STATE OF CALIFORNIA GAVIN NEWSOM, *Governor*

PUBLIC UTILITIES COMMISSION
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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 Date: **October 20-November 1, 2019**

IOU: **San Diego 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

October 20–November 1, 2019

San Diego 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.

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

[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.

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 October 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 the PSPS events that occurred in **San Diego Gas and Electric Company's (SDG&E)** service territory from **October 10th to November 1st, 2019**. This involves three separate shutoff events from October 10-11th, October 20th - November 1st, and November 17-18th, 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. This damage incident data is compiled from IOU field inspections on asset infrastructure after the PSPS event occurred. Note that damage incidents were only identified by SDG&E for the PSPS event from October 20th to November 1st, and accordingly, this report analyzes those incidents only.

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 does not consider suppression activities during the simulated fire spread and, therefore, the final fire impact could be less than calculated. Also, note that the fire modelling 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 buildings.

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

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

2. OVERVIEW OF PSPS EVENT

As damage incidents were only identified for the October 20th to November 1st PSPS event, the report only focuses on this event. Between October 20 and November 1, 2019, SDG&E's Emergency Operations Center (EOC) implemented two Public Safety Power Shutoff (PSPS) events in order to mitigate catastrophic wildfire damage presented by significant offshore wind events combined with low humidity levels and critically dry fuels. These PSPS were executed in one phase across different geographic areas as represented in Figure 1. In total, approximately 48,000 customers were impacted. Figure 2 presents the PSPS events for October 10-11 and November 17 in which no damage incidents were identified. These are provided as reference.

SDG&E's EOC was activated at 17:00 on Sunday, October 20, 2019 in response to Santa Ana weather conditions forecast to impact the San Diego region beginning in the late hours of October 20, 2019 and continuing through October 22, 2019. As SDG&E's meteorologists monitored conditions prior to and during the October 20–22 weather event, forecasts showed two successive fire weather events for the region. The second weather event took place October 24–26, and the third took place October 28–November 1. SDG&E's EOC was activated from Sunday, October 20 through Friday, November 1 in response to these three weather events.

The decision to de-energize for public safety was based on numerous criteria as explained below:

- Infrastructure in temporary configurations due to construction activities
- Weather observations in combination with local climatological and vegetation data
- Outages could be targeted to minimize impacts to customers
- Observer reports of imminent threats to power lines, including tree branches encroaching overhead lines, wire movement, debris blown into lines
- Fire-suppression air resources were potentially unavailable due to high winds and time of day should an ignition occur
- Current wildfire activity across the state, including the Kincade Fire, the Getty Fire, the Tick Fire, and the Easy Fire
- Accessibility could be constrained should an ignition occur
- A review of active outages on SDG&E's system

Based on Official National Weather Service (NWS) forecasts leading up to the October 20–22 weather event, SDG&E anticipated increased winds, low humidity levels and warm temperatures. As SDG&E's meteorologists monitored real-time weather, the forecast conditions that would necessitate implementation of PSPS did not materialize as expected. As such, SDG&E did not de-energize any customers during this weather event.

For the other two events, areas impacted by PSPS were experiencing Santa Ana winds and critical fire weather conditions, with wind gusts of 35–50 mph and humidity ranging from 5–10%. Large and damaging fires were occurring north and south of the SDG&E service territory in similar conditions, validating the severity of the fire weather conditions. SDG&E determined that conditions warranted de-energizing certain facilities which might otherwise provide a source of ignition of a fire. The average customer outage duration for the combined events was approximately 30 hours.

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/CPUCWebsite/Content/News_Room/NewsUpdates/2019/Nov.%2015%202019%20SDGE%20ESRB-8%20Report%20for%20Oct.%2020-Nov.%201%202019.pdf

Figure 1. SDG&E October 20-November 1 PSPS event areas.

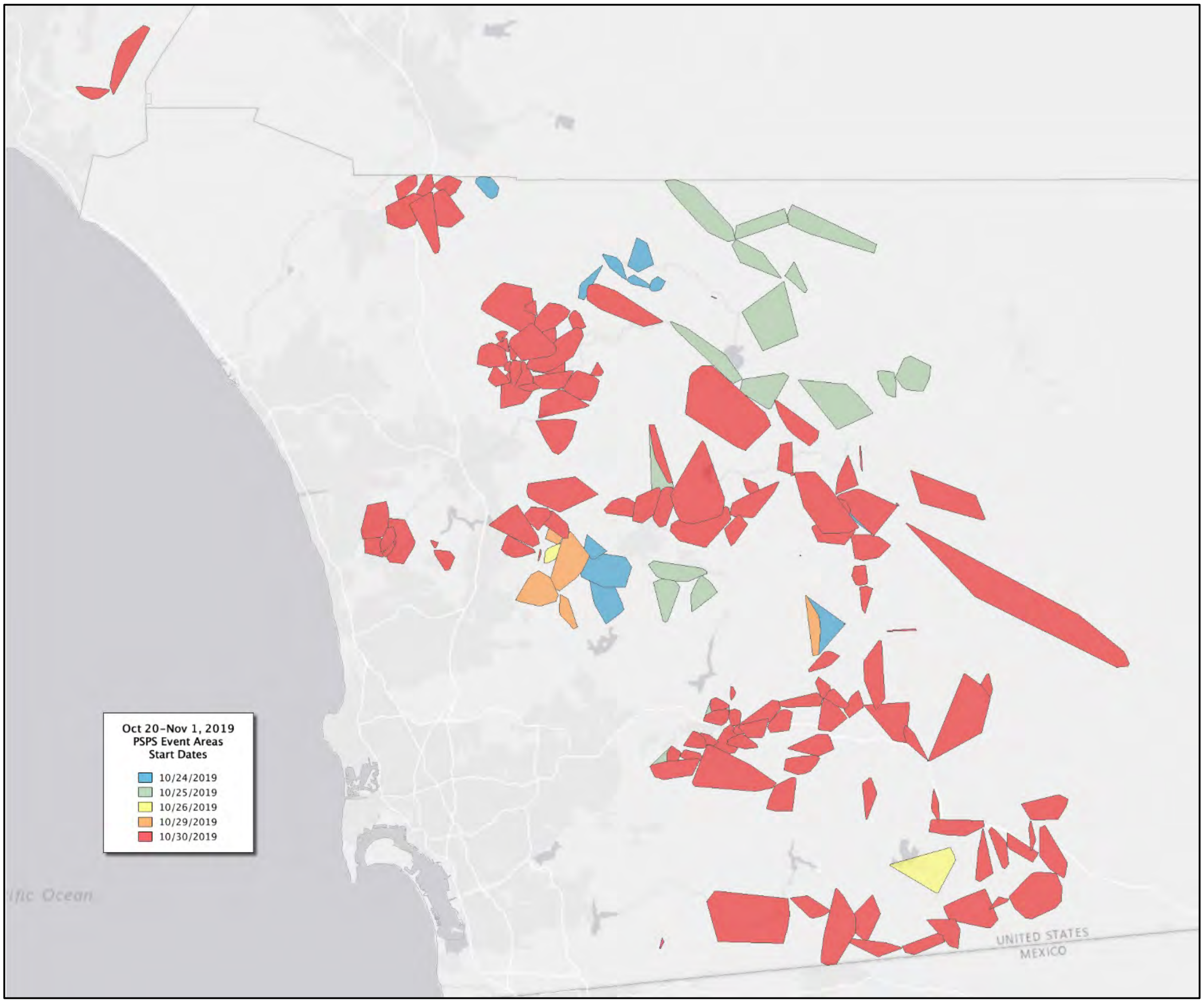
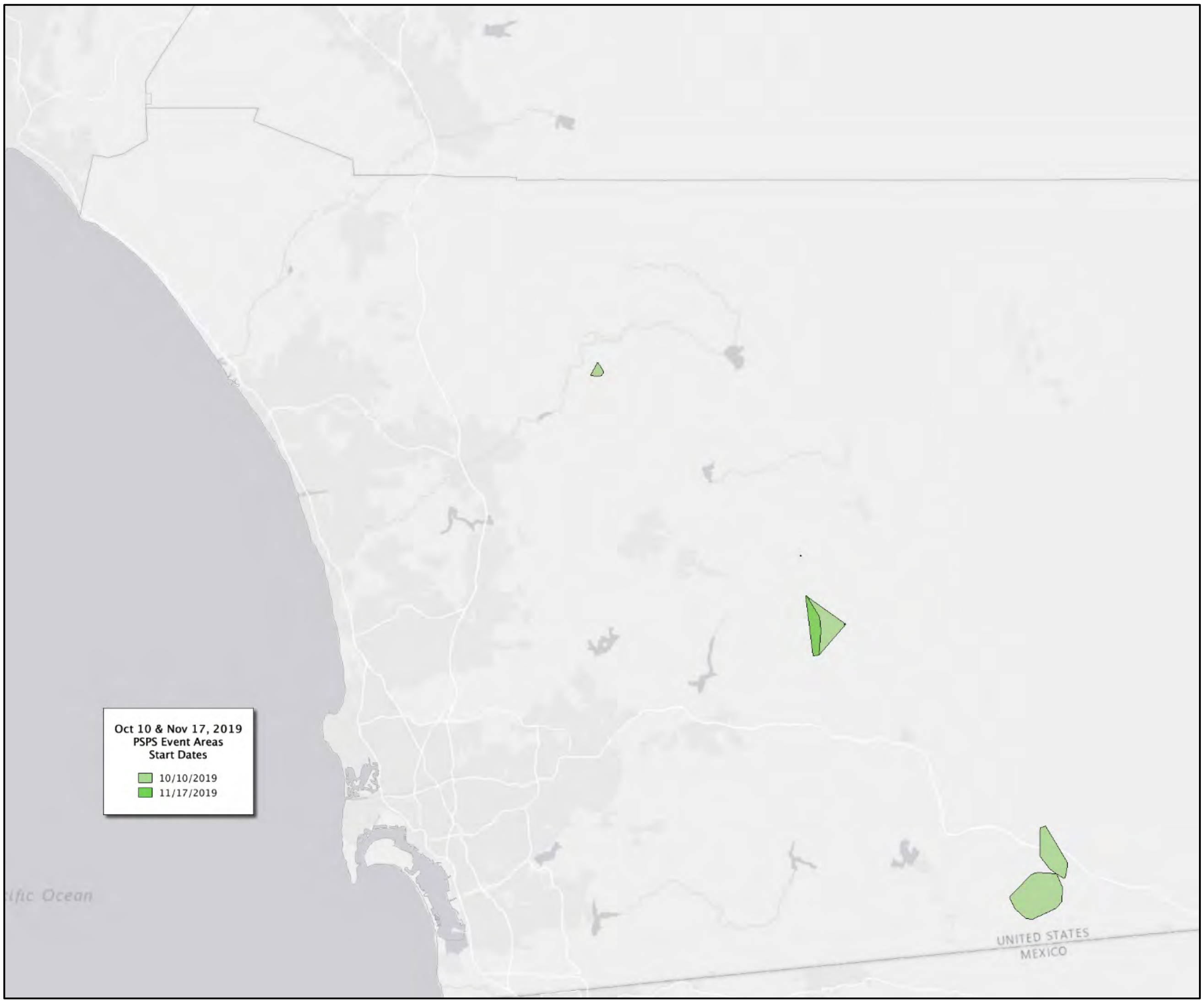


Figure 2. SDG&E October 10 and November 17 PSPS event areas.



3. ANALYSIS OF WEATHER CONDITIONS

3.1 Overview

There were two primary weather events that occurred starting October 24 and October 30. A Santa Ana Wind event occurred during each of these PSPS events. The first event produced more impressive winds, while the second event produced more impressive drying. The situation in San Diego was not characterized by extreme wind strengths, rather it was the extremely dry air that coincided with moderate wind speeds. Surface weather stations used in this analysis are shown in Appendix A. Among these stations, relative humidity (RH) was recorded as low as 1% in the lower elevations for the second event. It should be noted that there is a recognized tolerance for instrumentation error of approximately ±3% with the current technology. This makes verification of 1% RH very difficult, but the data clearly indicate that this event was exceptionally dry. Additionally, this event was drier than all other PSPS events examined. A dry airmass of this capacity is incredibly dangerous with dry fuel conditions and wind speeds less than 10 knots. Sustained wind speeds exceeded 20 knots with gusts over 40 knots concurrent with this exceptionally dry air.

A detailed review of the weather conditions is described in Appendix A.

3.2 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 SDG&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 and speed 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. The modeled values are totally reliable to model the fire progression, especially considering the probabilistic simulations executed for this report dealing with weather uncertainty.

4. SUMMARY OF DAMAGE INCIDENTS

4.1 Data Collection Methods

This report relied upon SDG&E's assessment of damage incidents for ignition potential. SDG&E utilizes an Incident Command Structure (ICS), where the Damage Assessment Coordinator (DAC) is tasked with the collection, logging, and storage of damage found during weather-related or other significant risk events requiring the activation of the Emergency Operation Center (EOC). When an event is capable of being forecasted, the DAC will create an event folder using a standard file structure within SDG&E's EOC SharePoint website. They also create a damage tracking sheet for each unique event, which contains a snapshot of all the damage found. The website has restricted access to only the DAC, Company Utility Commander, and the Critical Information Team. Before, during, and after an event, the DAC receives damage photos from the field crews via email. They take the photos and a description of the damage found and file it on the SharePoint website and update the damage tracking sheet with the corresponding information. The GPS point of the damage is also captured. When the event is over, the DAC goes through the damage found and filters for weather-related items. This damage information is included in SDG&E's PSPS post-event report, which is submitted to the CPUC.

SDG&E utilizes its surplus experience with operating its electric system under extreme conditions to assist with determining which damage type or conditions would likely result in arcing. This experience enables SDG&E to make certain assumptions based on the specific outage cause codes and subject matter expert review. The initial filter is associated with removing underground related outages and forced outages on behalf of safety (i.e., de-energized for safety). After the initial filter, the outages are then scrutinized to verify and validate the potential for arcing utilizing the data within the SharePoint report populated by the DAC. In general, overhead outages that result in a fault requiring the operation of SDG&E's protection system are typically identified as likely having an arcing event.

SDG&E is continuing to develop innovative ways to modify this process and is working on documenting the process to guide this type of review in the future. In addition, SDG&E is considering Information Technology upgrades to enhance the field responses, which would assist with streamlining the analysis for arcing likelihood.

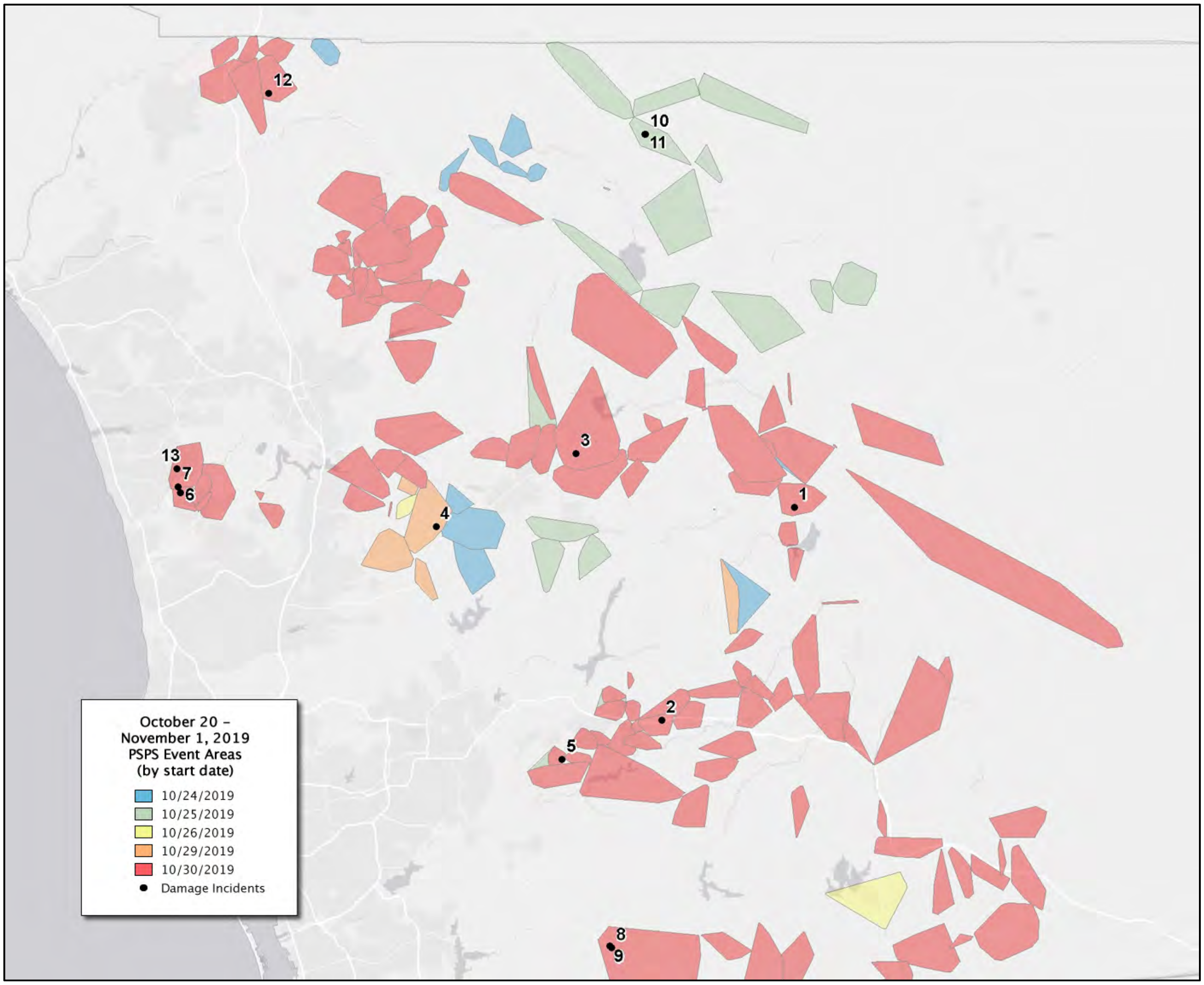
4.2 Description of Damage Incidents

According to the detailed report received from SDG&E and their field inspections, a total of 13 damage incidents were reported by SDG&E for the October 20–November 1 PSPS event, including location and estimated time of damage. All damage incidents were identified by SDG&E as having the potential to ignite a wildfire through electric arcing. Of the fifteen possible ignition points, two of them were located outside PSPS boundaries and were not located on asset de-energized, as identified in data provided by SDG&E. These two incidents were not included in the analysis.

