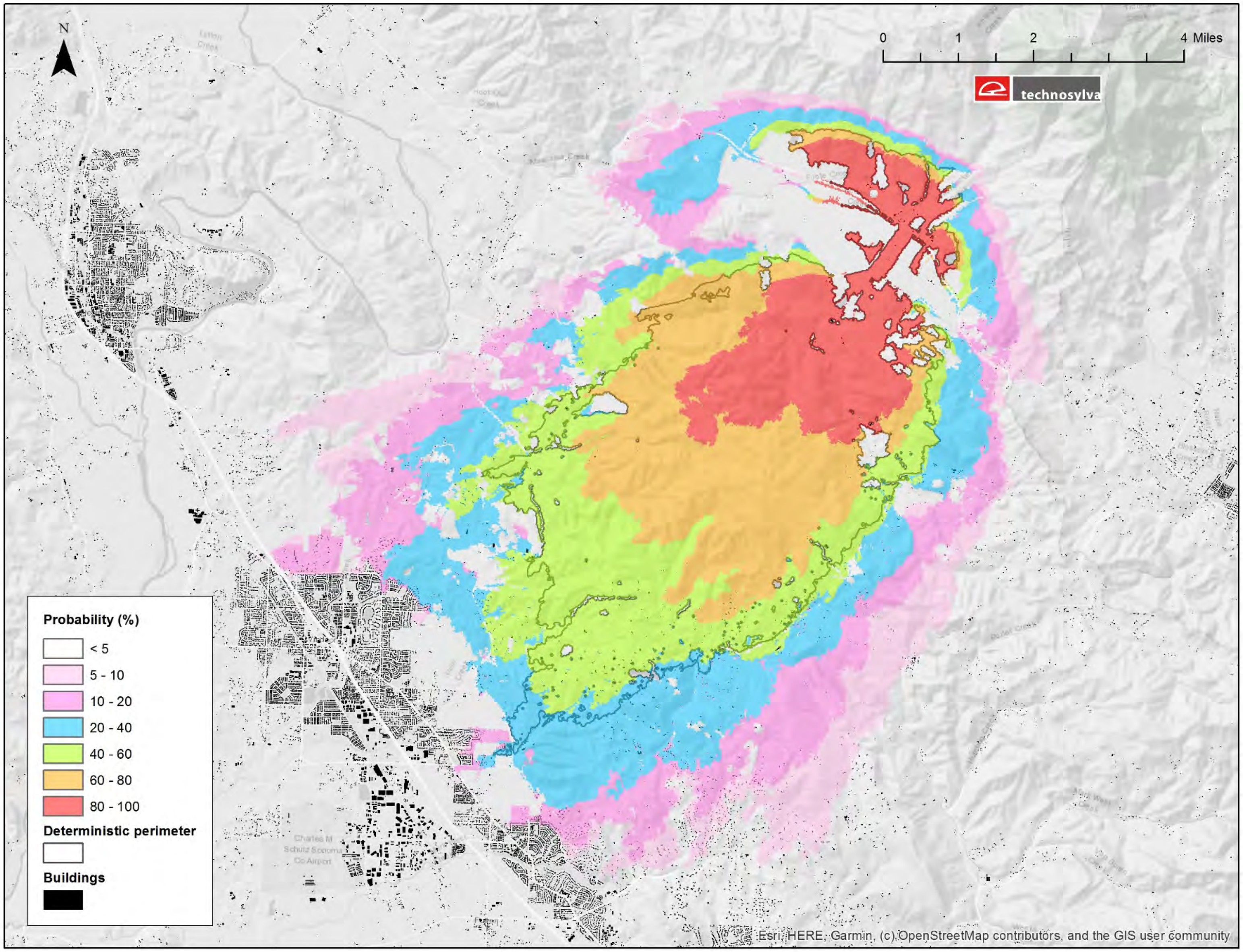
This incident is located near Calistoga in Sonoma County. The fire could similarly spread to the Tubbs fire (2017) given the similar fuels and wind-topography alignment. However, predicted wind speed by models and measured at weather station were significantly lower than in the Tubbs fire, decreasing the huge rate of spreads recorded in that fire. Here, the models predicted a higher wind speed than recorded in weather stations. The fire could impact scattered buildings throughout the fire progression and potentially reach the urban area of Windsor based on the probabilistic fire simulations.

INCIDENT SUMMARY	
Start Time	10/23/19 - 15:00
Duration (hrs)	24
Size (ac)	15,290
Initial Attack Assessment	3 - High
No. of Buildings	411
Total Population	526
Average ROS	Moderate-High

DAMAGE INCIDENT NO. 4 : DETERMINISTIC SIMULATION



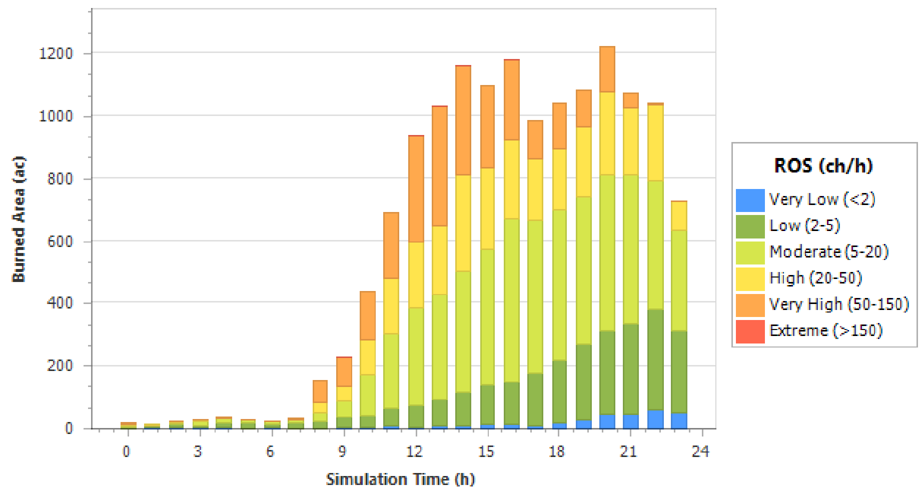
DAMAGE INCIDENT NO. 4 : PROBABILISTIC SIMULATION



