Report on Crown Castle's Compliance with Safety Audit, Wind Study, and Remediation Requirements in Decision 13-09-026

Safety and Enforcement Division

California Public Utilities Commission

March 24, 2017

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I. BACKGROUND

On October 21, 2007, at approximately 4:30 a.m., three wood poles broke and fell to the ground as a result of strong Santa Ana winds in Malibu Canyon, Los Angeles County. The resulting fire burned 3,836 acres, destroyed 14 structures and 36 vehicles and caused damage to 19 other structures. The estimated cost of the fire according to the Los Angeles County Fire Department was $14,528,300. There were no reported injuries or fatalities.

The poles supported overhead supply and communication facilities owned and operated by Southern California Edison Company, Verizon Wireless, AT&T Mobility LLC, Sprint Communications Company, LP, and NextG Networks of California, Inc. (later acquired by Crown Castle, and referred to herein as Crown Castle).

II. SED INVESTIGATION AND FINDINGS

The Safety and Enforcement Division (SED), known at the time as the Consumer Protection and Safety Division, investigated the incident and found all owners and operators of the facilities on the three poles in violation of California Public Utilities Commission's (Commission) General Order 95 (GO 95).

Specifically, SED found that the wind at the time of the incident was approximately 50 miles per hour. According to GO 95, Rule 44, the types of poles involved in the incident must be installed with a safety factor of 4.0. The safety factor can be reduced to two-thirds of the original value subsequent to installation. Even at that lower safety factor, the poles should have been able to withstand winds up to 92.4 miles per hour. SED found all owners and operators of the poles and attached facilities to be in violation of Rules 12, 31, 43 and 44 in GO 95 for failing to properly inspect and maintain their poles and facilities to prevent the safety factors from falling below the minimum requirements.

On October 21, 2008, SED provided the findings of its investigation to the Commission and the Commission released the SED report on December 18, 2008.

III. OII AND DECISION 13-09-026

On January 29, 2009, the Commission issued an Order Instituting Investigation (OII) into whether the owners and operator of the poles that failed in Malibu violated Commission rules. On February 21, 2013, SED and Crown Castle filed a joint motion for approval of a settlement agreement. The settlement agreement was conditionally approved by Commission Decision 13-09-026 on September 24, 2013.

Decision 13-09-026 ordered Crown Castle to:

- Pay $14.5 million, of which $8.5 million was to be paid to the State of California General Fund
- Use the remaining $6.0 million to have an independent contractor conduct a safety audit of all Crown Castle poles and pole attachments in California to ensure that they comply with safety factor requirements
- As part of the safety audit assess whether all facilities in the Malibu Canyon can withstand the maximum foreseeable Santa Ana windstorm and take corrective action as necessary
- Complete any remedial work necessitated by the audit within three years of commencing the audit
- Pay any remaining money after the safety audit is complete to the State of California General Fund
- Perform a safety audit of every new pole or pole attachment within 30 days of installation
- Provide bi-monthly reports on the safety audit and a final report to SED

Decision 13-09-026[1] also required SED to prepare a report, after Crown Castle's submission of its final bi-monthly report, that summarizes results of the safety audit, identifies the Santa Ana wind loads that Crown Castle used to assess its poles and pole attachments in Malibu Canyon,

[1] Subsection (xiv) of Ordering Paragraph 1 in Decision 13-09-026.

and addresses Crown Castle's remediation actions. SED prepared and is filing, serving, and posting this report as directed.

IV. COMPLIANCE WITH SAFETY AUDIT, WIND STUDY, AND REMEDIATION REQUIREMENTS IN DECISION 13-09-026

Crown Castle, with the assistance of Connect Solutions Engineering and Davey Resource Group, independent contractors, conducted a safety audit of its system in compliance with Decision 13-09-026. During the audit, Crown Castle provided bi-monthly reports to SED and a final report was delivered during a meeting with SED on September 8, 2016. Crown Castle used the $6.0 million in the stand-alone bank account safety fund for the safety audit. A copy of Crown Castle's final report to SED is attached (Attachment A).