Figure 3 presents the locations of the damage incidents relative to the PSPS event areas. A unique identification number is provided for each damage incident. The numbering of the incidents reflects the ranking of impacts on population derived from the fire spread simulations. For example, the number 1 incident contains the most amount of potential impacts while incident

13 contains the least amount of potential impacts. Impacts are measured in terms of buildings impacted, population impacted and acres burned. Please refer to Section 5 for a detailed description of the analysis methods.

Figure 3. Damage incidents relative to SDG&E PSPS event areas.



5. SUMMARY OF ANALYSIS RESULTS

Fire spread simulations were undertaken for the 13 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 (see Section 5.3). 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.

5.1 Methods Used

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

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
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

5.1.1 Fire Behavior Modeling

Fire simulations were performed with Technosylva's Wildfire Analyst™ software. Wildfire Analyst is a 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.

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[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).

[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.

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 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 duration of all incident fire simulations was 24 hours.

The outputs provided the simulated fire spread and 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.

5.2 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 13 damage incident locations.

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 used for those most significant fire simulations identified through deterministic methods. This accounts for possible variation in key input data providing an enhanced analysis of possible spread and consequence. Please refer to Sections 5.5, Section 5.6 and Appendix B for a description of this approach.

5.3 Defining Ignition Parameters

5.3.1 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 SDG&E from their field inspections.

5.3.2 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 falls on electrical assets. Accordingly, an estimated time of ignition was used for the fire simulations based on the following criteria:

1. Estimated time of damage provided by SDG&E, ensuring the estimated ignition time occurred within PSPS event boundaries.
2. In any instance in which the estimated ignition time was not within the PSPS event boundaries, we adjusted the time 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 13 damage incidents.

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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.

For 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).

5.3.3 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. 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.

Damage incidents and locations are identified by IOU field personnel performing post-PSPS event patrols and reported in post-event reports pursuant to Commission Resolution ESRB-8. This includes supporting documentation comprised of photographs and damage descriptions provided by SDG&E field personnel for each damage location.

SDG&E utilizes its considerable experience with operating its electric system under extreme conditions to assist with determining which damage type or conditions would likely result in arcing. This experience enables SDG&E to make certain assumptions based on the specific outage cause codes and subject matter expert review. An initial analysis removes underground related outages and forced outages on behalf of safety (i.e. de-energized for safety). After this, the outages are then scrutinized to verify and validate the potential for arcing utilizing the data within the SDG&E field report data populated by their Damage Assessment Coordinator. . It should be noted that these determinations are binary, and each damage incident is determined to either likely cause arcing or not. In general, overhead outages that result in a fault requiring the operation of SDG&E's protection system are typically identified as likely having an arcing event.

5.4 Summary of All Damage Incidents

Table 1 shows the number of buildings affected, population impacted, and acres burned for all 13 fire incident locations, after averaging 100 fire simulations during a 24 hour fire duration for each incident location, totaling 1,500 fire simulations conducted. More than 35,112 buildings and 34,471 people may have been affected by fires simulated for the identified damage incidents. Additionally, the fires may have burned approximately 327,277 acres. Predicted fire behavior is high for most of fire simulations, especially in terms of rate of spread, resulting in high to extreme IAAs. Therefore, it seems reasonable that shutdowns were executed based on these results. Note that all of these results do not consider fire suppression.

Note that 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 for SDG&E's decision to shutoff power. This was the purpose of this analysis.

Table 1. Total expected impact, mean and maximum per fire simulation for all 13 damage incident predictions.

Impact Type	Total	Mean	Maximum	Standard deviation
Population	34,471	2,651	10,295	3,080
Buildings	35,112	2,700	11,335	3,122
Acres Burned (ac)	327,277	25,175	96,333	26,465

5.5 Criteria for Selecting Significant Incidents

Once the fire spread prediction analysis was completed for all 13 damage incidents, specific criteria was applied to identify the most significant incidents. Worst cases were identified considering 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 accurately 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 buildings impacts.
4. Initial Attack Assessment index rating – identifies those fires that would likely escape initial attack suppression and would spread quickly.[11]

5.6 Summary of Significant Incidents

Using the criteria described in the previous section, a list of the most significant fire incidents was identified from the 13 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.

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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.

Table 2. List of significant simulated fires for this PSPS event (sorted by population impacted).

Damage Incident Rank	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	San Diego	10,295	11,335	96,333	5
2	San Diego	6,916	5,710	15,713	4
3	San Diego	4,446	4,697	17,905	5
4	San Diego	4,103	3,384	16,796	5
5	San Diego	3,276	3,126	9,108	4

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

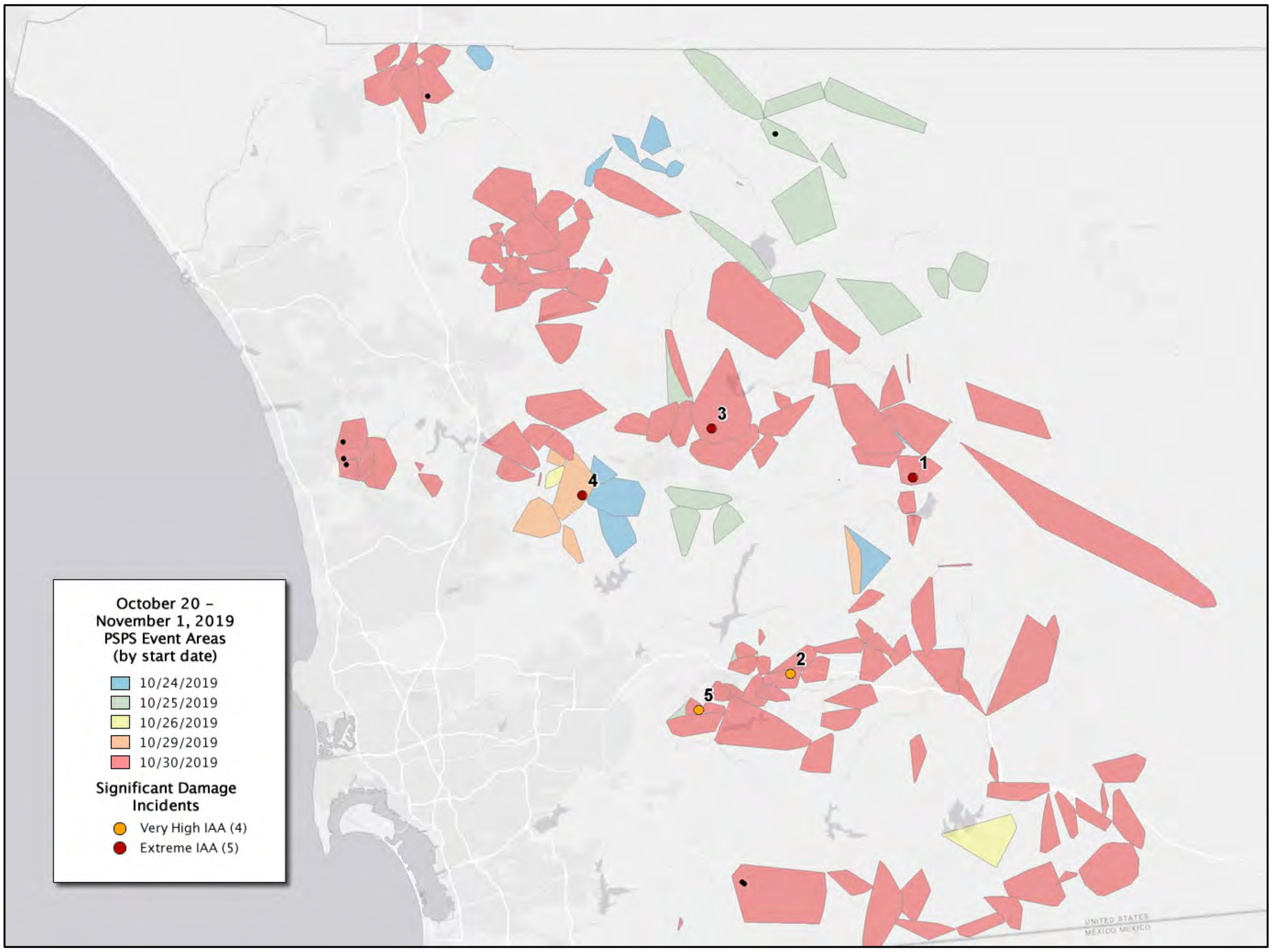
Figure 4 presents a map showing the location of the significant incidents identified in Table 3. Other incidents are shown in smaller **grey** points as reference.

Although large fires usually produce high impacts on buildings, population and the landscape, the ignition location and potential propagation play a key role on determining final impacts.

- The damage incident 1 has the highest impacts for all 3 categories.
- All significant incidents have a high or extreme IAA.

Figure 4 summarizes the population and buildings impacted for the most significant incident simulations.

Figure 4. Map of the significant damage incident locations.



Even though small and medium fires also result in large impacts due to their specific location and proximity of buildings and people, large fires generally had the higher impacts in this analysis as shown in Figure 5 for significant damage incidents.

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. In this analysis, all selected simulations had very high or extreme IAA. However, note that 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. As such, some fires with low-moderate IAA values also had high impacts.

Figure 5. Summary of population and buildings impacted for the significant incidents.

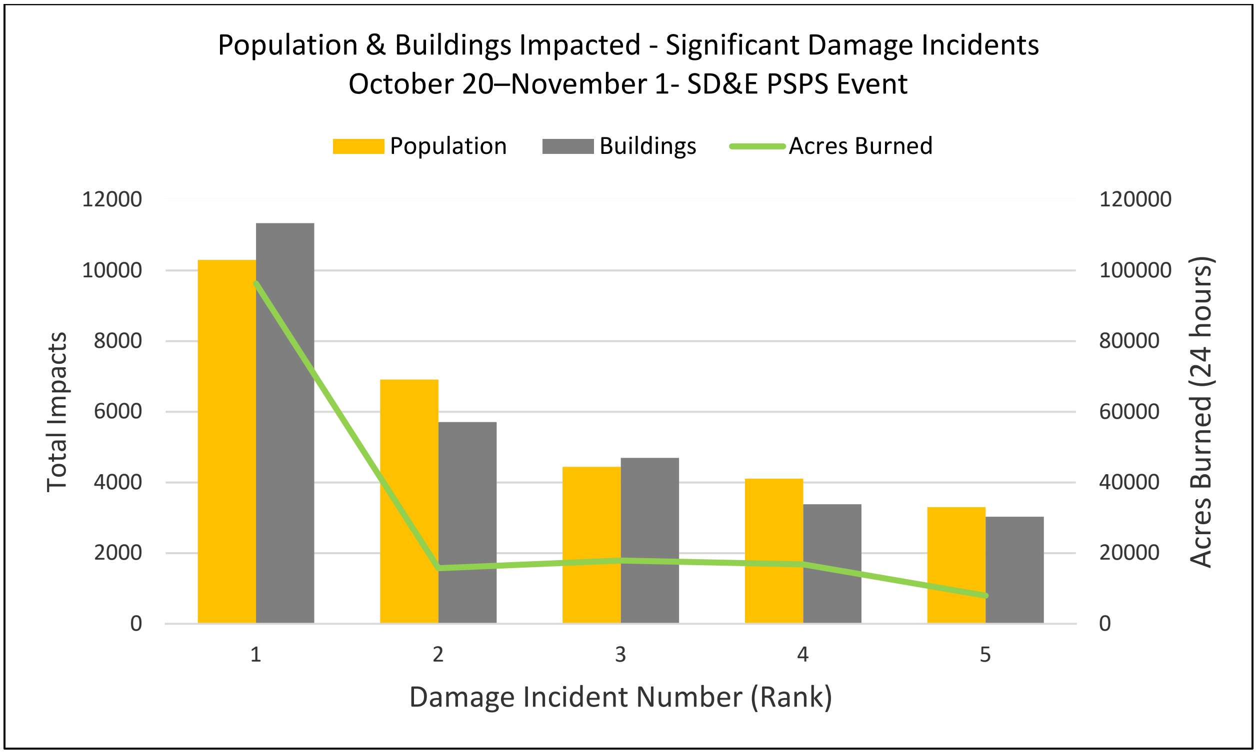


Figure 6 presents the population impacts of each fire simulation for significant damage incidents as a function of size (acres burned). Fires are color coded by IAA. This chart shows that all fire simulations had high IAA index values, resulting in large impacts. These fire simulations are significant from the start and are likely to escape initial attack.

Figure 6. Number population impacts as a function of fire size for the significant incidents. Colors represents IAA values from low (blue) to extreme (red)

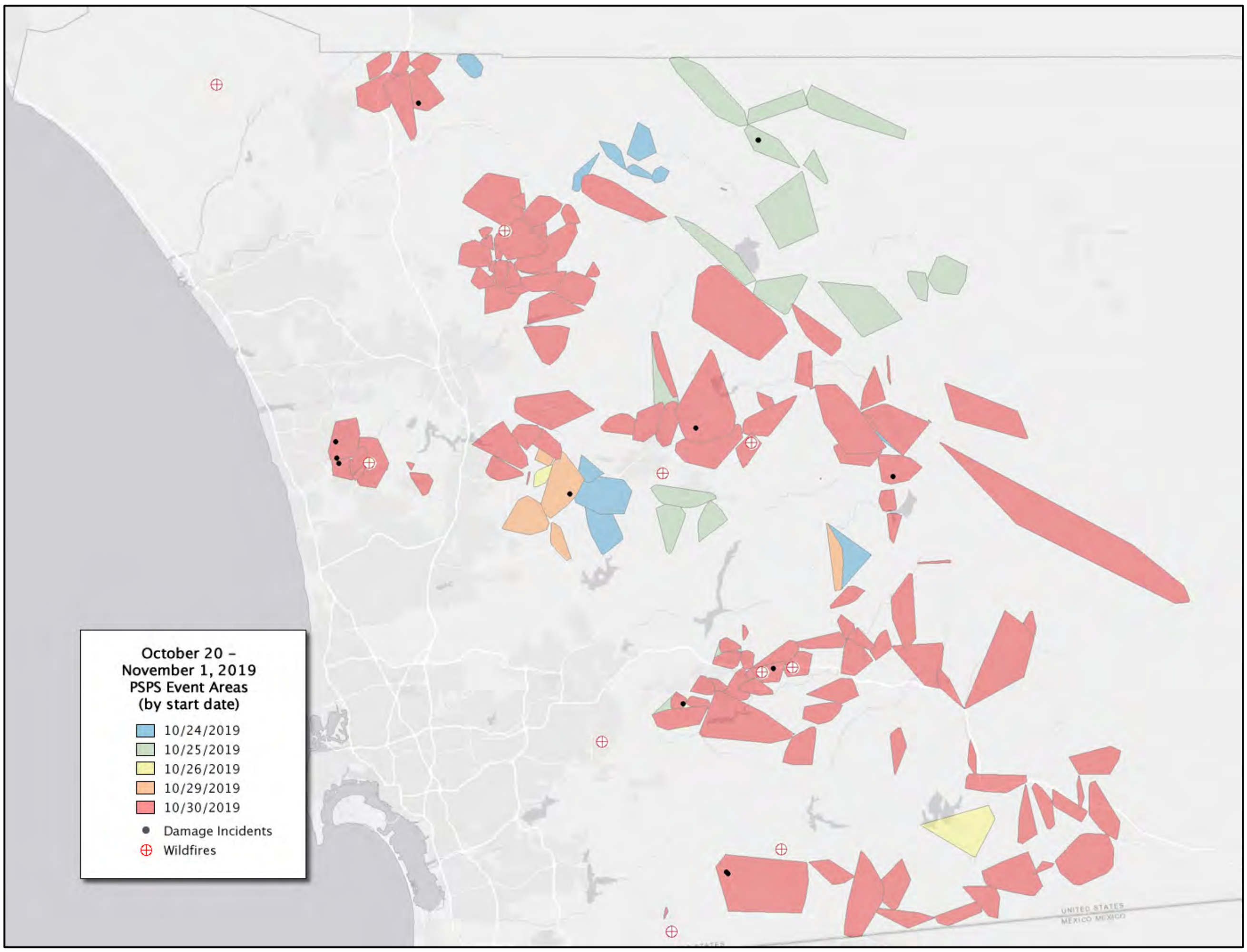
In summary, the following conclusions are reached:

- Generally large fires result in large impacts
- Moderate size fires can also result in large impacts
- Fires with the highest IAA have large burned areas and usually large impacts. This reflects that fires with high IAA are significant from the start.

6. SUMMARY OF ACTIVE WILDFIRES DURING THE PSPS EVENT

This section summarizes the active wildfires that occurred during the PSPS event in California. Five hundred and forty (540) fire incidents were recorded in the Integrated Reporting of Wildland-Fire Information (IRWIN) system from October 20–November 1, 2019 in California. This is considered high fire activity. The October 24 and 29 were the days with more recorded wildfires, coinciding with the incident damage dates of this PSPS event. However, wildfires were less frequent in the SDG&E service territory as shown in the following figure. Only eleven (11) small fires are located inside the PSPS event boundaries during this timeframe. Figure 7 shows all wildfires that occurred during this period along with damage incidents.