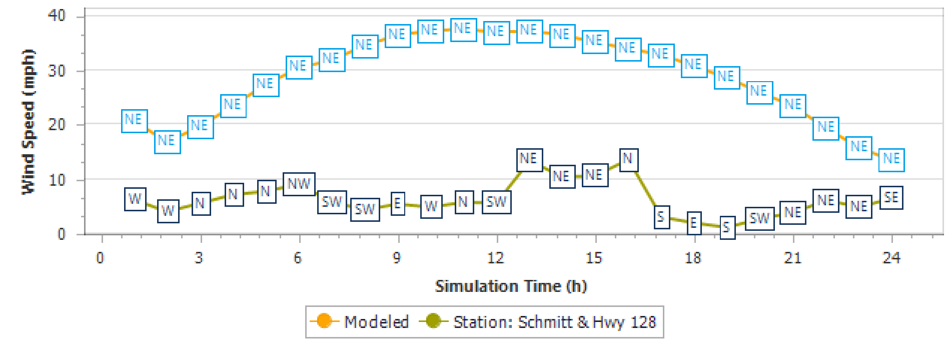
DAMAGE INCIDENT NO. 4

FIRE BEHAVIOR	WEATHER **Nearest Station:** Clark Ranch Way

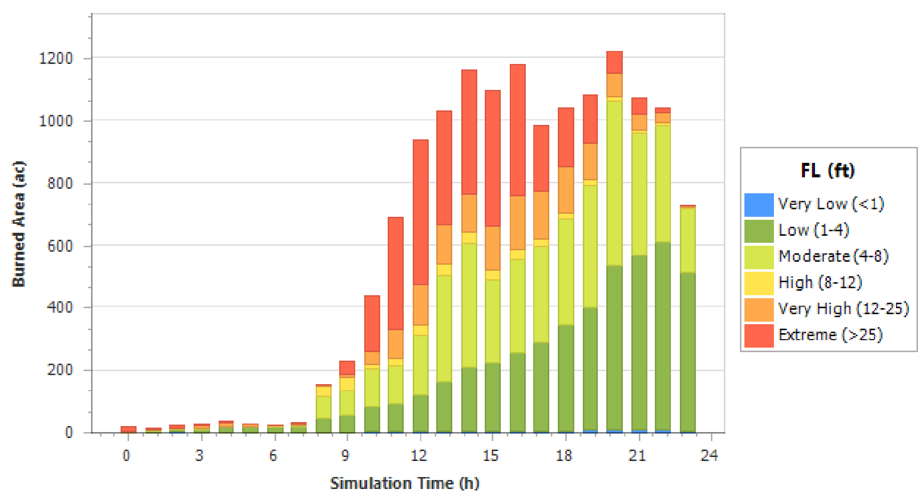
Rate of Spread

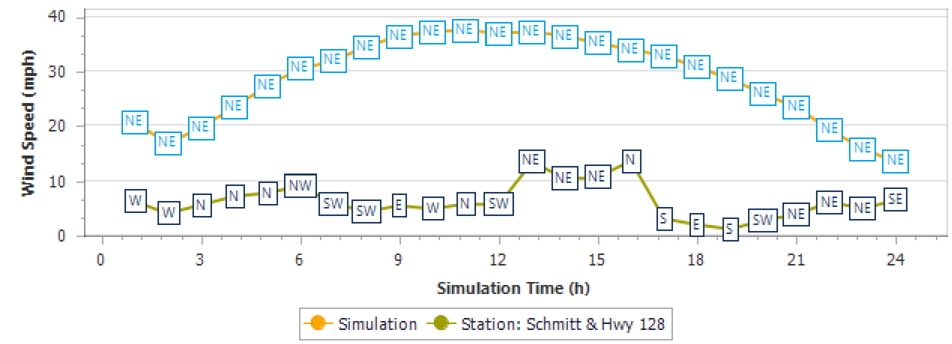


Station ID - PG424
Weather station (Wx) elevation - 300 ft
Fire ignition point (IP) elevation - 489 ft
Distance between Wx and IP - 0.75 mi