During the approximately three year period, 100% of Crown Castle's 61,751 poles were inspected for compliance. The inspections included photo collection and structural analysis generation. 33,640 poles were found to be compliant and maintenance issues were found on 28,111 poles. Over 12,000 maintenance issues were discovered and repaired. Issues belonging to other pole owners and operators were packaged and delivered to the affected parties.

Crown Castle developed an auditable database, referred to as the Pole Administration Utility. The database application is used to store and track pole inspections and repair data.

To calculate the maximum foreseeable Santa Ana winds in the Malibu Canyon, Crown Castle, in partnership with REAX Engineering, conducted a wind study. A copy of the wind study is attached (Attachment B). As part of the study, anemometer stations were installed to collect weather measurements during the 2014 and 2015 Santa Ana wind seasons. The weather data and wind speeds were collected to determine the maximum reasonably foreseeable wind speed. In addition, approximately 30 years of historical Santa Ana wind events were analyzed via Numerical Weather Prediction, a method that uses mathematical models to predict the weather based on current weather conditions to feed into a localized high resolution analysis of wind speeds in Malibu Canyon.

The study found that in one section of the canyon, the maximum foreseeable (50 year) 3-second gust wind speed is estimated to be 110 mph, from the SW direction. The other sections of the canyon had a maximum foreseeable wind gust speed of only 69 mph, corresponding to a possible

12 psf wind load. To accommodate these wind speeds, Crown Castle considered all spans to be subject to the 12 psf load, and the spans in the most severe section to be subject to the 110 mph wind, at its known orientation to the line. In all cases, appropriate safety factors were applied, based on the pole material and consistent with GO 95 Rule 31.1 "accepted good practice for the given local conditions."

There are 82 poles in the Malibu Canyon, beginning at the intersection of Malibu Canyon Road and Mesa Peak Tractor Way, to which Crown Castle has attachments. Under 8 psf wind load and a 2.67 safety factor, the current standard with no consideration for the maximum foreseeable wind, 17 poles would require corrective action. Under 12 psf wind load and a 4.0 safety factor, the standard that will be used for the Malibu Canyon, 34 poles would require remediation. As these poles are jointly owned and operated by parties other than Crown Castle and replacing them is a coordinated effort, Crown Castle plans to work with other joint pole owners to replace or reinforce the poles requiring remediation.

V. CONCLUSION

SED monitored Crown Castle's compliance with the safety audit, wind study, and remediation requirements in Decision 13-09-026 by:

- Reviewing the bi-monthly reports
- Discussing Crown Castle's detailed findings and corrective actions
- Conducting audits of Crown Castle's facilities in Northern and Southern California
- Meeting with Crown Castle and REAX Engineering on several occasions to discuss compliance details
- Reviewing Crown Castle's final report

SED has determined that Crown Castle is in compliance with these requirements in Decision 13-09-026, with the caveat that pole remediation in Malibu Canyon is taking longer than anticipated, due to reasons not within Crown Castle's control. SED does not recommend any further action at this time.

ATTACHMENT A

CROWN CASTLE'S AUDIT FINAL REPORT

SED Audit Final Report

Project Summary

Introduction

On September 19, 2013, the California Public Utilities Commission ("CPUC" or "Commission") approved a settlement agreement between NextG Networks of California, Inc. ("NextG") and the Commission's Safety and Enforcement Division ("SED").[1] That decision resolved all issues in the underlying investigation proceeding and outlined certain terms required of NextG in order to implement the settlement agreement over the course of a three-year period.

During the past three years Crown Castle has provided the Commission bi-monthly updates regarding its work to implement the terms of the Settlement Decision. A final report was submitted to the Commission in September and this project summary provides an overview of the entirety of the settlement implementation efforts. As detailed in the bi-monthly reports and below, Crown Castle has met and exceeded the required conditions of the Settlement Decision through the development and implementation of a comprehensive audit program that involved the inspection of over 60,0000 utility poles. Crown Castle's network facilities have been audited by Commission staff and Crown Castle has implemented an aggressive inspections program to ensure the ongoing safety and reliability of its utility infrastructure.