Figure 7. Wildfires occurring during the PSPS event.



7. CONCLUSIONS

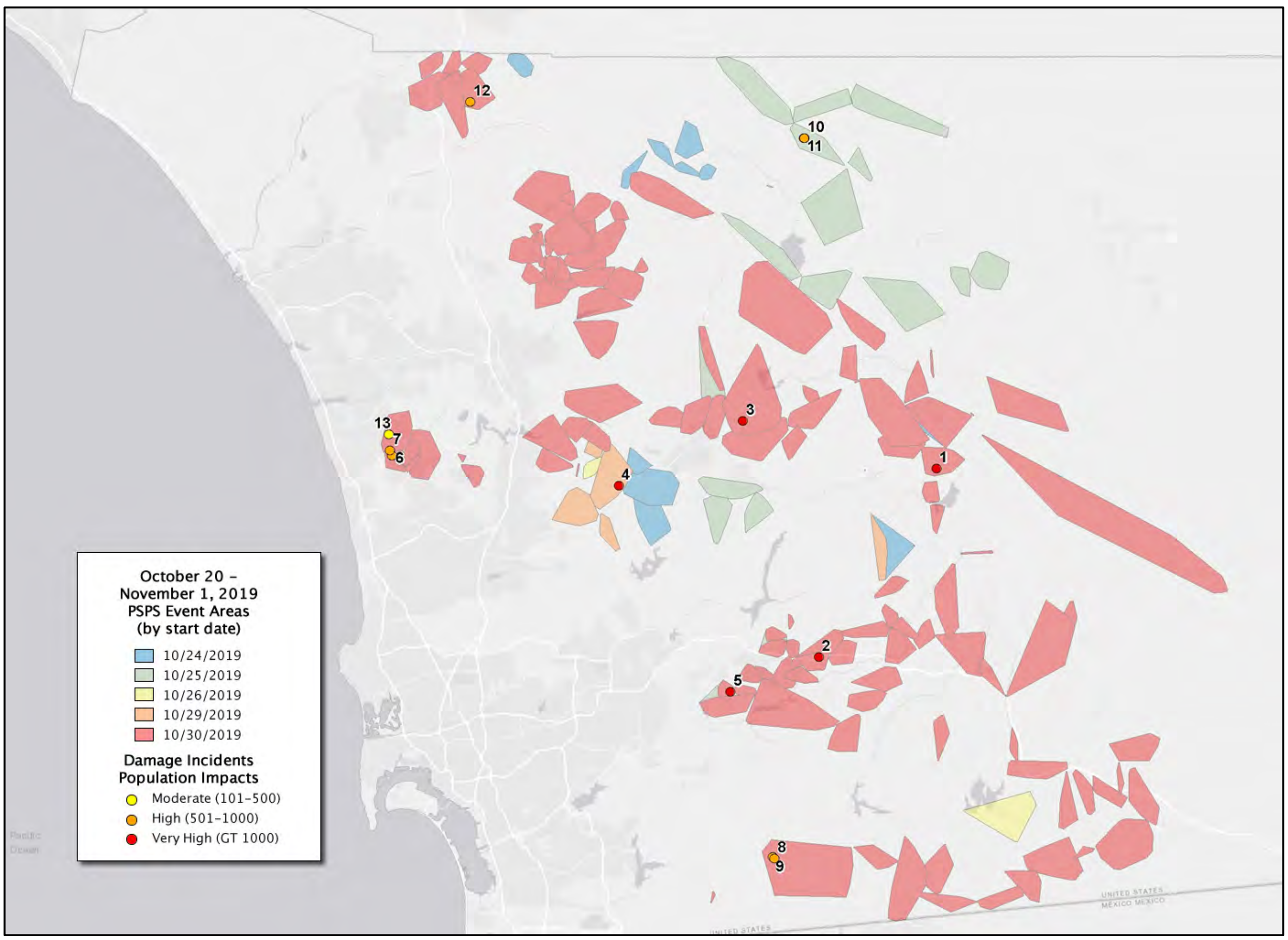
7.1 Findings

- Damages sustained to de-energized PG&E facilities during the October 20–November 1 PSPS event PSPS events could have impacted more than 35,112 buildings, 34,471 people and burned approximately 327,277 acres with only 13 recorded damage incidents. Fire impacts are high for all simulations with an average impact of 2,700 buildings, 2,651 people and 25,175 acres. The simulation with the lowest values would impact 111 buildings and 195 people even though it only burned 117 acres.
- The fire activity reflected by IRWIN incidents during the October 20–November 1 PSPS event (539 fires during the PSPS event; average number of fires per day = 42) was high in California. This could limit the availability and effectiveness of suppression resources due to fires occurring simultaneously. However, wildfires were less frequent in the county of San Diego in Southern California. Only eleven (11) small fires are located inside the PSPS event boundaries. Although fire activity was low, our analysis shows that both modeled and recorded weather conditions could lead to large fires with high rate of spread impacting thousands of people across the San Diego county.
- The selected significant damage incidents reflect that these fires could be very intense with fast moving fires (> 50-100 chains/hr) driven by high wind speed, low fuel moisture content and grass-shrub fuel types, possibly exceeding fire suppression capabilities during initial attack. All significant incidents had an IAA very high or extreme. [12]
- The potential impacts of each damage incident depends on specific environmental conditions (i.e. fuels, weather, topography, etc.) and the exposure of assets (buildings, population) near the incident ignition locations. The fire impact deviation was very high among simulations and not all fires in the same day would create the same impact, reflecting the need of analyzing all incidents independently to properly assess SDG&E's decision to shutoff power.
- There are minimal differences between modeled wind speed data, and the nearest weather station data. This is due to a large number of weather stations in a small service territory. This has led to an accurate weather prediction model that commonly closely matches weather station observation data. Accordingly, the prediction data is very reliable to model the incident simulations, especially when considering the probabilistic simulations that incorporate weather uncertainty.

[12] Chains per hour is the accepted standard for describing wildfire rate of spread within forestry and wildfire management agencies and science. A chain is equivalent to 66 feet.

- Probabilistic simulations analyze potential fire impacts considering input data uncertainty. In operational settings, its use seems mandatory given the high degree of input data uncertainty, especially in terms of wind speed. Local winds are difficult to accurately predict and weather stations are sometimes far to be representative of specific locations. While this situation is typical of the other IOU service territories due primarily to their large size, it is not for SDG&E. Nonetheless, it is important to consider probabilistic approaches to estimate the potential impact of fires in real-time operations. These are included in Appendix B for all significant incident simulations.
- The custom weather and fuel types provided in Technosylva's Wildfire Analyst™ software module allow users to modify input data based on real observations. The analysis conducted highlights the importance of these capabilities to improve and calibrate the fire simulation outputs based on integrated input data (i.e. cameras, weather station integration, IRWIN incident locations, etc.).

Figure 8. Population impacts for damage incidents.



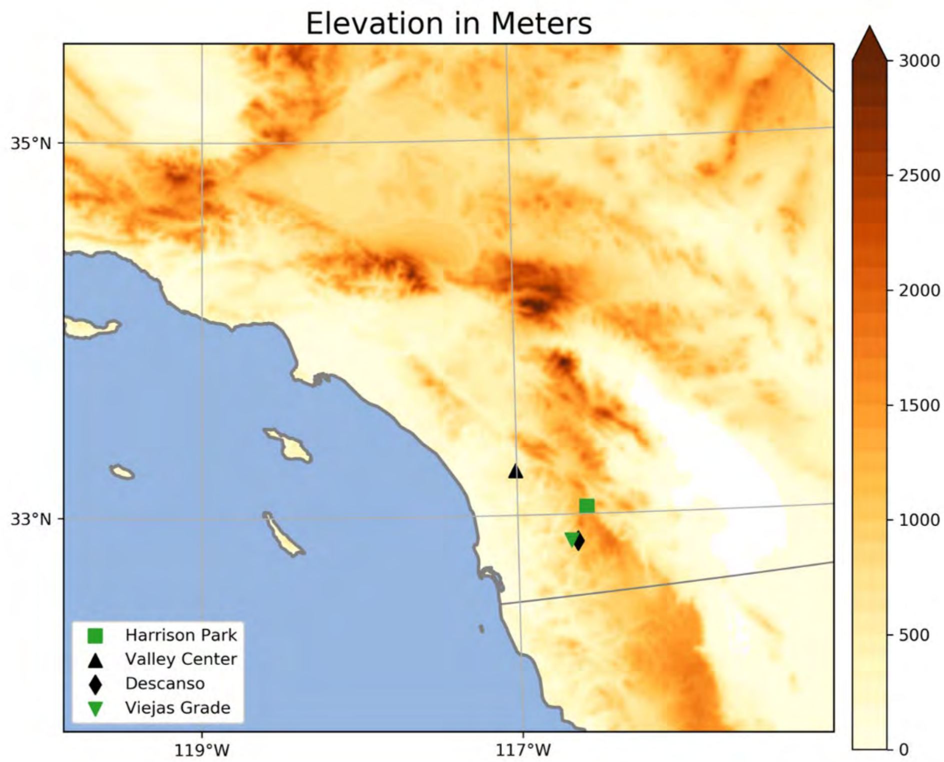
7.2 Recommendations and Opportunities for Improvement

- The analysis includes the potential impact of damage incidents on population, buildings, and acres burned if ignitions were to occur from the damages incurred to de-energized utility facilities during a PSPS event. The incidents need to be analyzed with caution due to the uncertainty ofinput data used during the analysis. Specifically, in the future, the probability of ignition may be evaluated more granularly than the binary yes/no assessments used for this analysis to facilitate more detailed future analysis for specific events.
- 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 SDG&E's forecasted weather data. With this preemptive data in hand, de-energizing decisions can be evaluated both temporally and spatially in advance.
- 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 on-going research of IOUs and Technosylva on wildfire modelling methods and data will increase the opportunities for improvement of future analysis. This includes better data collection and modeling of surface and canopy fuels, live fuel moistures, and enrichment of urban area delineation for encroachment analysis. These methods will enhance the accuracy of impact analysis and consequence modeling consistent with risk management industry approaches.

APPENDIX A: DETAILED WEATHER ANALYSIS

Surface weather stations used in this analysis are shown in the following figure.

Figure 9. Surface weather stations that are used in this analysis are shown above. Black symbols represent RAWS stations and green symbols represent SDG&E stations.

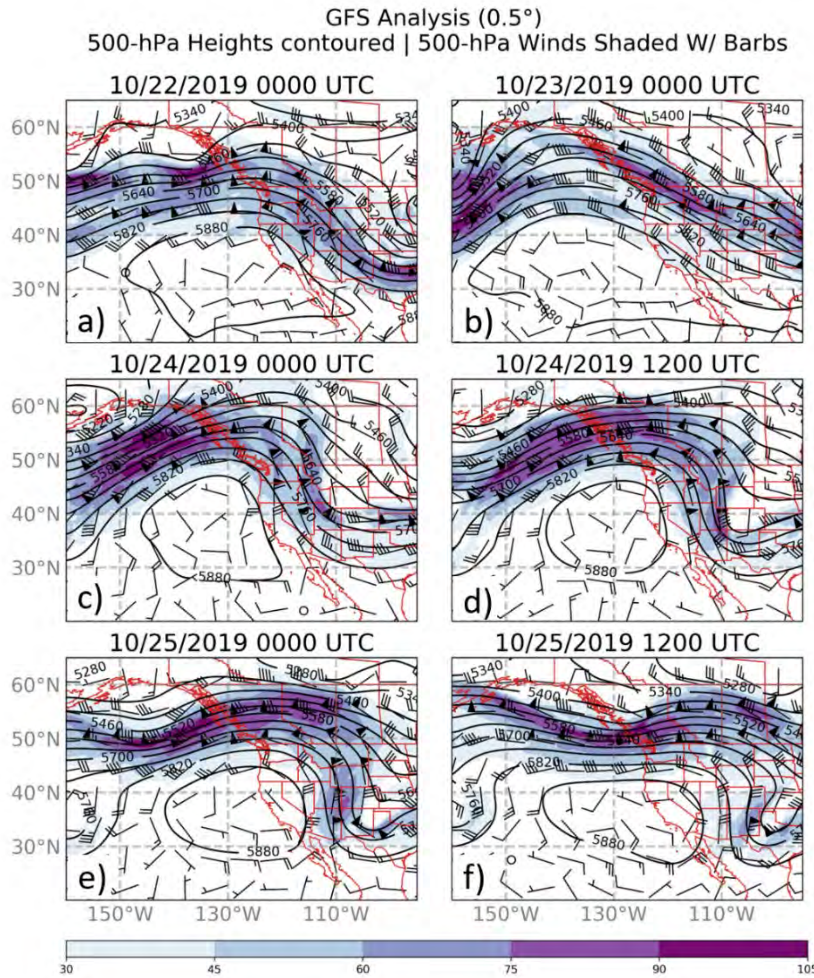


In-Depth Case Analyses

24 October 2019

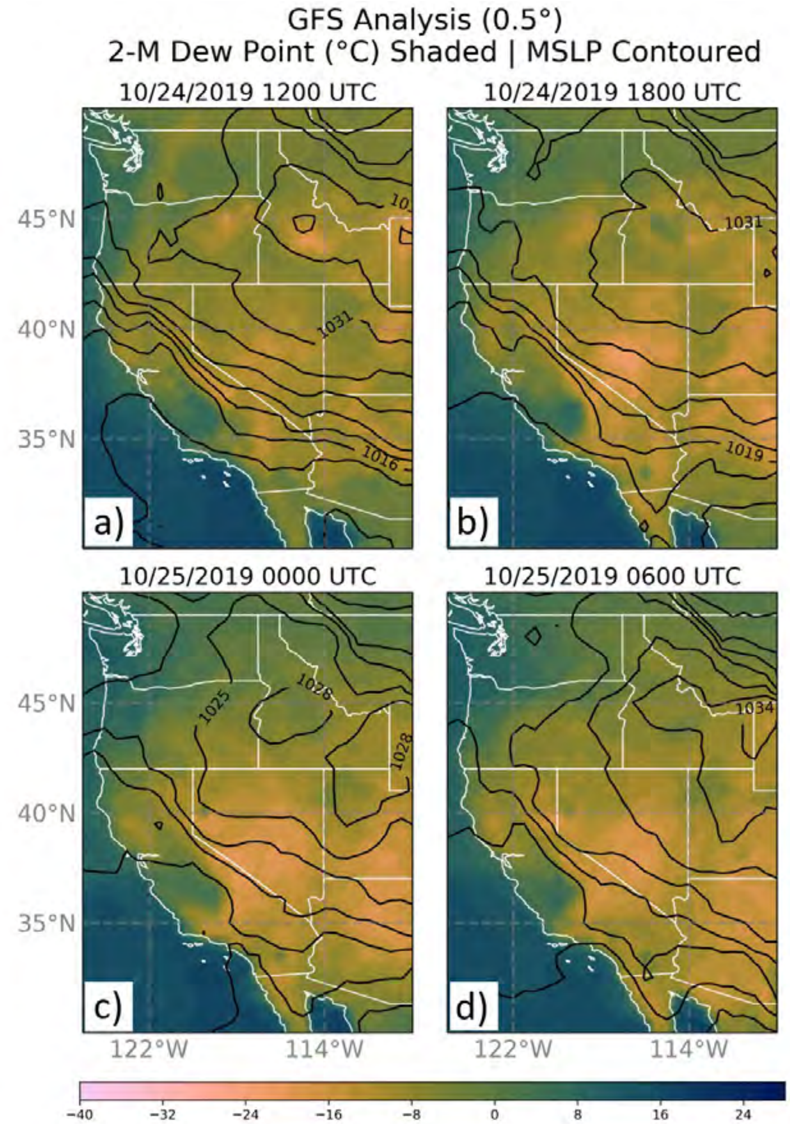
The synoptics of this event can be described by an upper level shortwave that began embedded in a longwave ridge. The shortwave slowly evolved into a trough, but it had to first traverse the upper level ridge that was situated over the western US (Figure 10a). This traverse was completed twenty-four hours later at 0000 UTC 23 October 2019 and signified the start of the trough's 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 well to the east of California.

Figure 10. Geopotential heights (meters) at 500-hPa are contoured and winds are shaded in knots. Time is labeled in UTC.