Flame Length



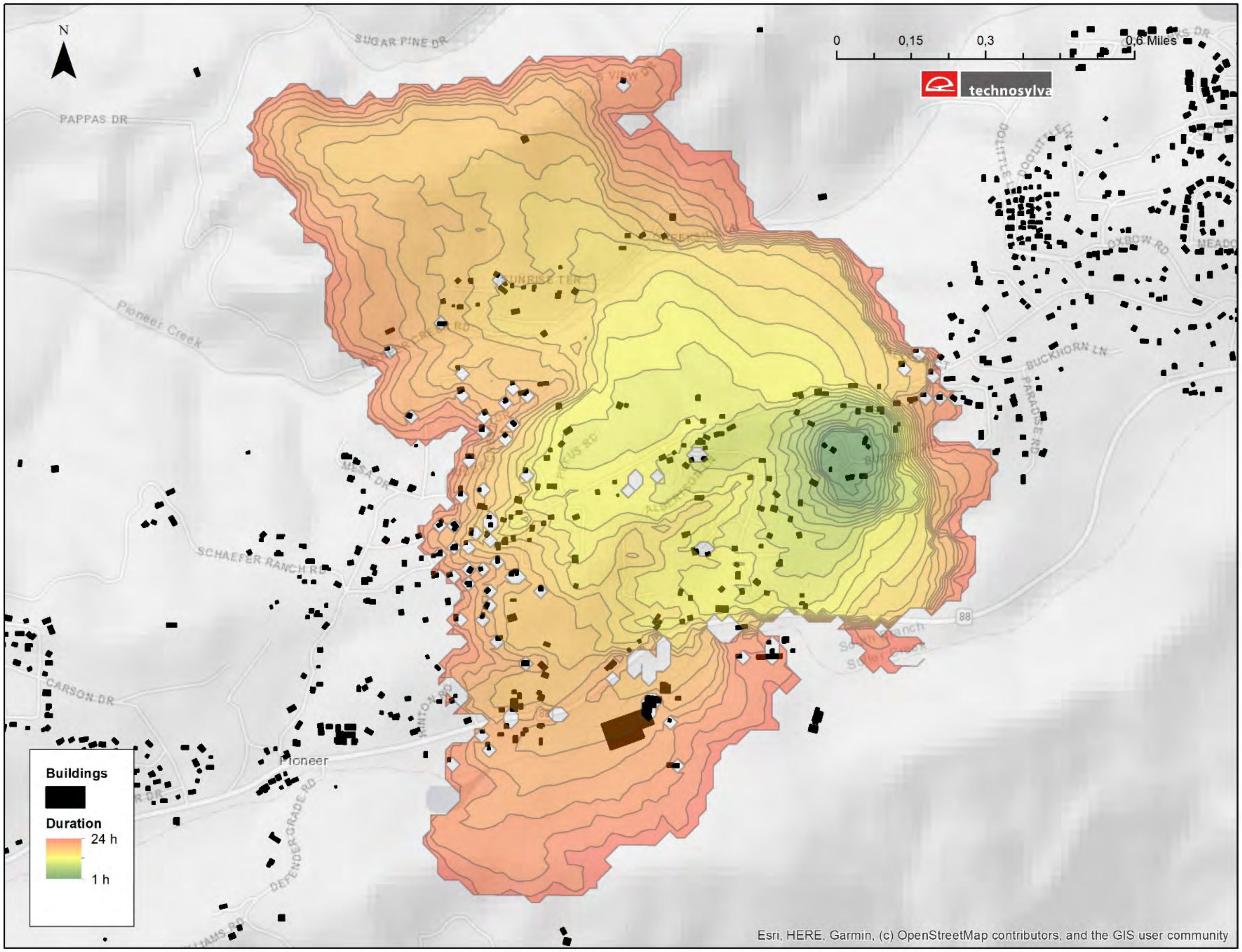


DAMAGE INCIDENT – 5

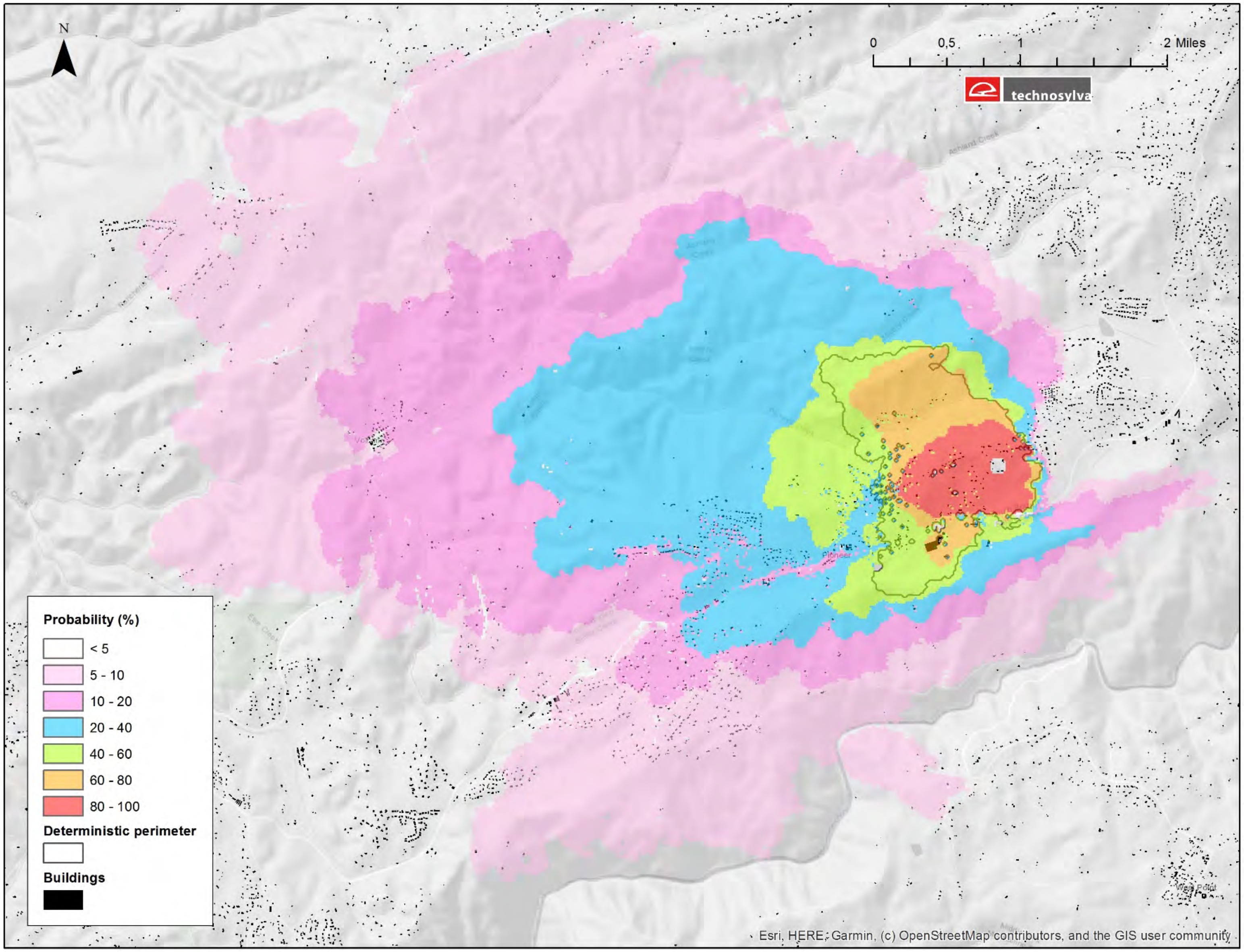
This incident is located near Calistoga in Amador County. The fire would have low rate of spread, fire intensity and, subsequently, low IAA (1). The fire impact on population and buildings would be low-moderate, being affected the isolated and scattered buildings disseminated across the burned area. Anyway, without fire simultaneity, the fire would be easily suppressed by the corresponding fire agency with measured wind speed lower than 10 mi/h at weather station during all fire duration. Modeled wind speed was higher than measured at weather stations.

INCIDENT SUMMARY	
Start Time	10/23/19 - 16:00
Duration (hrs)	24
Size (ac)	937
Initial Attack Assessment	1 - Low
No. of Buildings	145
Total Population	328
Average ROS	Low