Facility Audit Overview

Crown Castle audited all poles and pole attachments in California, previously owned by NextG Networks, over the course of approximately two years, totaling 61,751 pole inspections. During this audit, each attachment was visually reviewed by an authorized engineering contractor for GO 95 compliance related to safety risks and authorized attachment practices. All poles, whether exhibiting issues or not, were photographed and timestamped to document the state of construction. A record was created in a Filemaker Pro system, cataloging the inspection information, any issues, and all pole asset information, such as GPS coordinates, location information, and pole tag data. Any and all found issues for which Crown Castle was responsible were slated for immediate review and reconciliation. All issues for which another utility was responsible were packaged and delivered via a formal notification to the affected party. Notifications, resolution documentation, and correspondence were all recorded.

[1] Decision No. 13-09-026 (also referred to as the "Settlement Decision"). Notably, NextG was acquired by Crown Castle in 2012 and Crown Castle ultimately assumed responsibility for implementing the terms of the settlement agreement.

In addition to GO 95 compliance and maintenance issues, the audit also involved the collection and review of data regarding joint use agreements for each pole, comparing internal record asset data and the Southern California Joint Pole Committee (SCJPC) pole card data to ensure all attachments had appropriate authorizations. Items missing an attachment authorization or requiring additional review were cataloged for resolution through the SCJPC. Due to the lack of a pole record system at the Northern California Joint Pole Association (NCJPA), poles located in this region were researched against our internal records only.

Pole and attachment specification data was collected at every pole and input into a structural analysis program, documenting heights of attachment, equipment sizes, and facility specifications of all attached utilities. This data was used to calculate existing pole capacity and generate a level of safety for further review. These analyses incorporated pole height, class, type and age, as well as stress contributions at several different load points. Poles found to be out of compliance were scheduled for engineering remediation. Equipment non-compliances belonging to another utility, such as an insufficient guy or an overloaded cross-arm, were documented and the utility in question was notified in order to resolve the issue.

Lastly, intrusive inspection data for all poles to which Crown Castle was attached, were requested from each base pole owner, documented and cataloged in our records. All returned data was reviewed and catalogued. The date of the last intrusive inspection was added to Crown Castle's pole data manager (see section on system development) to ensure proper tracking of future intrusive requirements.

Facility Repairs

All issues found to be the responsibility of Crown Castle to remediate were entered into an auditable system in Filemaker Pro. The resulting data was then reviewed and reconciled by an internal assets team to determine the appropriate repair type, including the following categories:

- Fiber Pole Attachment Issues

  (e.g. cable sag, clearance, guying, as-built verifications)
- Node Pole Attachment Issues

  (e.g. risers, bonding, grounding, clearance, as-built verifications)
- Visual Condition of the Pole

  (e.g. excess lean, cracking, pole damage)
- Vegetation Management Issues

  (e.g. cable abrasion, strain on cables)

- Miscellaneous Issues

  (e.g. lat/long verification, pole record issues, abandoned equipment)

All issues were reconciled to determine the level of remediation review that would be required; preliminary engineering remediation or general construction. Items requiring engineering remediation were sent out for bids to multiple authorized contractors. These contractors were responsible for reviewing the issues presented, suggesting options for resolution, and documenting proposed remediation. Their review included a re-fielding of the pole in question to assess the most current state of construction and the provision of a new structural analysis, both before and after the proposed remediation was applied. If the issue requiring engineering review could be resolved with minimal construction, such as an additional down guy or structural retrofit, that remediation was proposed for construction and a bid was solicited for work by an authorized construction contractor. If the issue required undergrounding of facilities or the replacement of existing infrastructure, Crown Castle contacted the other affected utilities to coordinate the work and ensure all proper documentation was tracked and maintained through Joint Pole Applications (JPAs).

For items that did not require a preliminary engineering review, remediation bids were solicited from Crown Castle's authorized construction vendors immediately. The vendors were required to schedule repairs based on safety priority, per the timelines outlined in GO 95. Their construction work required mobilizing to the pole location, often preceded by a pre-construction field visit, assessing the work required at the time of fielding, including any issues previously documented and any that had since occurred, and conducting the work to ensure overall safety and compliance.