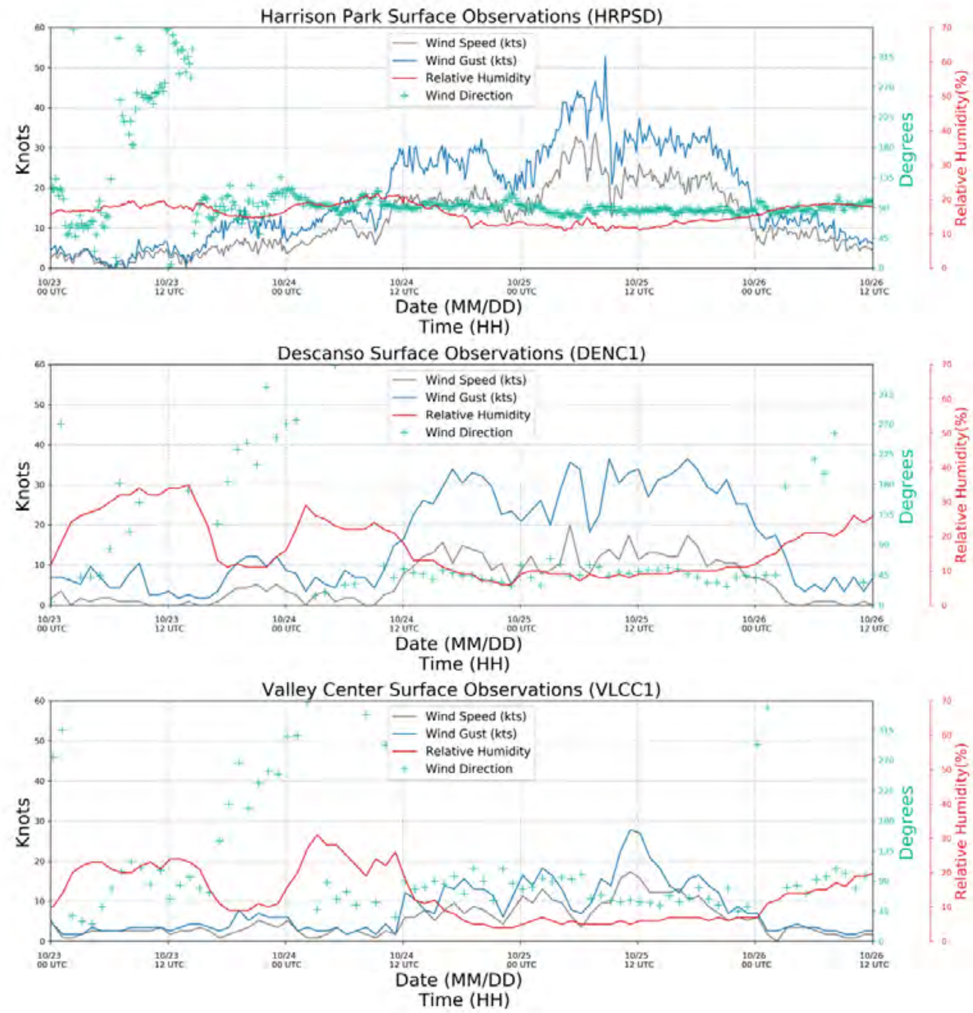
Regional analyses at the surface were started using two-meter dewpoint temperatures and mean sea level pressure. A dry airmass entered northern California as the pressure gradient stacked along the Sierra Nevada (Figure 11a). Dewpoint temperatures of roughly -20 °C occupied the Southern California region at 1800 UTC 24 October 2019. The pressure gradient subsided significantly by 0000 UTC 25 October which ended the wind event in northern California. At that time dry air continued to advect over the southern end of the Sierra Nevada and Tehachapi Mountains and into broader areas of Southern California.

Figure 11. Dew points at two meters are shaded (Celsius) with black contours of MSLP and time is labeled in UTC.



Prior to the start of this event, a dry airmass was in place which only observed minimal overnight RH recoveries in the lower elevations due to diurnal patterns. This is not to say drying did not occur with the onset of the wind event. The lowest elevation site, Valley Center, observed a distinct drop in RH which persisted in the single digits for almost 24 hours (Figure 12). These lower elevations recorded the lowest RH measurements as expected from a downslope windstorm. Adiabatic warming, a key mechanic of downslope windstorms, is responsible for lowering the relative humidity and is maximized at the base of the topography. Gusts associated with this dry airmass were typically within 25-50 knots with sustained wind speeds between 20-30 knots. The higher elevations, while they recorded less dry air, observed stronger winds.

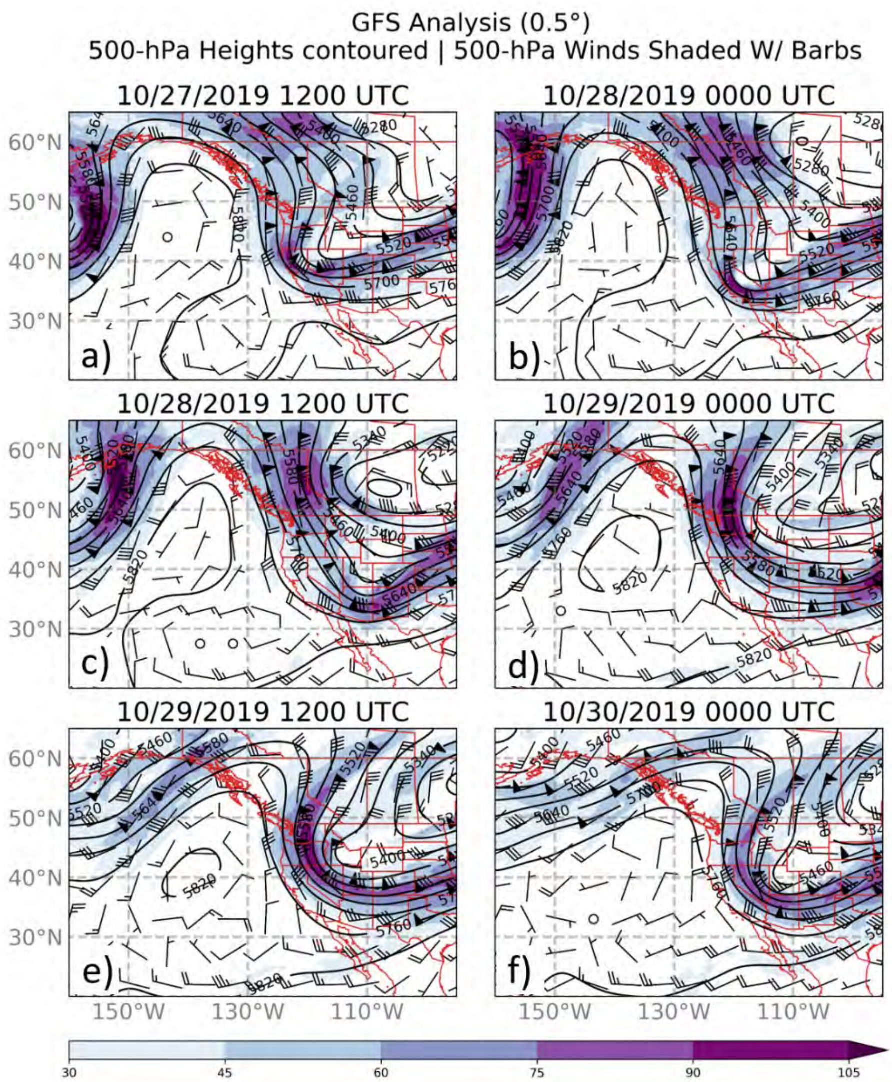
Figure 12. Surface weather station data shown above with Harrison Park, Descanso, and Valley Center representing high, medium, and lower elevations respectively.



30 October 2019

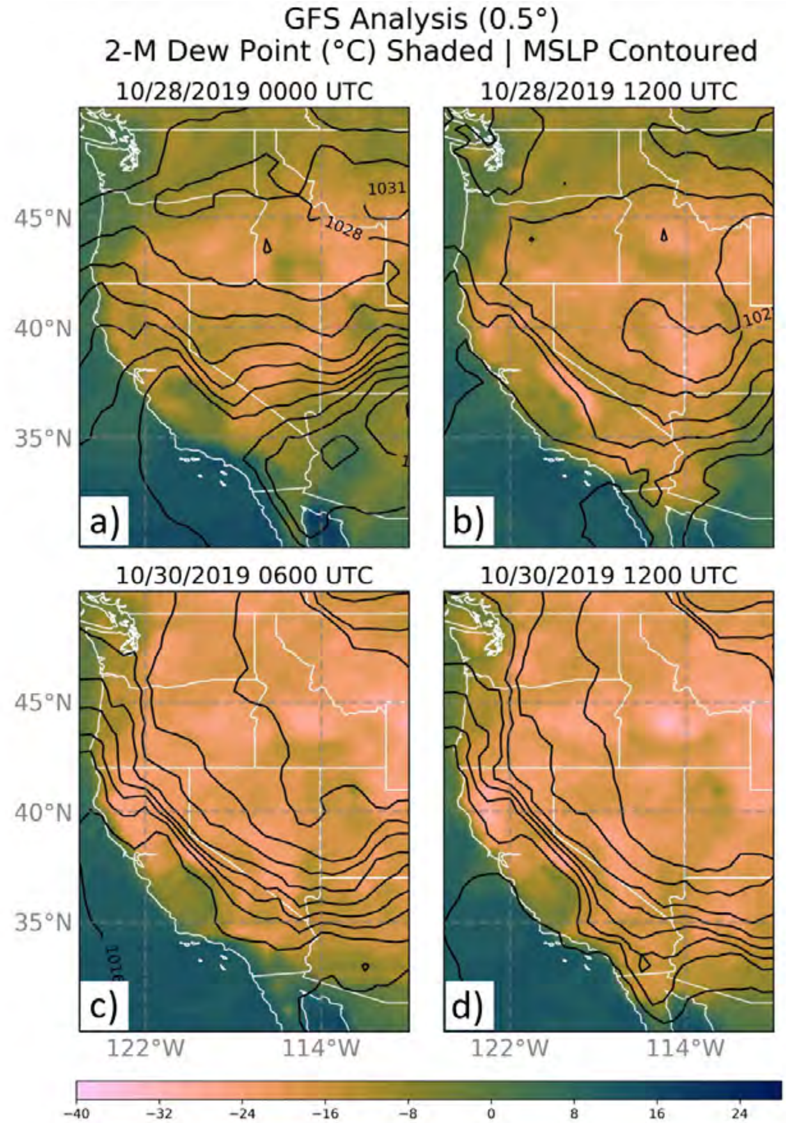
The synoptics of this event can be described by the passage of multiple upper level shortwaves that propagated south along the coast of the western U.S. The original shortwave began with a very strong positive tilt which weakened as the shortwave propagated further south. At about 1200 UTC 28 October 2019, the axis of the trough was again stretched with a strong positive tilt as a secondary shortwave propagated through the long wave trough (Figure 13c). The upstream ridge built as the trough propagated further south. The trough axis of the secondary shortwave resided directly over the Great Basin at 0000 UTC 30 October 2019.

Figure 13. Geopotential heights (meters) at 500-hPa are contoured and winds are shaded in knots. Time is labeled in UTC.



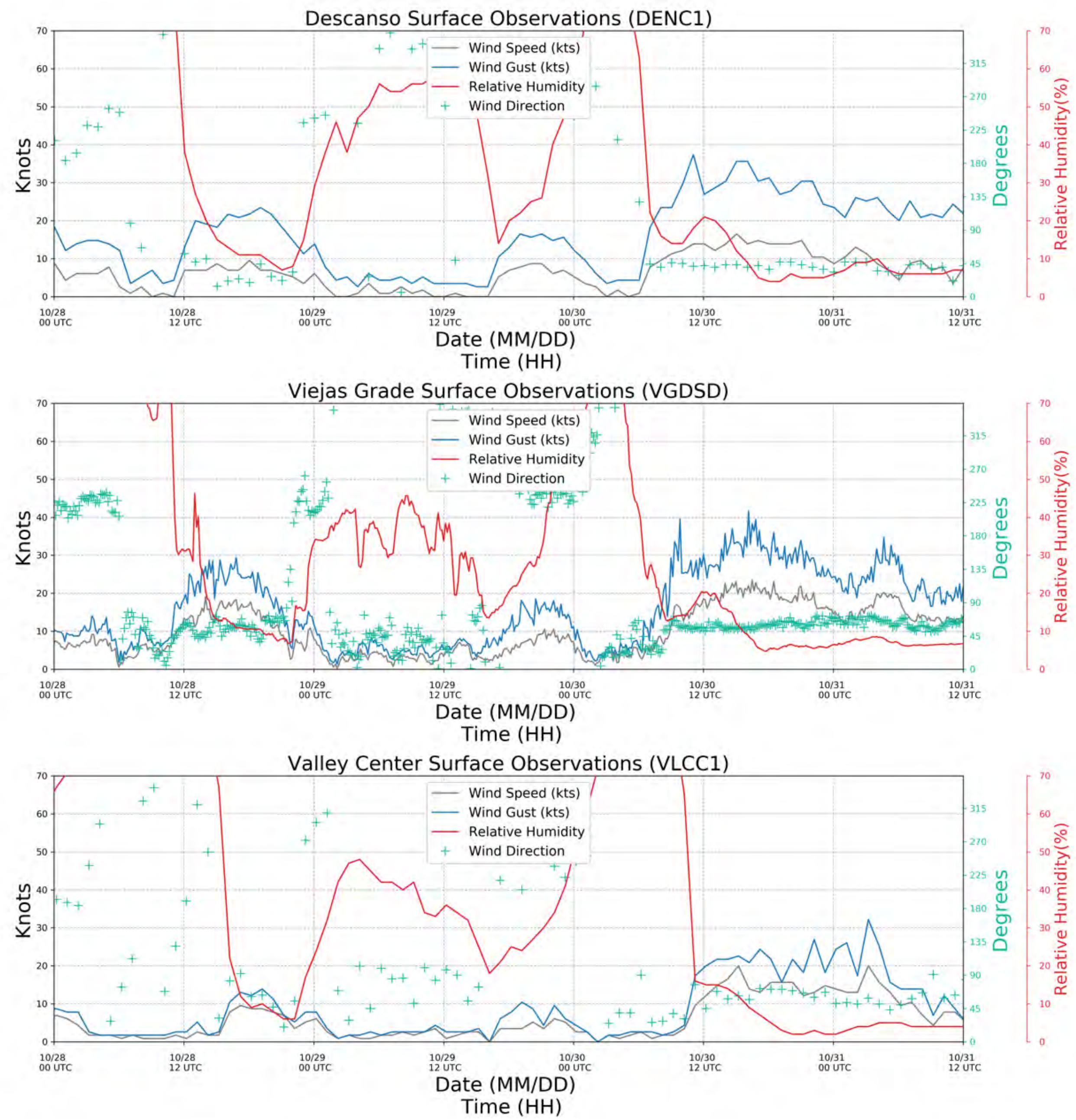
Regional analyses at the surface were started using two-meter dewpoint temperatures and mean sea level pressure. Weaker surface pressure gradients were apparent along southern California on 28 October 2019 (Figure 13a, b) as compared to 30 October (Figure 14c, d). Dewpoint temperatures also revealed a much drier airmass in place over the entire western U.S. not only locally in southern California. Surface weather stations were used to verify wind and humidity conditions for specific regions.

Figure 14. Dew points at two meters are shaded (Celsius) with black contours of MSLP and time is labeled in UTC.



Extremely dry air was observed by surface weather stations. All elevations observed RH in the single digits, but Valley Center observed RH as low as 1%. This dry air coincided with gusts in the range of 30-40 knots and sustained wind speed between 15-25 knots (Figure 154). Further, this was the second wind event in two days which allowed the fuels to undergo very critical drying conditions for extended amounts of time. While the winds may not have been as extreme as observed in other regions, the extremely dry air warrants fire weather risk with wind speeds in the single digits.

Figure 15. Surface weather station data shown above with Descanso, Viejas Grade and Valley Center representing high, medium and lower elevations respectively.



APPENDIX B: 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 Section 5. 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.

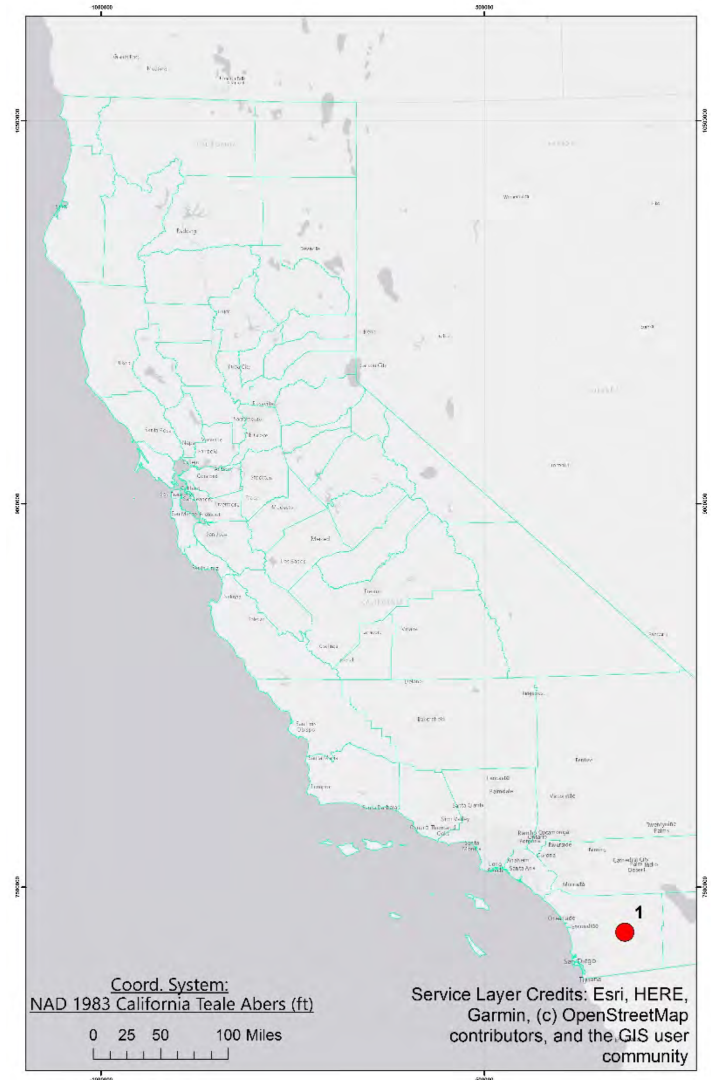
For each incident, critical input data such as wind speed and direction are analyzed, including fire behavior and impact metrics shown through tables and figures.

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.