DAMAGE INCIDENT NO. 5 : DETERMINISTIC SIMULATION

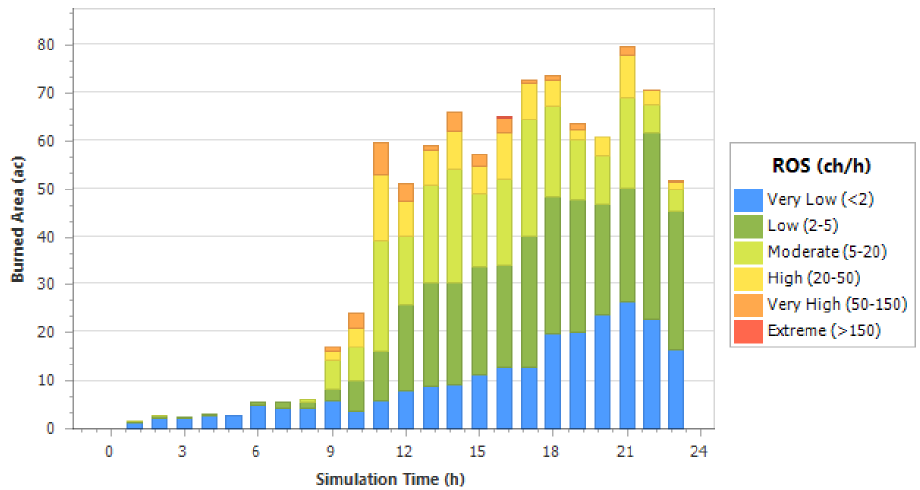


DAMAGE INCIDENT NO. 5 : PROBABILISTIC SIMULATION

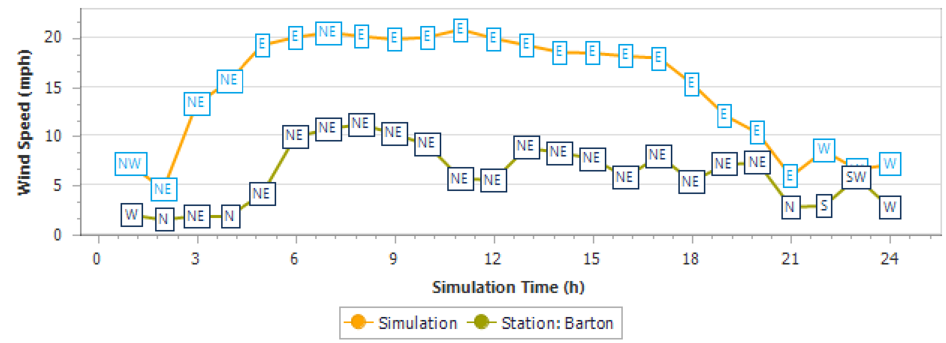


DAMAGE INCIDENT NO. 5	
FIRE BEHAVIOR	**WEATHER** **Nearest Station:** Barton

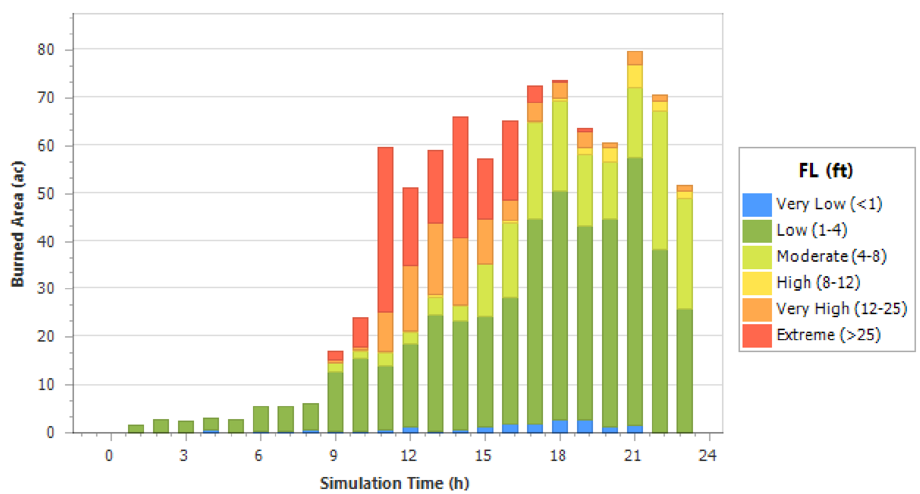
Rate of Spread

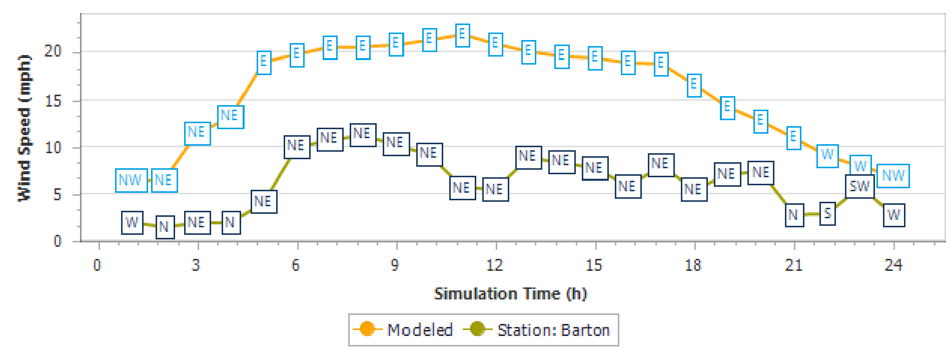


Station ID - PG108
Weather station (Wx) elevation - 3328 ft
Fire ignition point (IP) elevation - 3348 ft
Distance between Wx and IP - 0.58 mi