System Development

In order to capture all inspection and repair data in an auditable system for future analysis and provisioning, Crown Castle has developed a comprehensive, Oracle based, proprietary database. The system, referred to as Crown Castle's Pole Administration Utility, consists of several different tool modules:

- **Applications**: Used to store existing attachment authorization, generate applications for new installations or required maintenance, and track authorization throughout the life cycle of a submittal.
- **Owners & Contacts:** A repository of all utilities, jurisdictions, and municipalities with whom Crown Castle conducts business, sends applications for joint use or permitting, and collaborates with on a recurring basis. Within this owner module, contact data for regional and district contacts are stored for streamlined communications.
- **Pole Data:** The Pole Data manager is used to store location, asset, and historical data for all poles to which Crown Castle has attached facilities. The data that is maintained includes GPS coordinates and

location details, pole specifications (e.g. size, class, material), last inspected date and future inspection schedule, etc.

- **Inspections:** Based on the inspection data logged and compiled in the Pole Data manager, recurring inspections are batched and monitored through our inspections tool. The Inspection manager includes an internal interface to generate inspection requests based on geographical determinations, assign them to authorized vendors, and track the inspections through completion. An external vendor tool was also built to provide external users access to the inspection and pole data, ability to enter and update data, including the uploading of photos and structural analysis, and enable project management and vendor accountability. For additional information regarding our Routine Inspections program, please reference the section outlined later in this document.
- **Tickets:** Following the completion of an inspection, all found issues generate a ticket within our Ticket manager for review, prioritization, and resolution. Users can also create tickets manually if a notification of required work is received via a third-party notice or application.

Though housed in different platforms of the system, all modules communicate and interact for efficient data processing and review. For example, data stored in the Pole Data manager is utilized in the modules for Inspection, Ticket, and Application data to ensure overall accuracy and data integrity. Moreover, all data stored within our system is able to be reported on and is auditable via standardized data reports.

Malibu Canyon Wind Study

In order to estimate foreseeable wind speeds and potential safety risks in Malibu Canyon, Crown Castle engaged Dr. Christopher Lautenberger to conduct a wind study in the area outlined in the Settlement Decision, an approximately 3.5-mile stretch along Malibu Canyon Road beginning at the intersection with Mesa Peak Tractor Way and concluding at the intersection of Potter Drive. The wind study included the installation of three weather monitoring stations on wooden utility poles. The station equipment included an anemometer bolted to a cross arm at 21’ above ground level, a solar panel to power the anemometer, and an equipment box below 18’ to house additional monitoring equipment.

The three stations were dispersed throughout the canyon to provide a range of comprehensive weather data. Due to a lack of available utility poles to accommodate the anemometers, two of the stations were placed on temporary poles, with the plan that they would be removed following the completion of the study. The temporary pole for station one was placed approximately 600 feet south of Mesa Peak Tractor Way; the temporary pole for station two was located approximately 1.8 miles south of Mesa Peak Tractor Way. Station three was installed on existing utility pole 1639255E, located approximately 1.15 miles north of Potter Drive. JPA NG-WIND-01 was filed on

December 17, 2014 to notify the existing attached utilities of Crown Castle's proposal and in order to obtain approval for the attachment.

Stations one and two were installed on July 29 2015, while station three was installed on October 30, 2015. All stations were installed by Pacific West Communications ("PWC"), under supervision of the weather engineering team at REAX Engineering. The delay in the installation of station three was due to processing times for required local permitting. All attachments were made in concurrence with GO 95 regulations and safety compliance, as well as under the approval of the impacted utilities and the local jurisdictions. Following installation, data was collected by REAX until June 1, 2016, for a total of 12 months at stations one and two and 8 months at station three. A total of of nine Santa Ana wind events were recorded during the study. REAX also researched historical data for the area and incorporated standard weather patterns in their projections for highest foreseeable wind speeds.[2]

The REAX report has been incorporated into Crown Castle's structural analysis for 82 poles within the 3.5 mile Malibu Canyon project area. Preliminary data has also been shared with the joint pole owners in the same project area and a copy of the final report is being distributed to the joint pole owners. Any and all poles that did not exhibit the required standards have been identified for remediation. Poles with minor issues that could be resolved with minimal reconstruction have been engineered for a solution and solicited for bid by a construction vendor for implementation. For poles with more significant loading issues, Crown Castle is working with other joint pole owners in the area to ensure these poles are replaced as part of the ongoing effort to upgrade all poles in Malibu Canyon.[3]