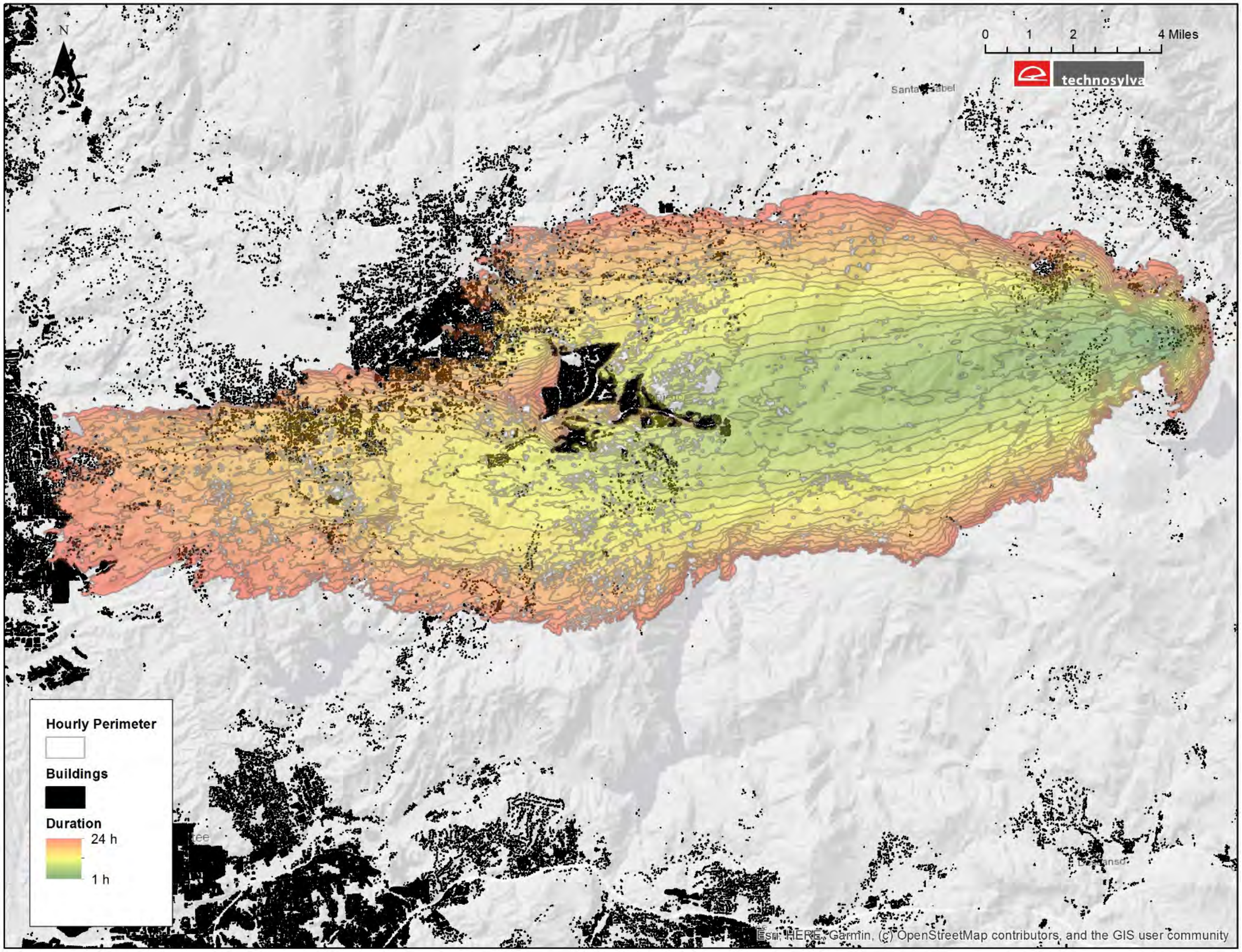
DAMAGE INCIDENT – 1

This damage incident could ignite a very large fire of almost 100,000 acres with direct impact to the city of Ramona and urban areas such San Diego Country Estates. The fire could potentially reach Poway, impacting lots of buildings and population in dense urban areas throughout the fire spread as shown in the incident summary table and maps. The rate of spread would be very high with moderate-high intensity. The fire would be driven by high winds coming from east ranging between 20 and 30 mi/h. All this area was already burned by the Cedar fire in 2003 (280,278 ac).

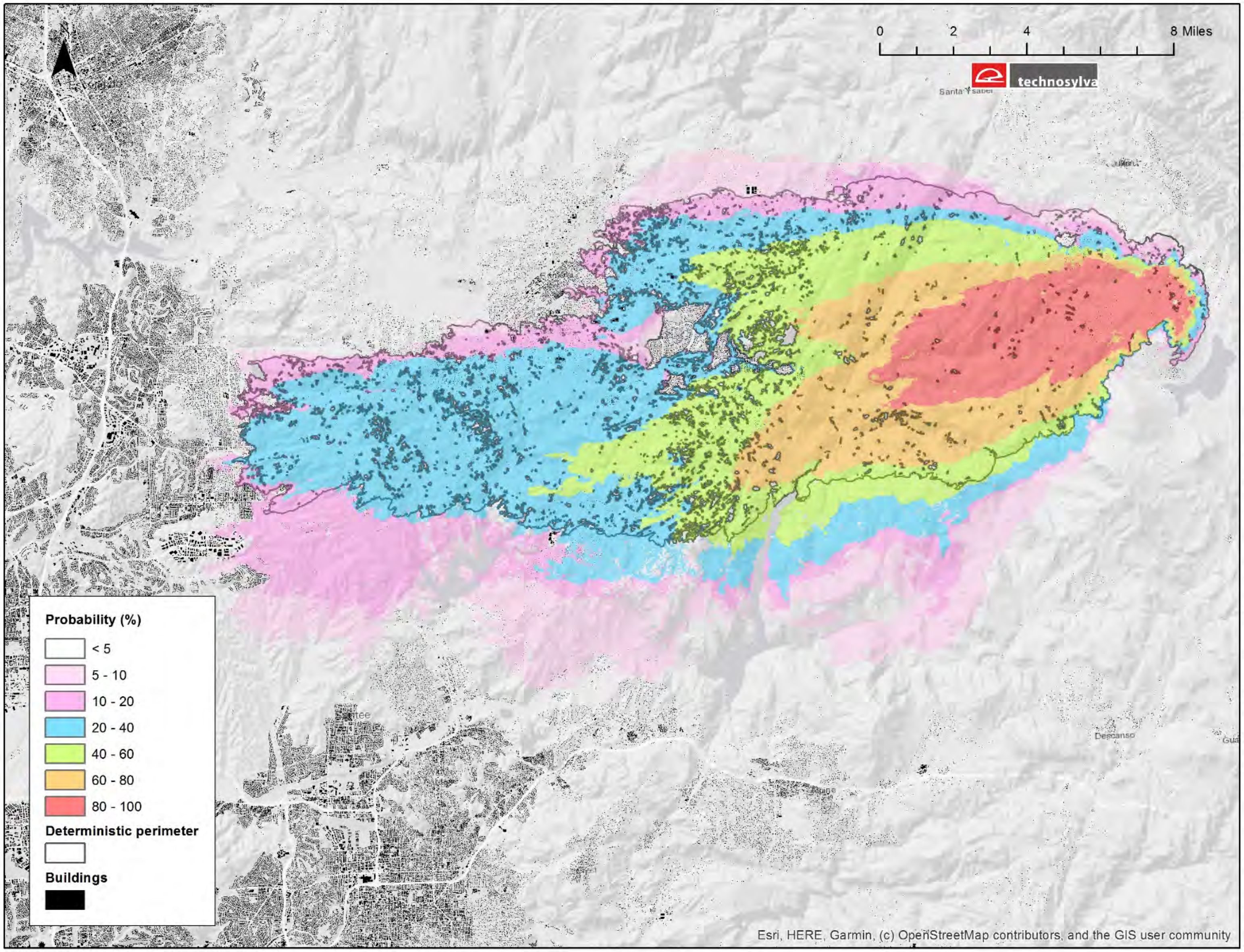


INCIDENT SUMMARY	
Start Time	10/24/2019 - 23:35
Duration (hrs)	24
Size (ac)	96,333
Initial Attack Assessment	5 - Extreme
No. of Buildings	11,335
Total Population	10,295
Average ROS	Very High

DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION

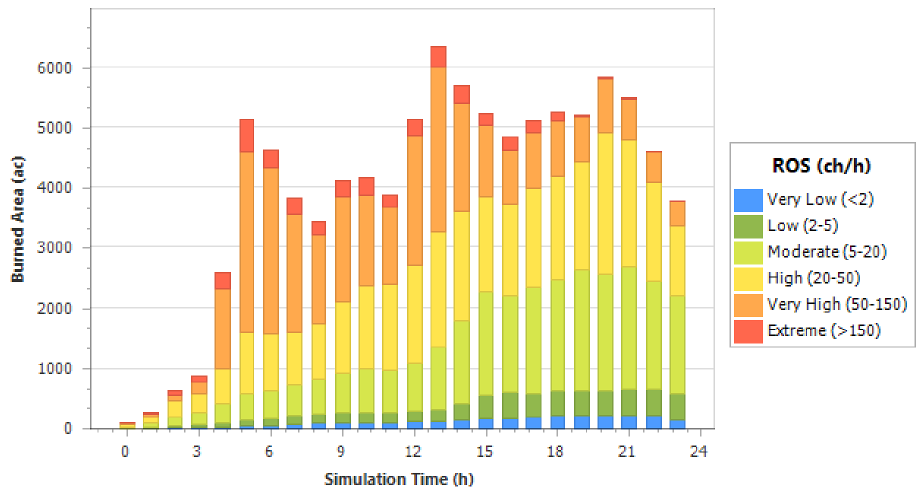


DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION

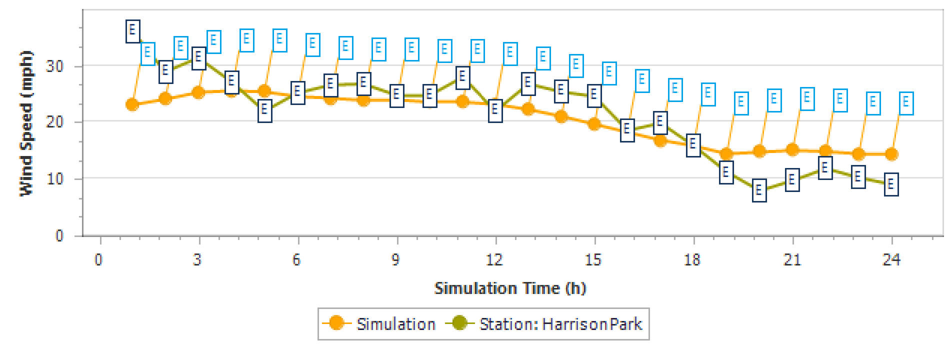


DAMAGE INCIDENT NO. 1	
FIRE BEHAVIOR	**WEATHER** **Nearest Station:** Harrison Park

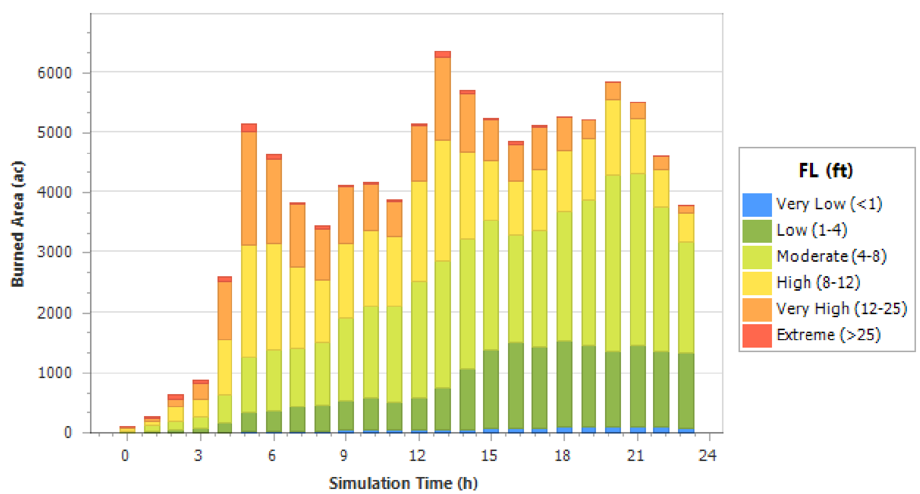
Rate of Spread

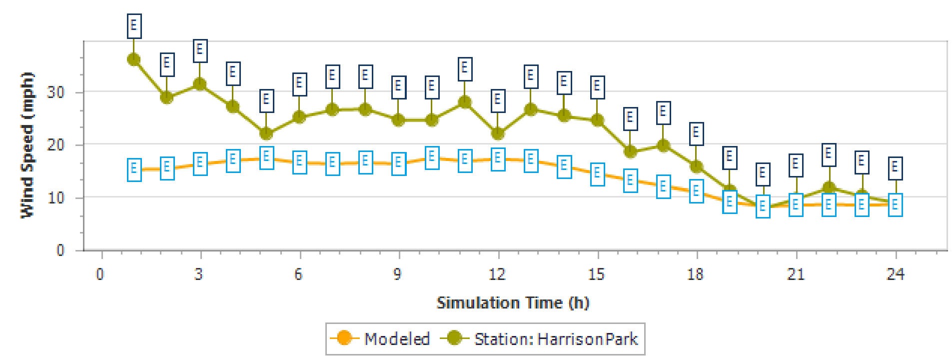


Station ID - PG139
Weather station (Wx) elevation - 4861 ft
Fire ignition point (IP) elevation - 4649 ft
Distance between Wx and IP - 1.6 mi