Flame Length



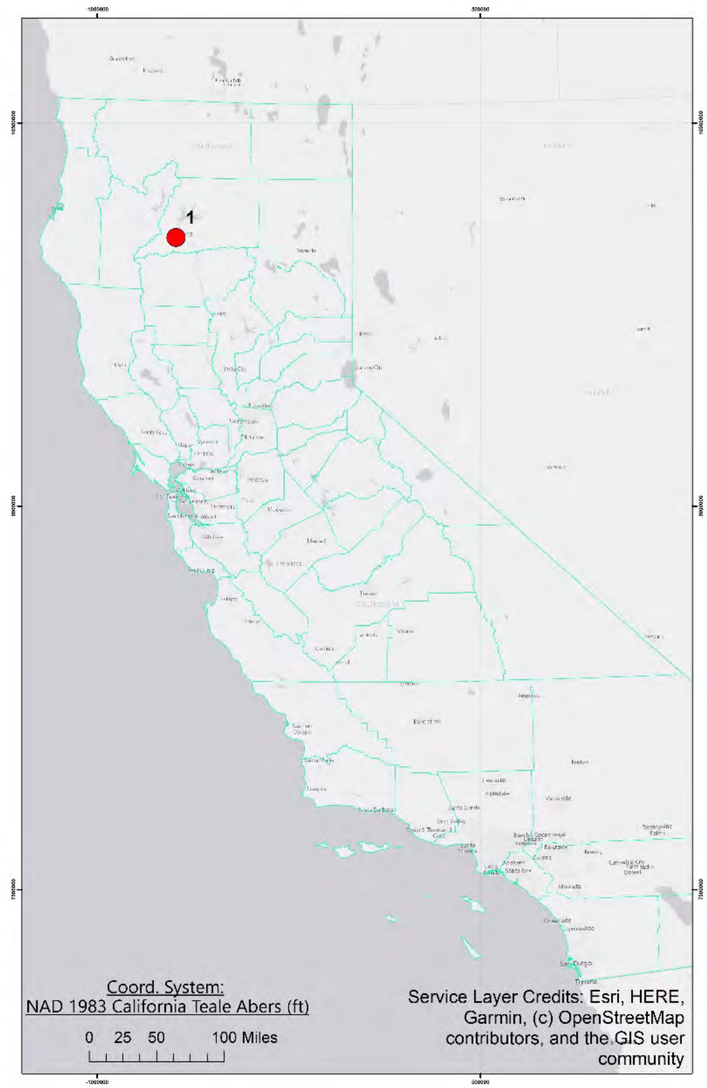


APPENDIX E: NOVEMBER 20-21, 2019 - ANALYSIS OUTPUTS FOR SIGNIFICANT DAMAGE INCIDENTS

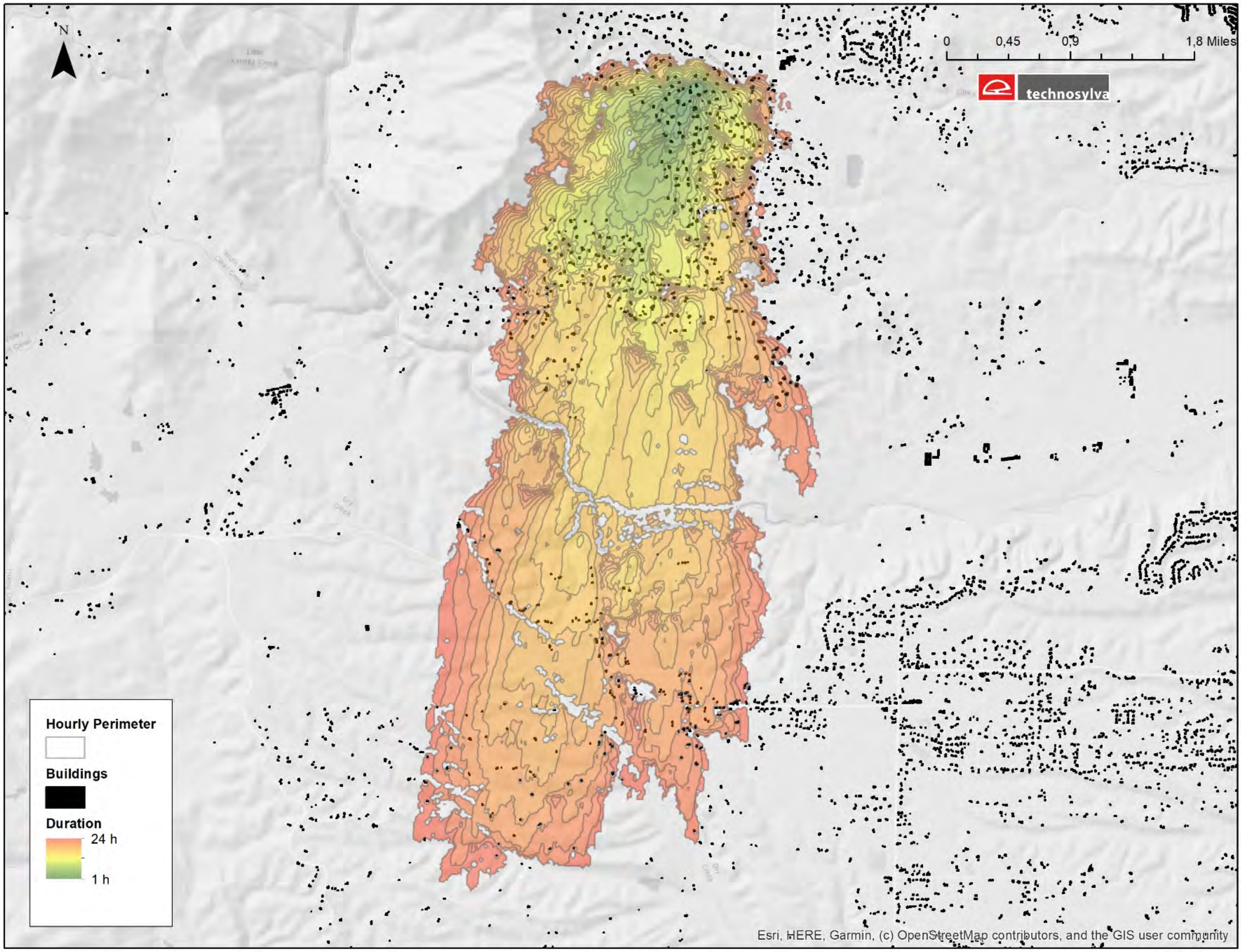
DAMAGE INCIDENT – 1

This incident is located in Shasta County in Northern California, a fire-prone area based on the FRAP CALFIRE Dataset. The fire would start spreading with a low-moderate rate of spread and intensity but impacting lots of scattered buildings. After some hours, the rate of spread would increase meaningfully, speeding up the fire growth with north winds. The probabilistic output shows high variability among single simulations depending on weather that should be considered in operational settings based on wind uncertainty reflected in the weather charts.

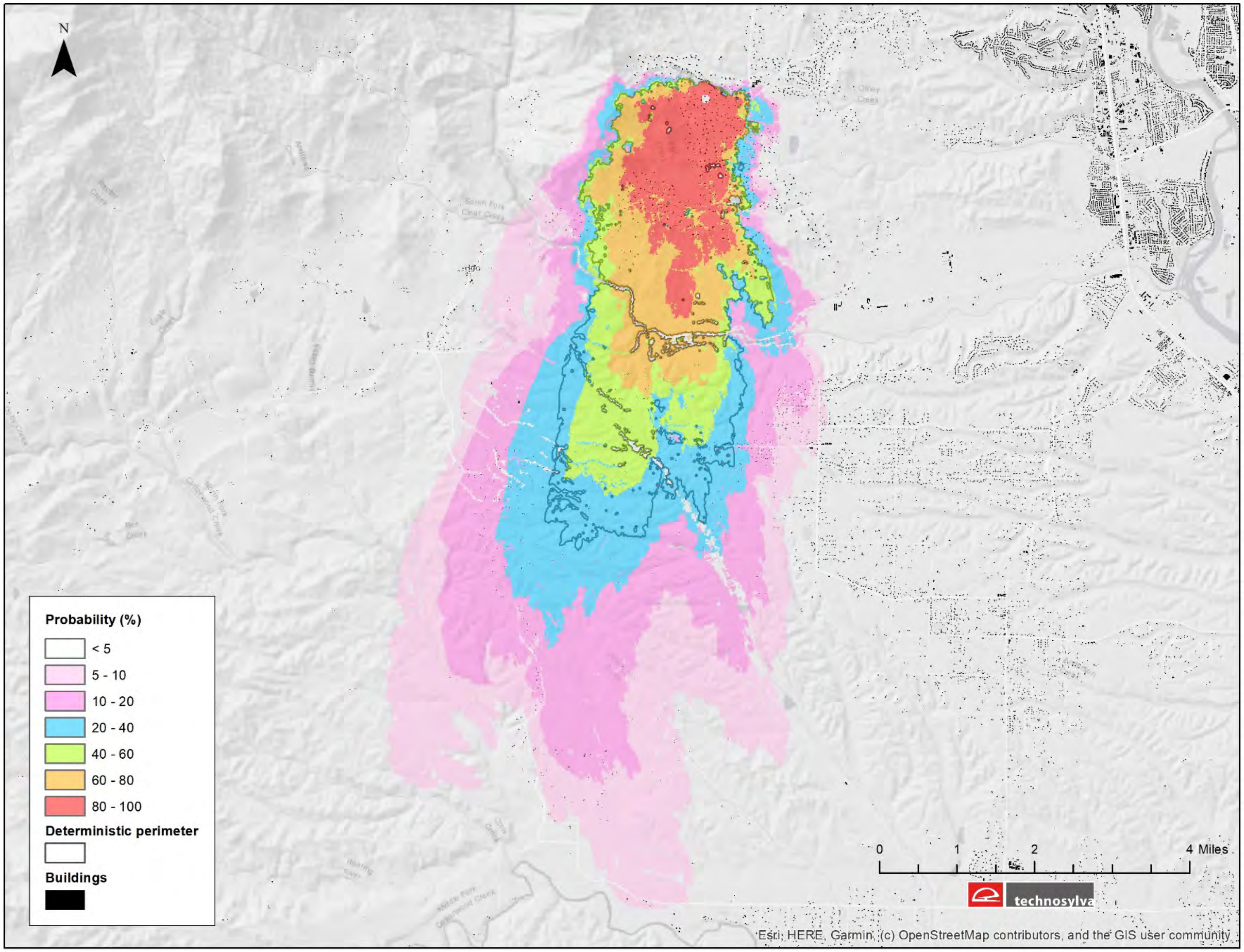
INCIDENT SUMMARY	
Start Time	11/20/19 - 08:00
Duration (hrs)	24
Size (ac)	7110
Initial Attack Assessment	1 -Low
No. of Buildings	549
Total Population	975
Average ROS	Moderate-High



DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION



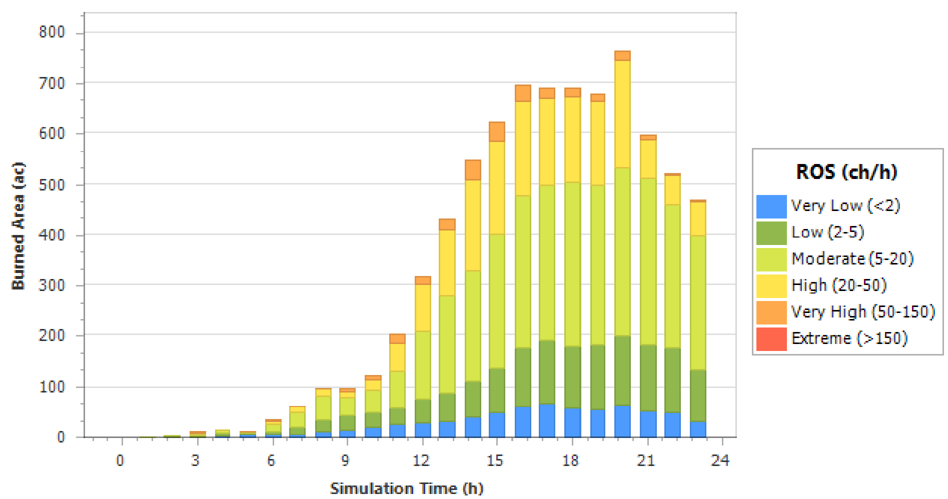
DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION



DAMAGE INCIDENT NO. 1

FIRE BEHAVIOR

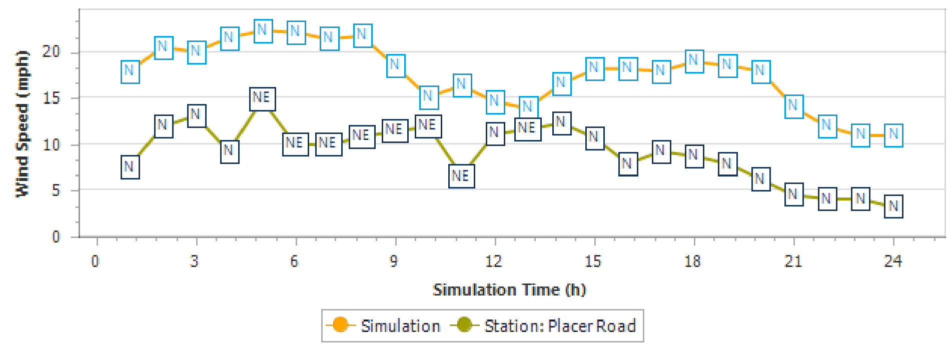
Rate of Spread



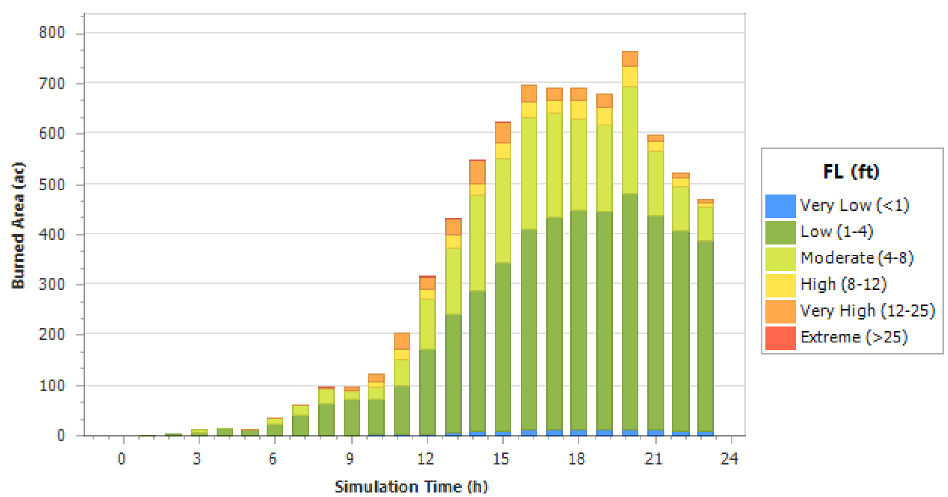
WEATHER

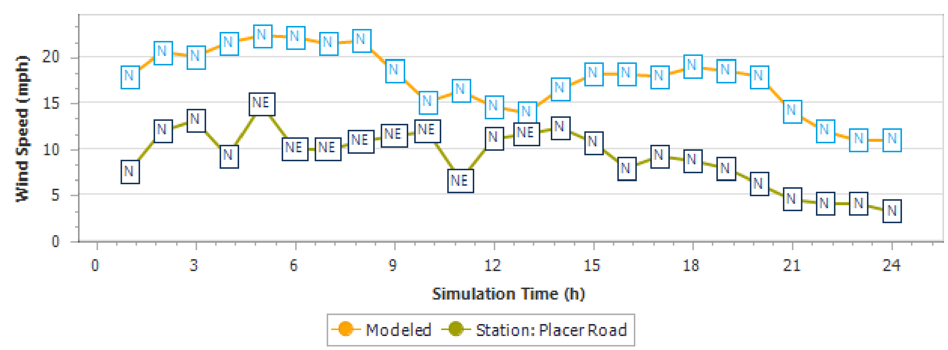
Nearest Station: Mt. Hood

Station ID - PG139
Weather station (Wx) elevation - 2937 ft
Fire ignition point (IP) elevation - 3330 ft
Distance between Wx and IP - 6.66 mi