Flame Length



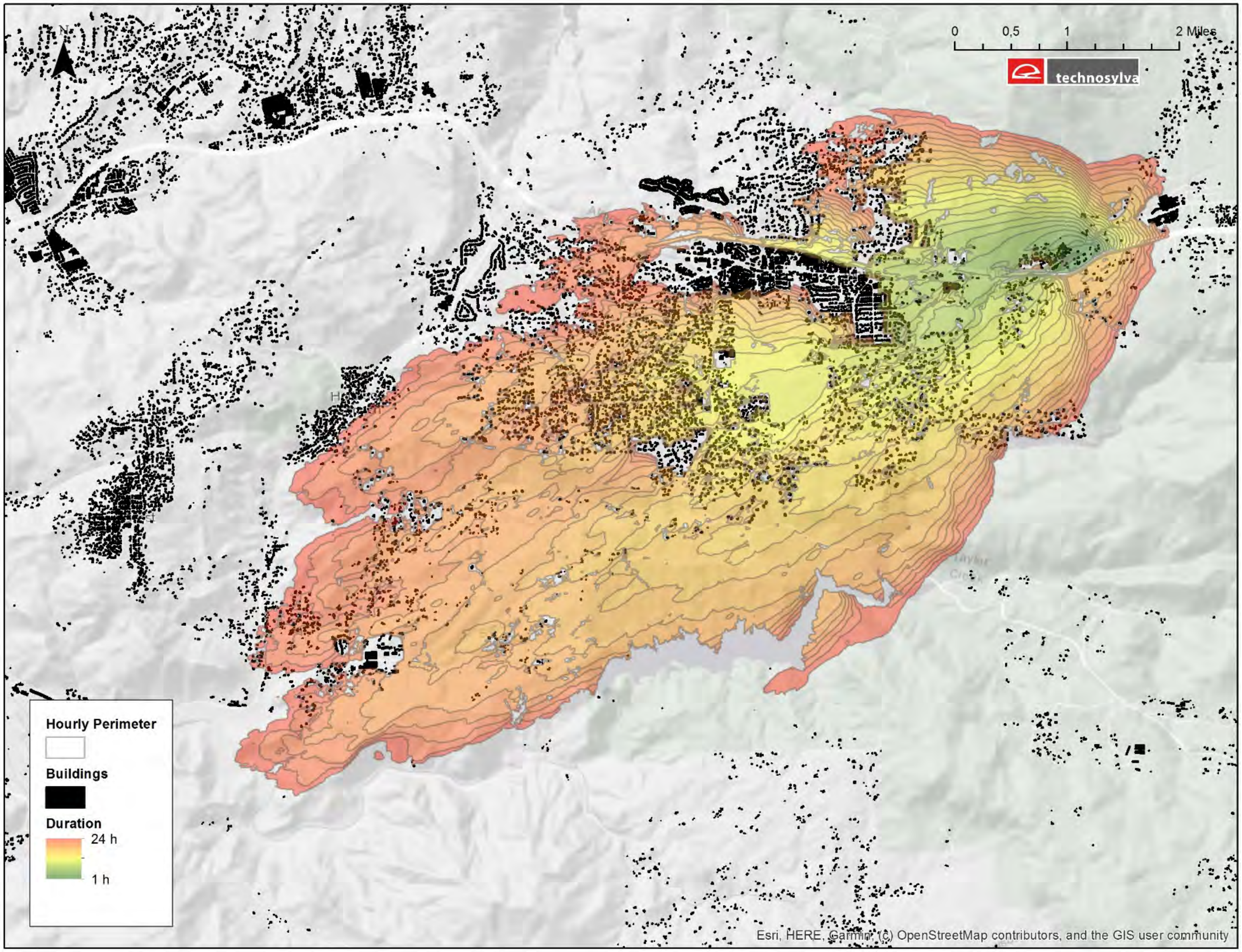


DAMAGE INCIDENT – 2

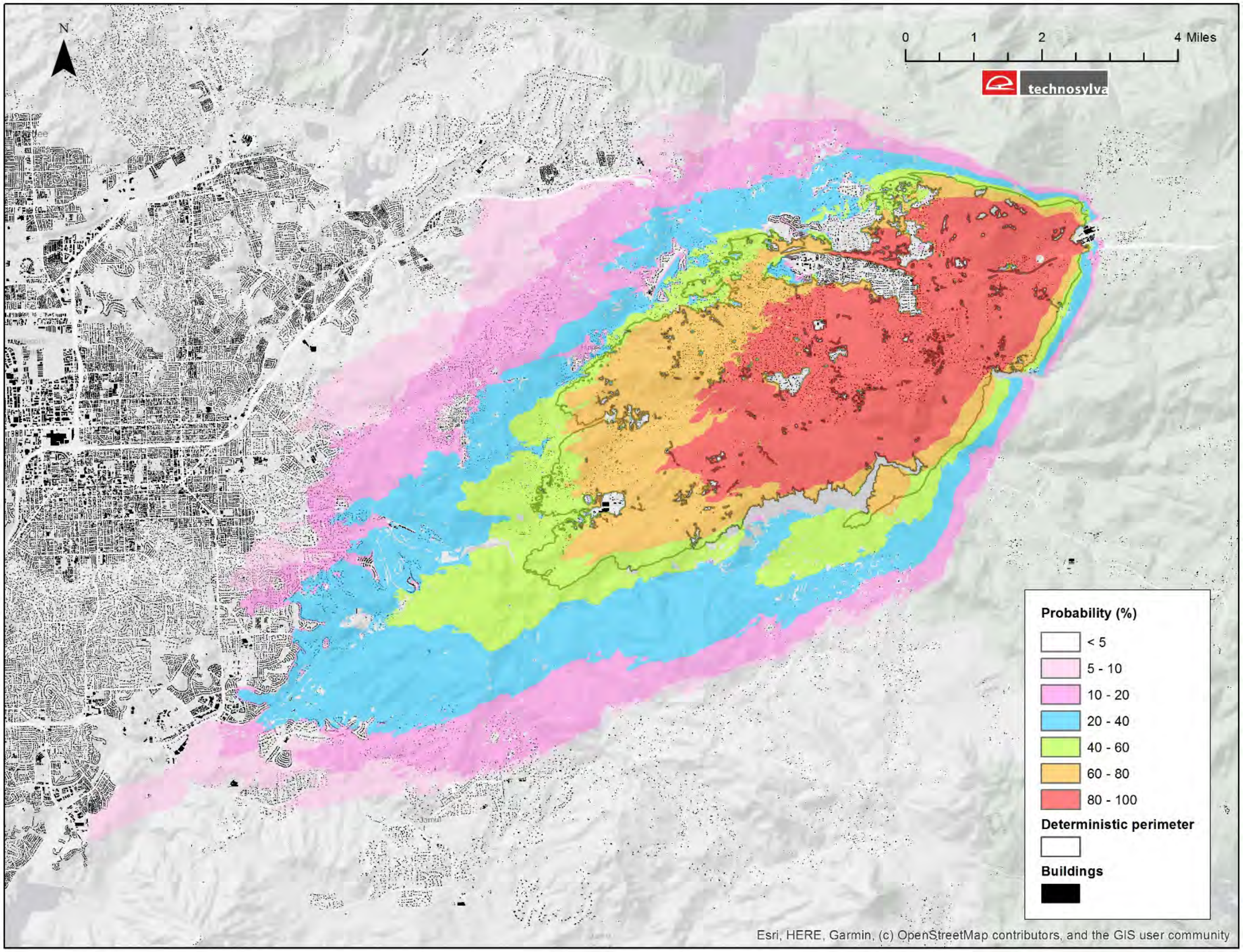
This incident is located in in the south of San Diego County and could impact lots of scattered buildings throughout the progression and dense urban areas as reflected in the maps. It would have been a wind-driven fire with winds coming from East (20-25 mi/h) giving rise moderate-high rate of spread during all fire duration. Modeled winds are consistent with weather station records. The fire would burn a large area of shrub and grass and have a high difficulty of containment in the initial attack. The area was burned by the VIEJAS fire in 2001 (10,353 ac) and the LA LAGUNA fire in 1970 (174,158 ac).

INCIDENT SUMMARY	
Start Time	10/30/2019 6:24
Duration (hrs)	24
Size (ac)	15,713
Initial Attack Assessment	4 – Very High
No. of Buildings	5,710
Total Population	6,916
Average ROS	High

DAMAGE INCIDENT NO. 2 : DETERMINISTIC SIMULATION

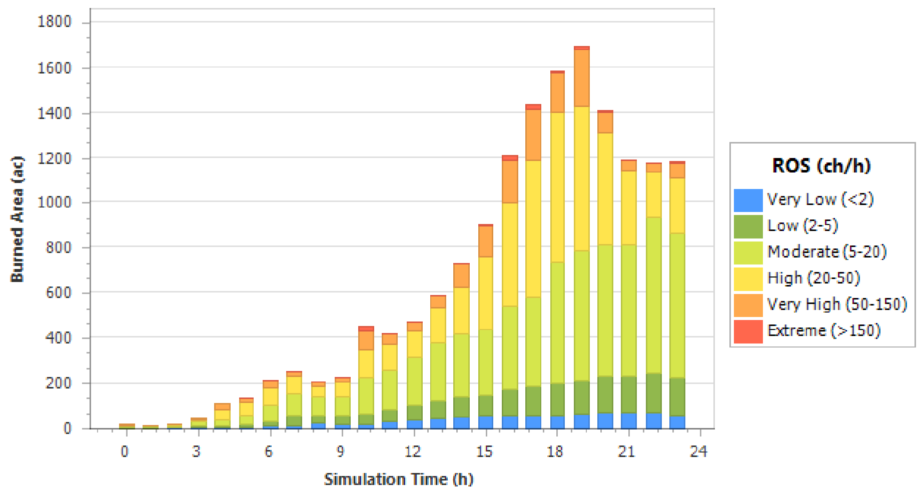


DAMAGE INCIDENT NO. 2 : PROBABILISTIC SIMULATION

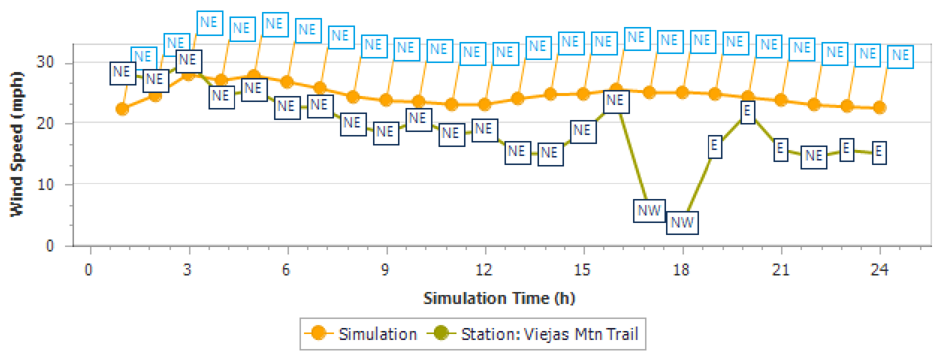


DAMAGE INCIDENT NO. 2	
FIRE BEHAVIOR	**WEATHER** **Nearest Station:** Viejas Mtn Trail

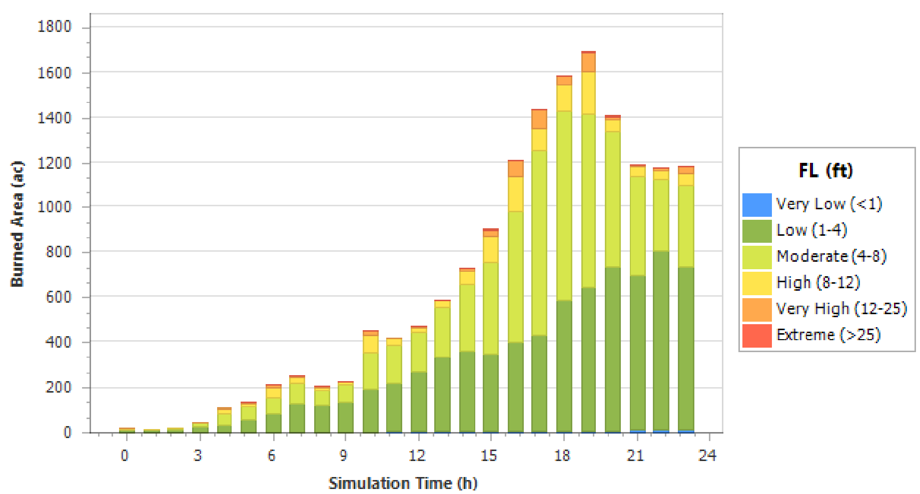
Rate of Spread

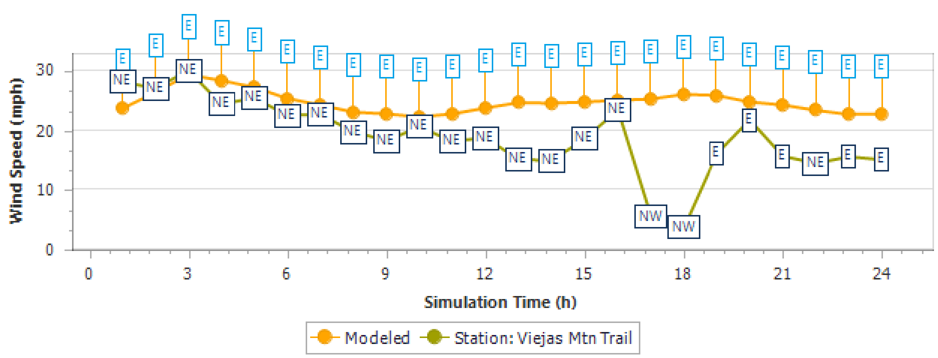


Station ID - VMTSD
Weather station (Wx) elevation - 649 ft
Fire ignition point (IP) elevation - 891 ft
Distance between Wx and IP - 2.59 mi



Flame Length

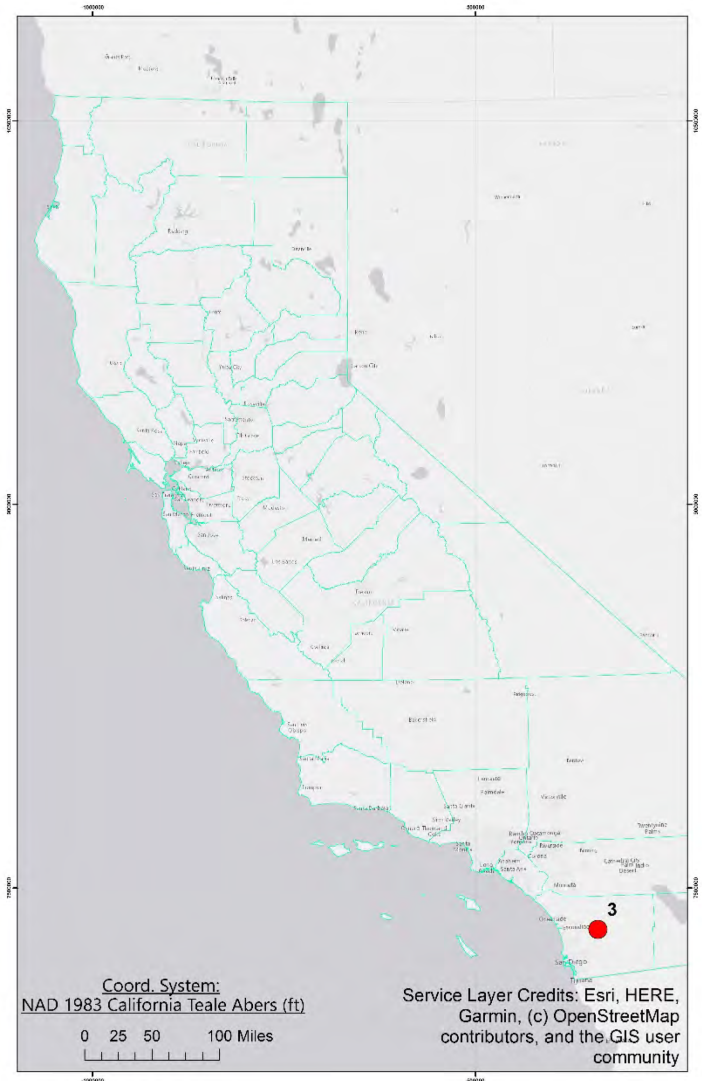




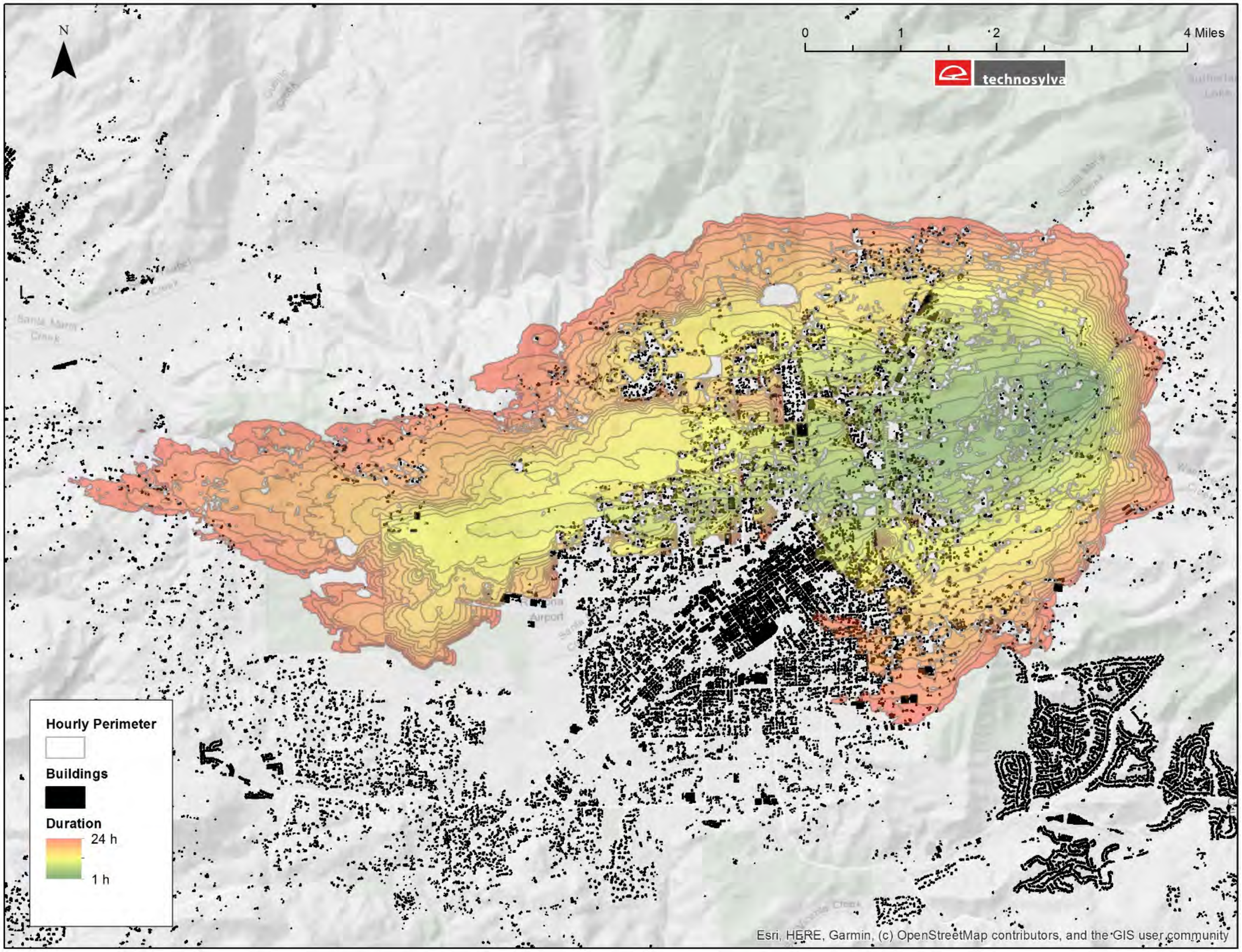
DAMAGE INCIDENT – 3

This damage incident could ignite a very fire with direct impact in the city of Ramona. The fire could potentially reach the Wildland Urban Interfaces of Poway and Escondido. Lots of buildings in both scattered and urban communities throughout the fire spread as shown in the incident summary table and maps. It would have been a wind-driven fire by high winds coming from east ranging between 20 and 30 mi/h. The rate of spread would be very high with moderate-high intensity. All this area was already burned by the Cedar fire in 2003 (280,278 ac).

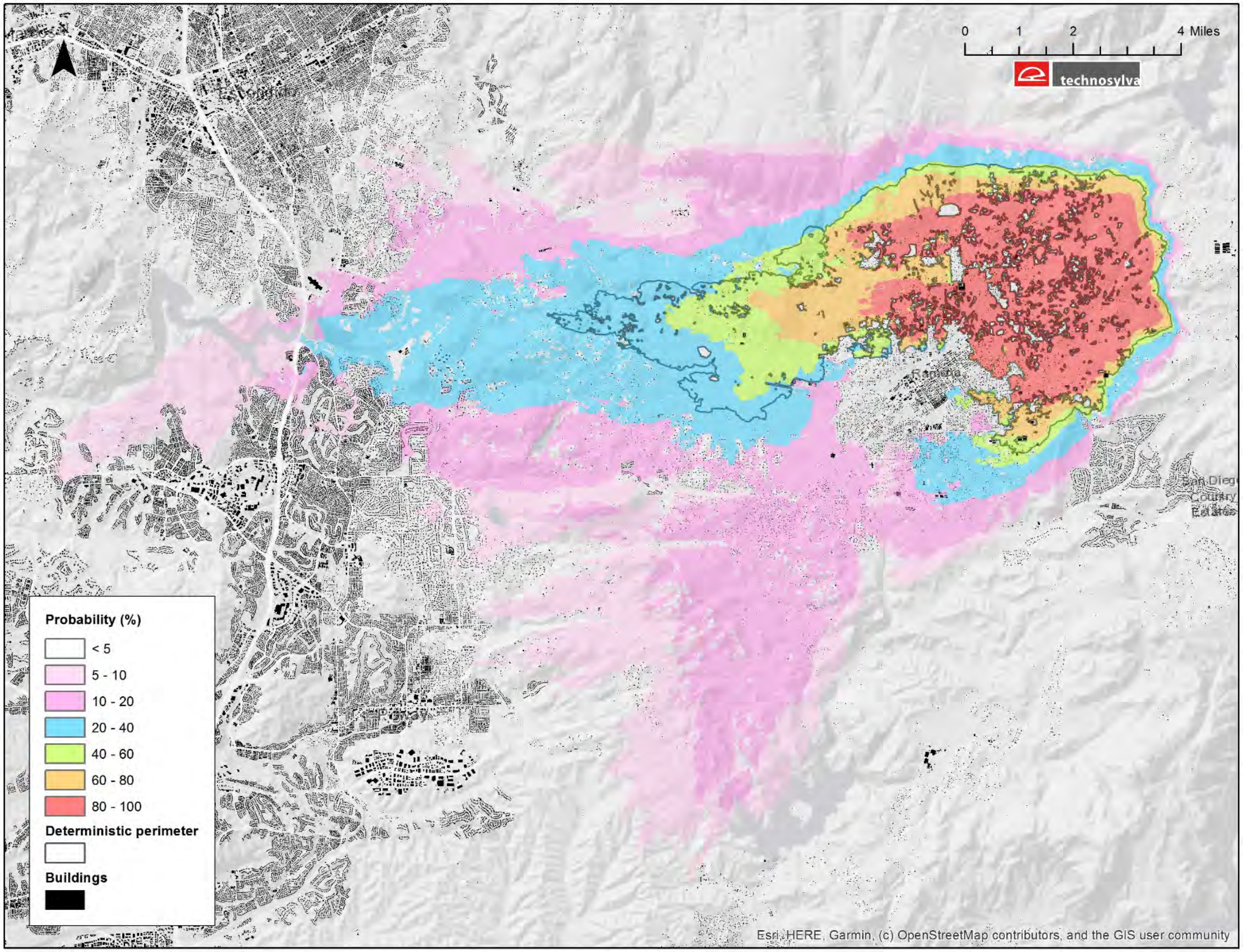
INCIDENT SUMMARY	
Start Time	10/30/2019 - 9:15
Duration (hrs)	24
Size (ac)	17,905
Initial Attack Assessment	5 - Extreme
No. of Buildings	4,697
Total Population	4,446
Average ROS	High



DAMAGE INCIDENT NO. 3 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 3 : PROBABILISTIC SIMULATION

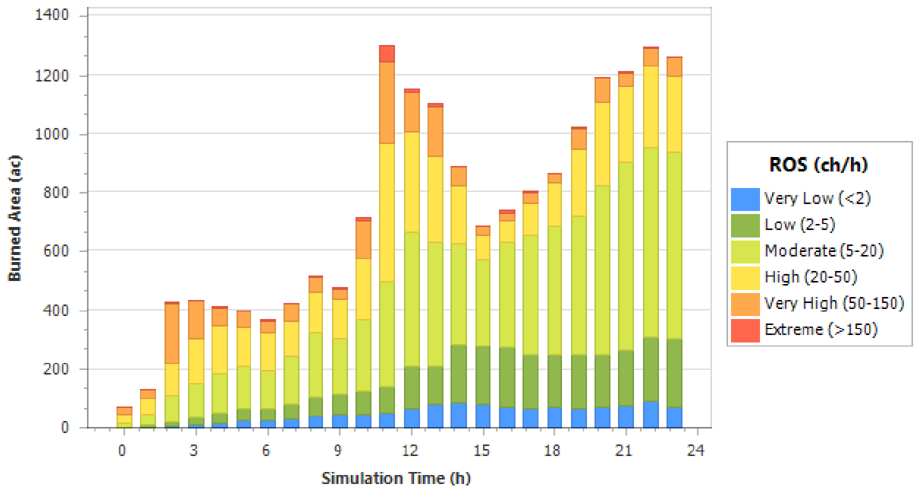


DAMAGE INCIDENT NO. 3

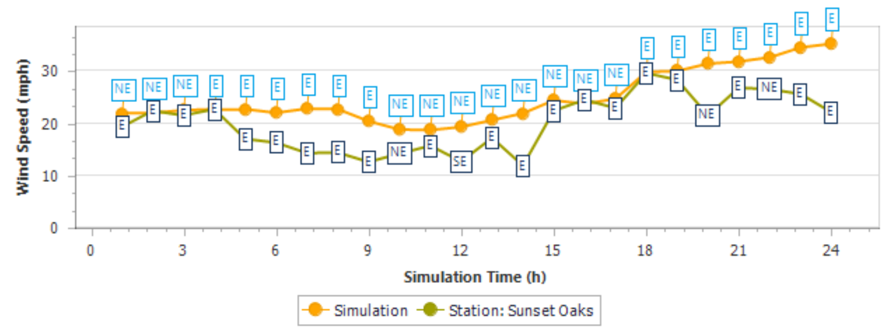
Nearest Station: Sunset Oaks

FIRE BEHAVIOR	WEATHER

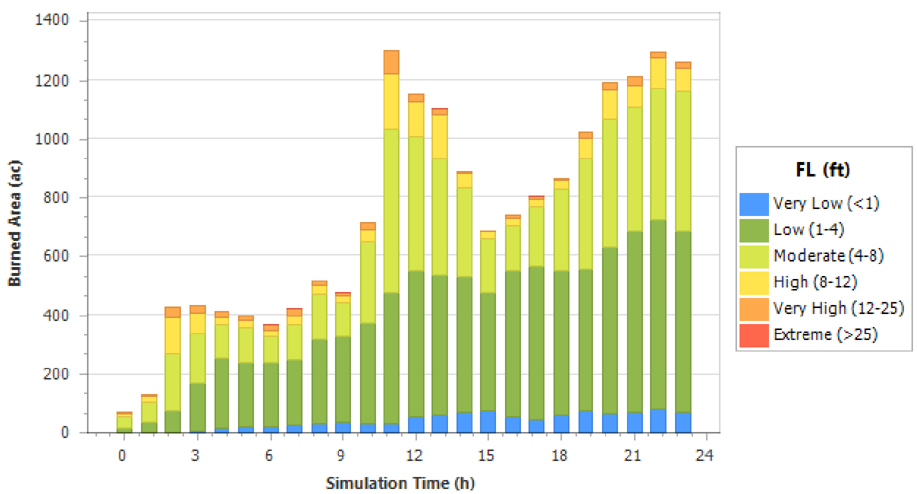
Rate of Spread

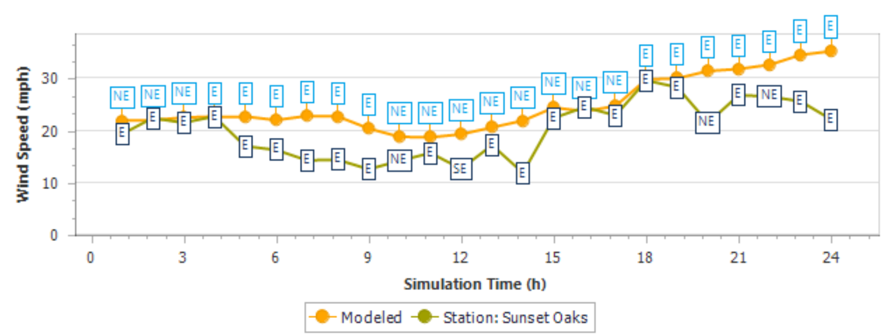


Station ID - SSOSD
Weather station (Wx) elevation - 2337 ft
Fire ignition point (IP) elevation - 2024 ft
Distance between Wx and IP - 0.54 mi



Flame Length

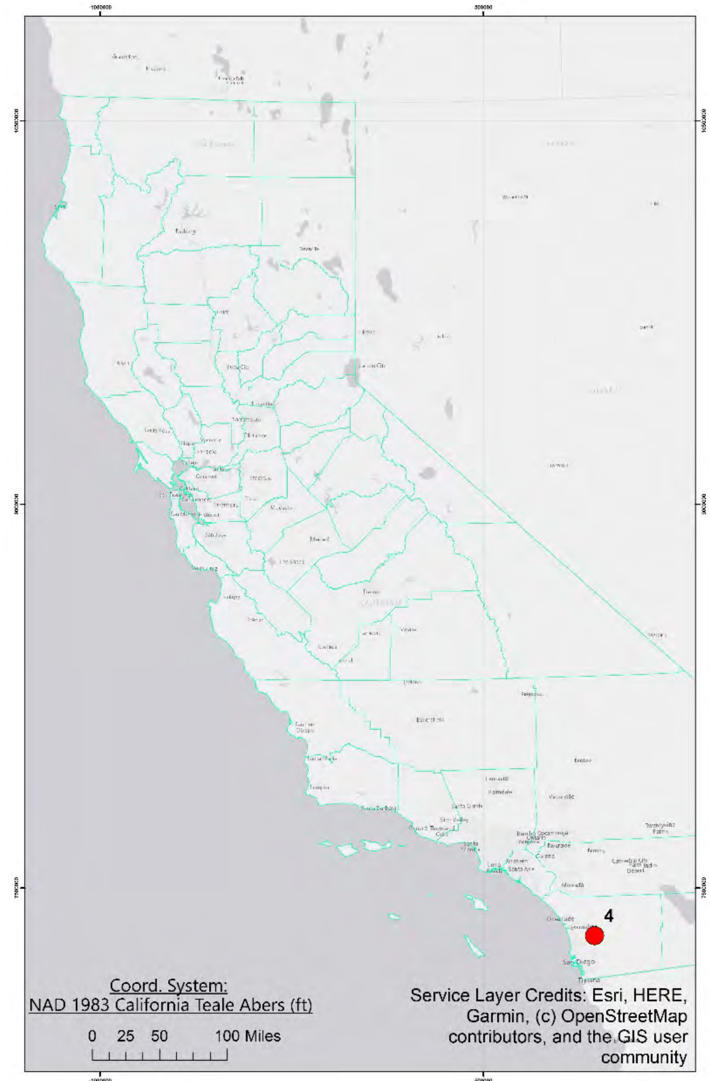




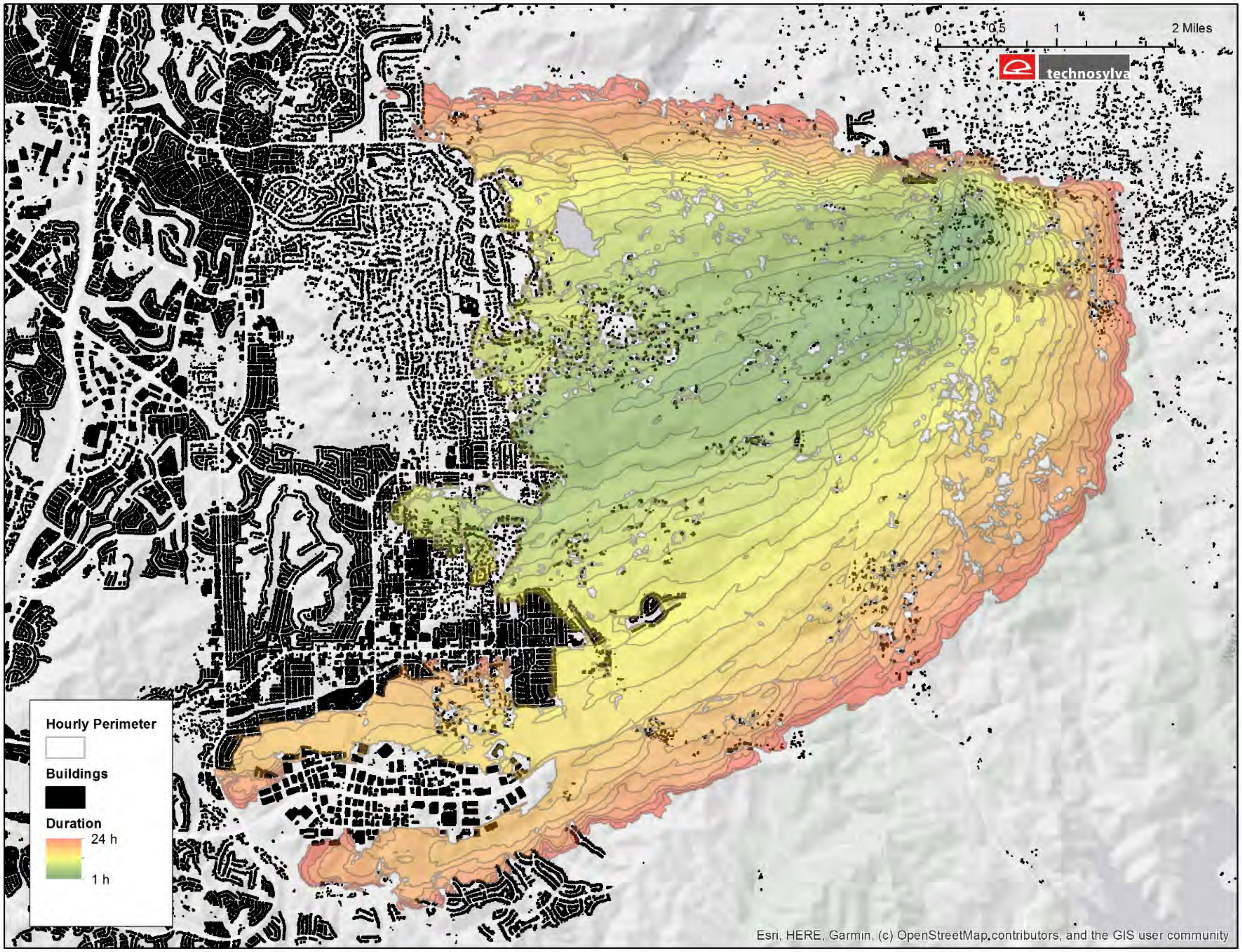
DAMAGE INCIDENT – 4

Fast wind-driven fire affecting the dense urban area of Poway. Scattered buildings could also be potentially impacted by the fire. The fire would start growing with a high rate of spread and moderate intensity, probably exceeding fire suppression capabilities. Winds coming from east ranging between 13 and 25 mi/h would support the fire spread on shrub fuel types resulting in high impact in both number of buildings and population.

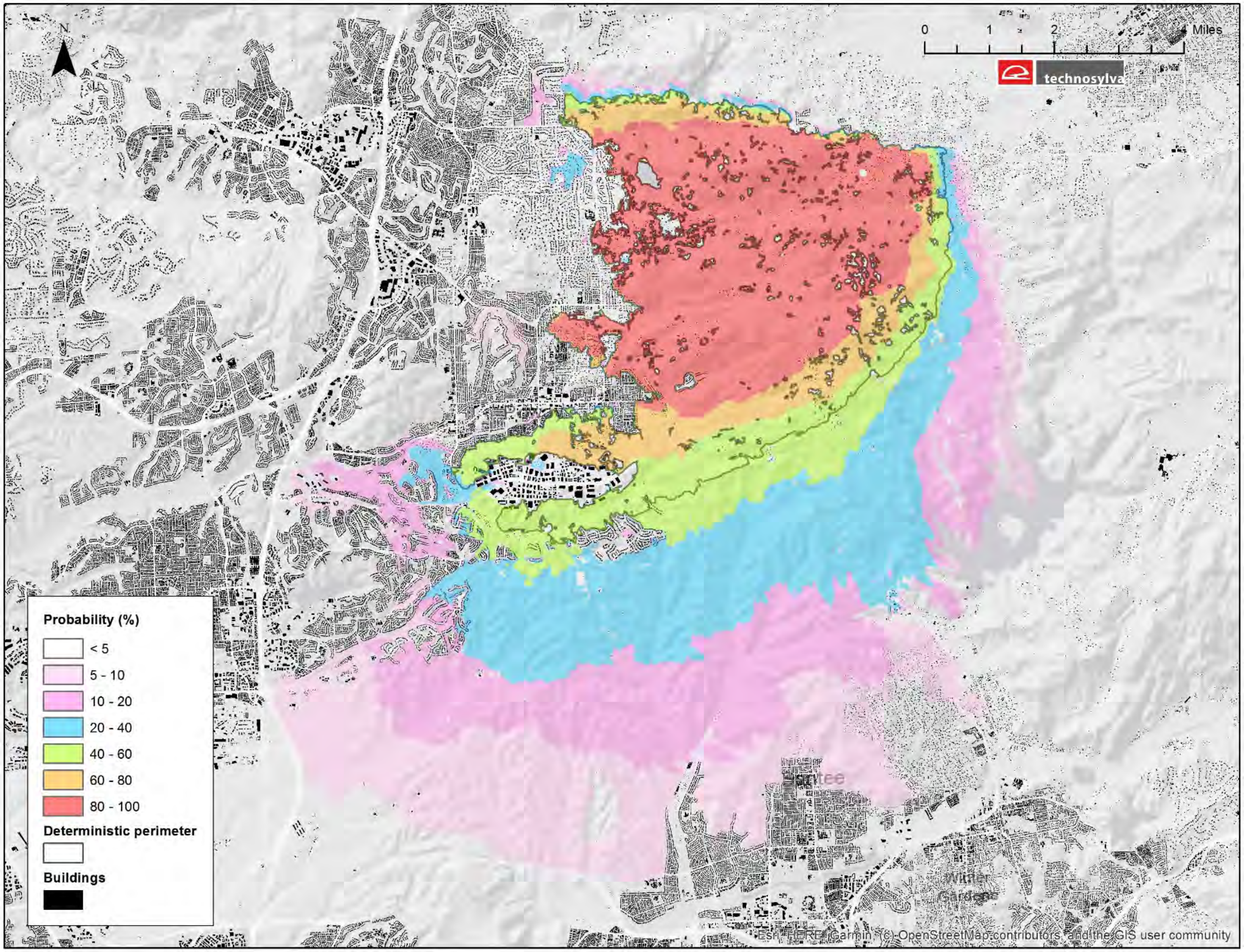
INCIDENT SUMMARY	
Start Time	10/24/2019 11:33
Duration (hrs)	24
Size (ac)	16,796
Initial Attack Assessment	5 – Extreme
No. of Buildings	3,384
Total Population	4,103
Average ROS	High