Flame Length

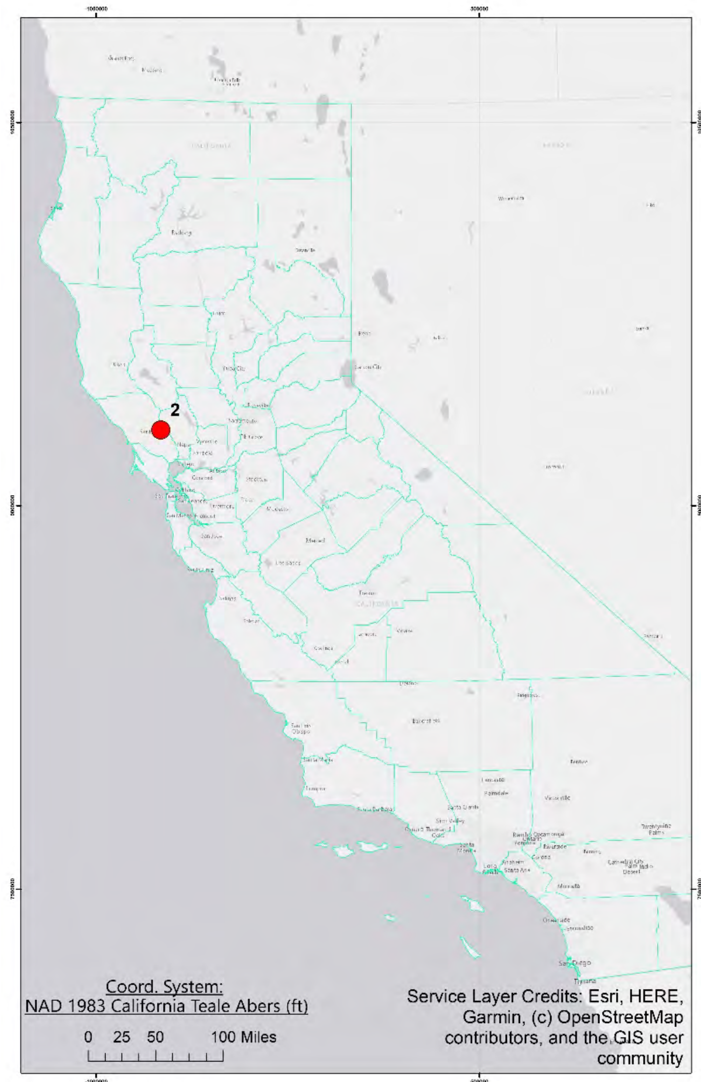




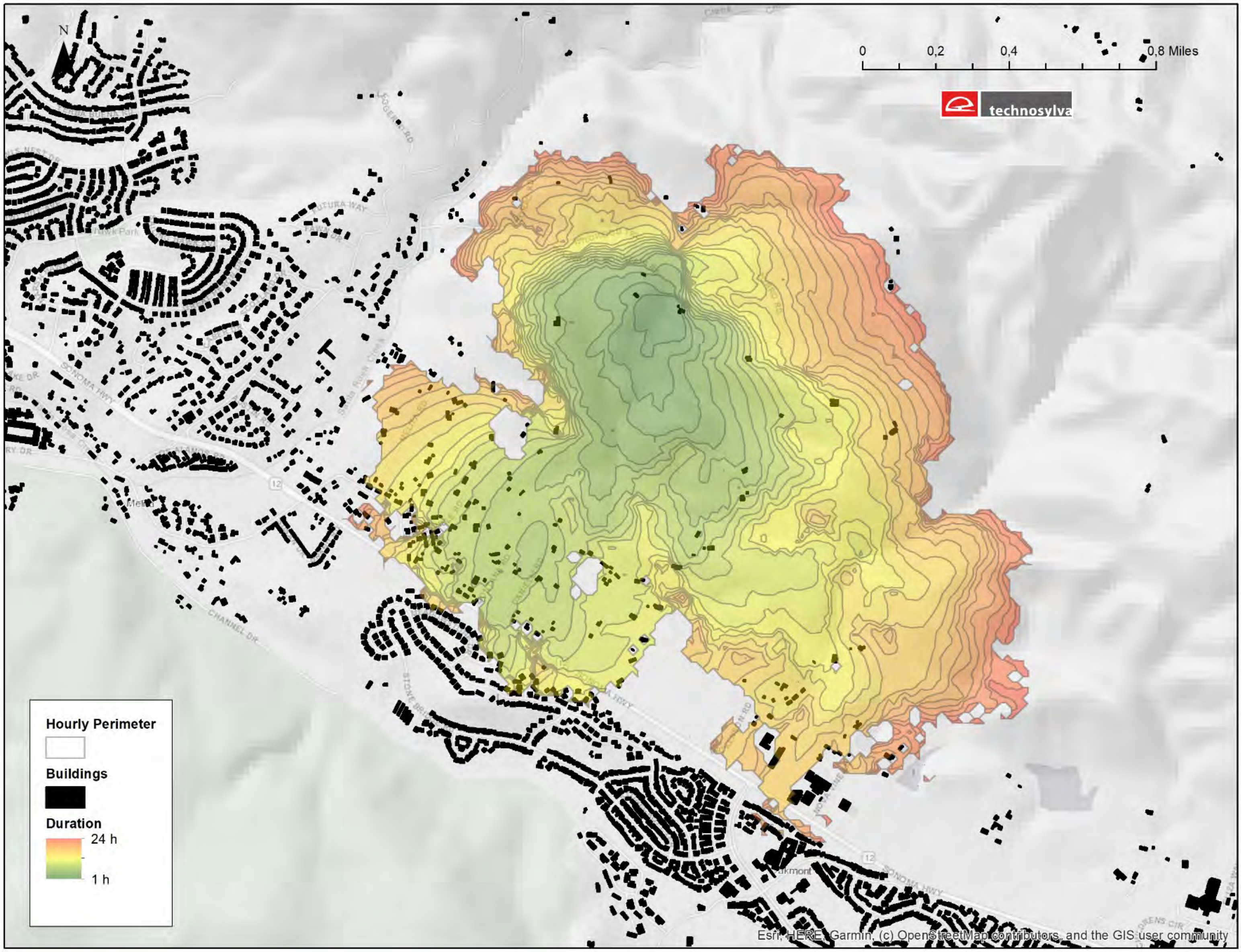
DAMAGE INCIDENT – 2

This incident is located in Sonoma County. The fire would burn a mosaic of forest fuels including timber, shrub and grass areas. The fire would spread rapidly presenting moderate resistance to control with an IAA of 2, impacting a consolidated urban area in a few hours. Throughout the fire progression, the fire could impact some isolated buildings as shown in the maps. Modeled wind speed is mostly consistent with observations at weather station. Near the damage incident location, there were several large fires in the last years: the NUNS (55,797 ac; 2017) and TUBBS (36,701; 2017) fires are two examples.