DAMAGE INCIDENT NO. 4 : DETERMINISTIC SIMULATION



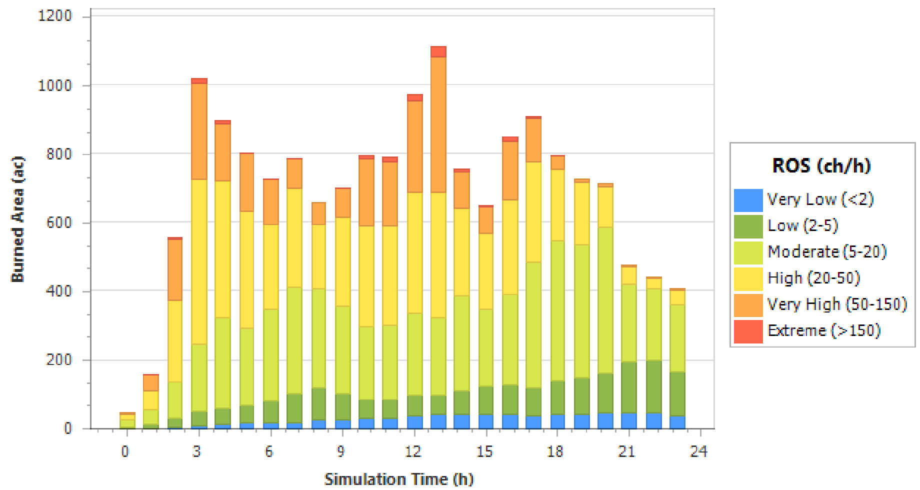
DAMAGE INCIDENT NO. 4 : PROBABILISTIC SIMULATION



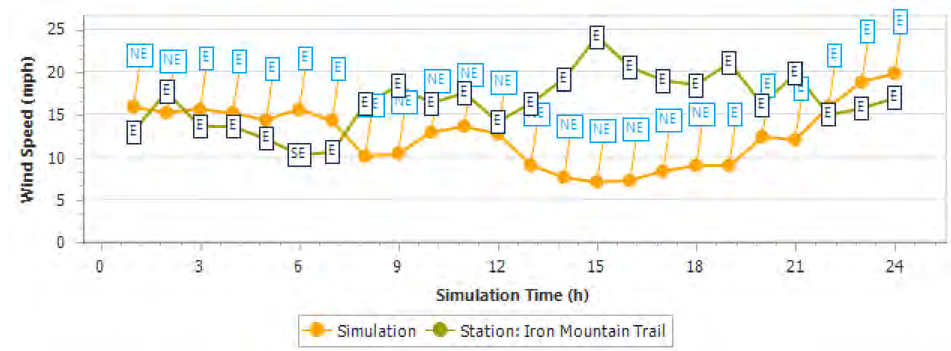
DAMAGE INCIDENT NO. 4

FIRE BEHAVIOR	WEATHER **Nearest Station:** Iron Mountain Trail

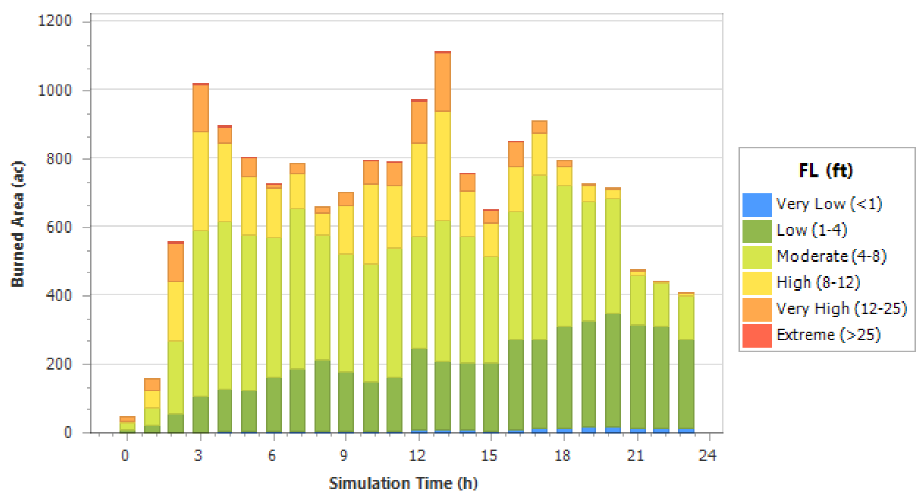
Rate of Spread

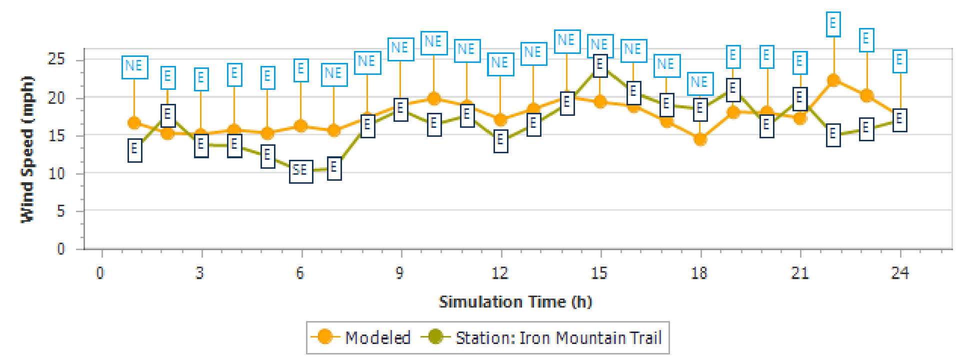


Station ID - IMTSD
Weather station (Wx) elevation - 1610 ft
Fire ignition point (IP) elevation - 1722 ft
Distance between Wx and IP - 2.36 mi



Flame Length



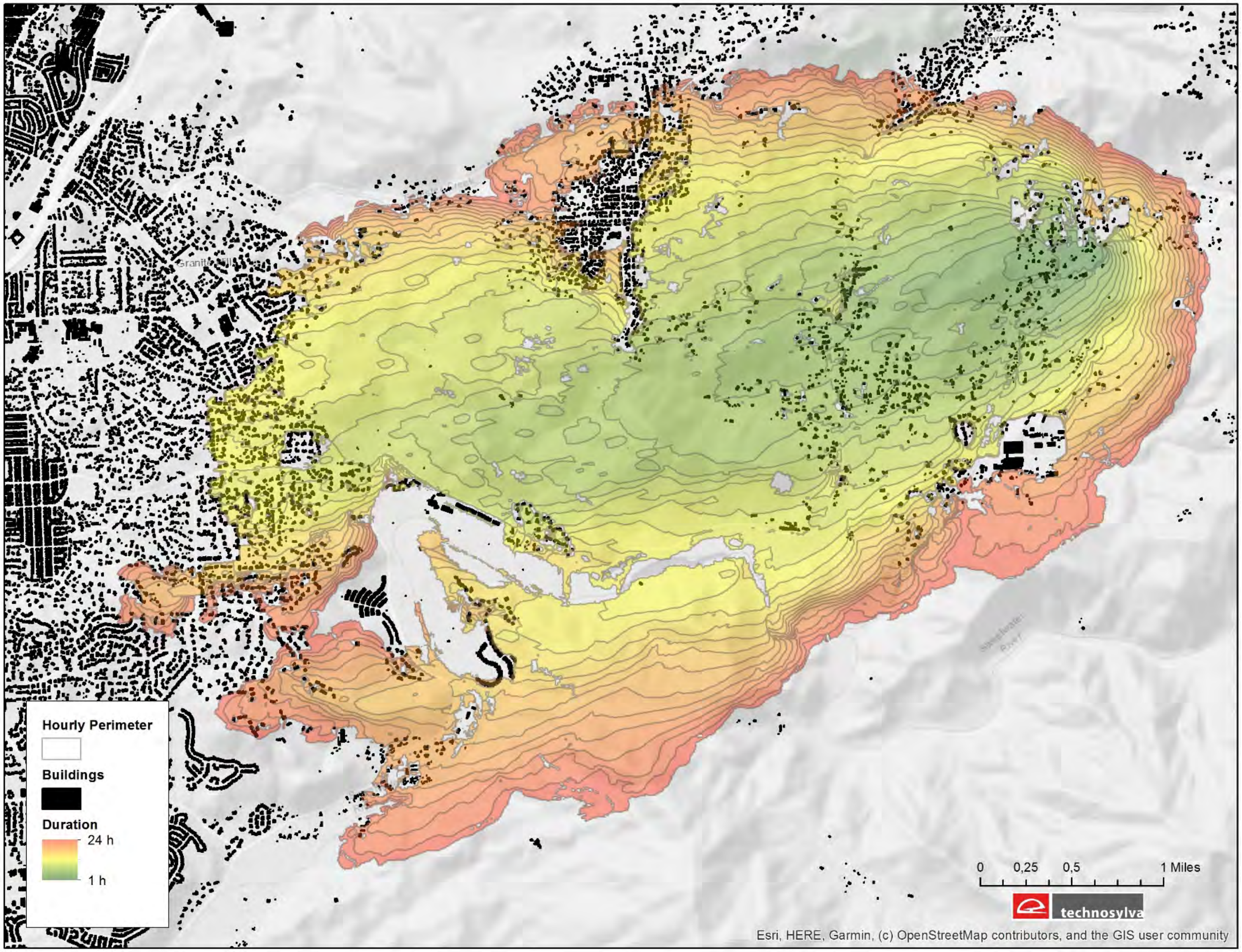


DAMAGE INCIDENT – 5

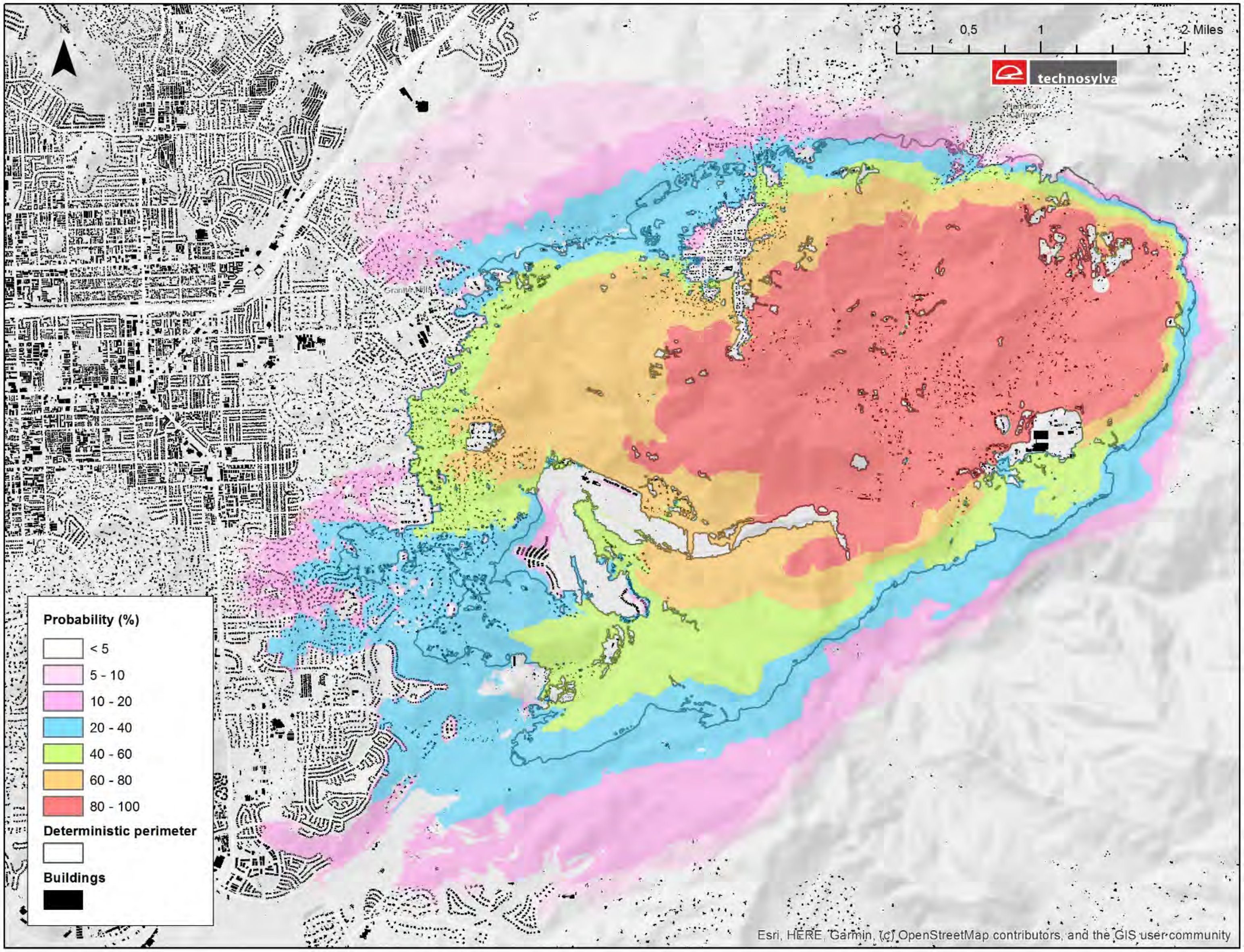
This damage incident, located in the county of San Diego, could ignite a large fire with high impact in terms of population and building loss in urban areas such as Granite Hills, Crest or Harbison Canyon. The rate of spread would be high with moderate-high intensity. The fire would be driven by high winds coming from northeast ranging between 15 and 30 mi/h. Modeled and recorded winds at weather station were similar given the uncertainty derived from weather predictions. The fire would exceed fire suppression capabilities in the initial attack with a very high IAA.

INCIDENT SUMMARY	
Start Time	30/10/2019 9:00
Duration (hrs)	24
Size (ac)	9,108
Initial Attack Assessment	4 – Very High
No. of Buildings	3,126
Total Population	3,276
Average ROS	High

DAMAGE INCIDENT NO. 5 : DETERMINISTIC SIMULATION



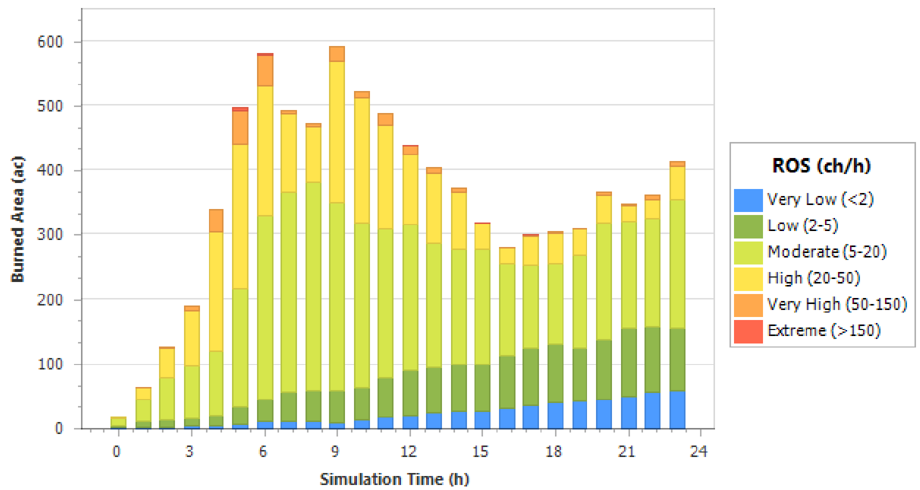
DAMAGE INCIDENT NO. 5 : PROBABILISTIC SIMULATION



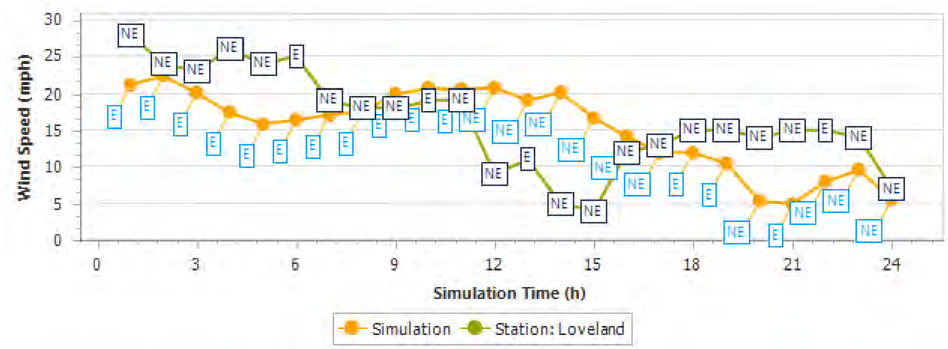
DAMAGE INCIDENT NO. 5

FIRE BEHAVIOR	WEATHER **Nearest Station:** Loveland

Rate of Spread



Station ID - LLDSD
Weather station (Wx) elevation - 1375 ft
Fire ignition point (IP) elevation - 758 ft
Distance between Wx and IP - 1.97 mi



Flame Length