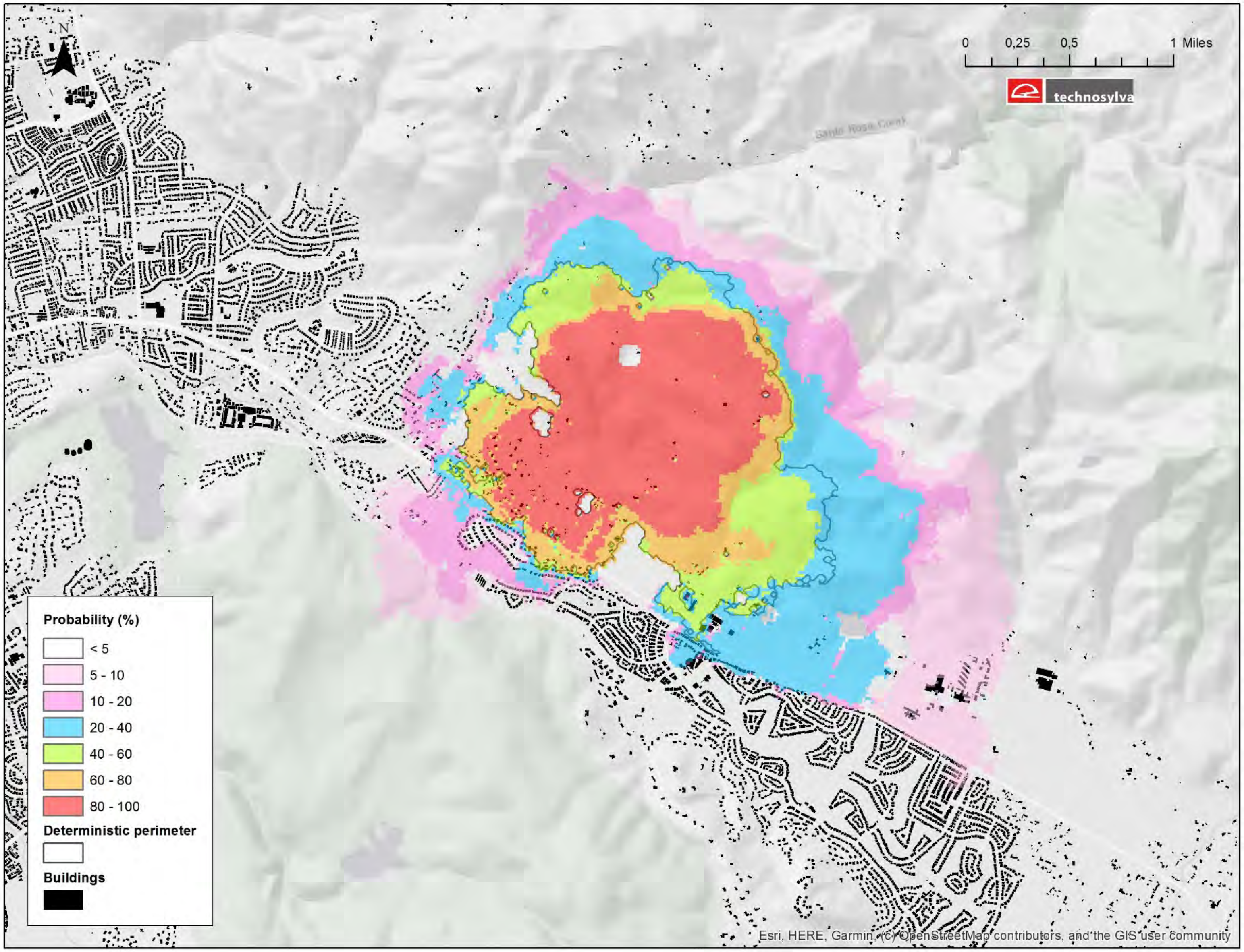
INCIDENT SUMMARY	
Start Time	11/20/19 - 07:00
Duration (hrs)	24
Size (ac)	1,328
Initial Attack Assessment	2 - Moderate
No. of Buildings	202
Total Population	148
Average ROS	Low-Moderate



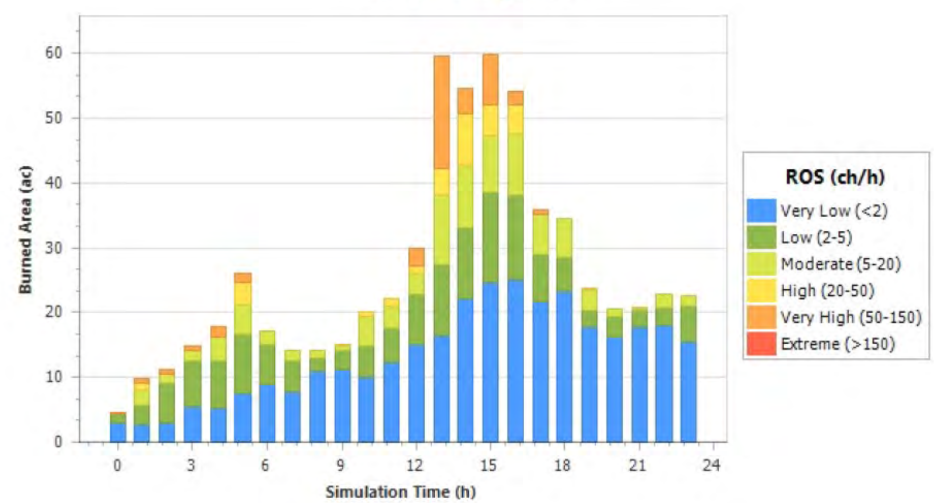
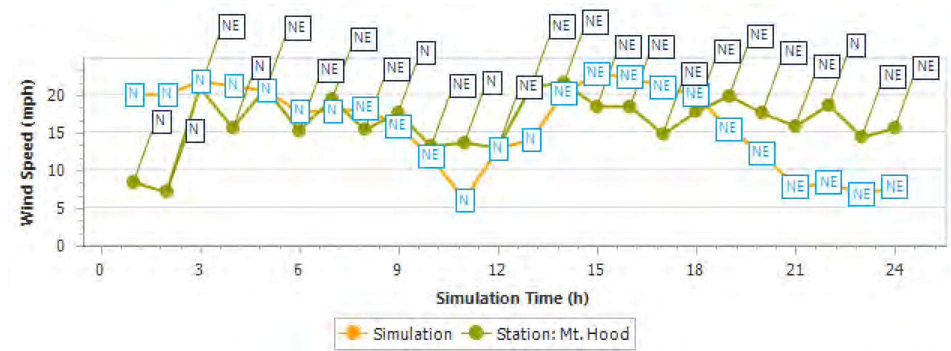
DAMAGE INCIDENT NO. 2 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 2 : PROBABILISTIC SIMULATION



DAMAGE INCIDENT NO. 2

FIRE BEHAVIOR	WEATHER **Nearest Station:** Placer road
Rate of Spread 	Station ID - PG162 Weather station (Wx) elevation - 1939 ft Fire ignition point (IP) elevation - 702 ft Distance between Wx and IP - 4.18 mi 
Flame Length