Routine Inspections and Repairs Program

During the same time-period Crown Castle was implementing the terms of the Settlement Decision, it likewise employed a rigorous routine inspections and repairs program. This program involves batching all poles to which Crown Castle has attachments to better facilitate efficient inspections and reduce mobilization costs. Assets within the state of California were broken up by region (Southern California versus Northern California) and then further into sectors (e.g. S1, S2, S3, etc) and clusters (e.g. S1-A, S1-B, S1-C, etc.) based on geographical boundaries. For Southern California, each sector has approximately 12,243 poles included, with each cluster containing

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[2] For complete details on the data collected and proposed wind safety standards in the area, please reference the attached final report from REAX, outlining what the study revealed and recommendations regarding future installations in Malibu Canyon.

[3] *See* Decision No. 12-09-019 and Decision No. 13-09-028.

approximately 1,360 poles. Similarly, for Northern California, each sector has approximately 954 poles included. Due to the smaller volume of poles in Northern California, clusters are not utilized in this region.

Inspection dates from state-wide audit were input into our Pole Data manager and used to determine when the next recurring inspection was due, based on the terms outlined in GO 95 for Patrolling and Detailed inspections. A schedule was then created to chart out which clusters should be inspected at which date for each calendar year. Each cluster is assigned its own inspection request within our Inspection manager of the Pole Administration Utility for tracking and completion.

Crown Castle plans to conduct approximately 53,000 patrolling and approximately 13,000 detailed inspections annually, for a total of approximately 66,000 poles. To date in 2016, Crown Castle has assigned 34 patrolling and detailed inspections, totaling approximately 43,244 poles. Approximately 22,651 additional poles will be assigned by the end of the year.

CPUC Audits – Southern California & Northern California

During the course of the Malibu Fires settlement project, Crown Castle underwent two Commission audits: one covering Southern California networks and another for Northern California networks. In both instances, Crown Castle was able to present comprehensive and complete data regarding our networks, processes, and internal programs for the PUC to review.

The Southern California audit took place from March 4 to March 8, 2013, and included a review of Crown Castle facilities in Los Angeles and Orange County regions, particularly focusing on poles in the West Los Angeles-Malibu district. The audit results, provided on June 3, 2013, found a few minor issues in relation to guying standards and attachment practices, all of which were resolved on an expedited schedule.

Two years later, the Northern California audit was held from October 12 to October 14, 2015. During this review, facilities in Crown Castle's San Jose and San Mateo networks were reviewed for compliance. Crown Castle received preliminary feedback from the PUC on February 8, 2016, outlining some minor issues requiring review, which were reconciled and resolved promptly.

ATTACHMENT B

MAXIMUM REASONABLY FORESEEABLE SANTA ANA WIND LOADS IN MALIBU CANYON

Reax Engineering Inc.
Job # 14-0276

Maximum Reasonably Foreseeable Santa Ana Wind Loads In Malibu Canyon

Prepared for Crown Castle USA Inc.

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August 22, 2016

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1.0 INTRODUCTION

California Public Utilities Commission Decision 13-09-026, dated September 19, 2013, documents the conditions of the Settlement Agreement between NextG and the California Public Utilities Commission's Safety and Enforcement Division (SED) following the 2007 Malibu Canyon Fire. One of the conditions of the settlement agreement is that NextG shall conduct a safety audit that includes, among others, the following tasks:

> (A) determine the maximum, reasonably foreseeable Santa Ana wind load(s) in Malibu Canyon; and
> (B) assess whether NextG's poles and pole attachments in Malibu Canyon can withstand the maximum, reasonably foreseeable Santa Ana windstorm. NextG shall document, and retain as part of its audit records, the
> (C) specific Santa Ana wind load(s) that were used in this assessment, and
> (D) wind-loading calculations that were used in this assessment.

This report addresses items (A) and (C) and is intended to serve as an input to items (B) and (D) above (to be completed by others). It involves determining the "maximum, reasonably foreseeable Santa Ana wind load(s) in Malibu Canyon" as per the Settlement Agreement.

2.0 BACKGROUND

2.1 Basic meteorology of Santa Ana winds

Santa Ana winds, or Santa Anas, are hot and dry winds that typically blow through Southern California each year, often between the months of October and April. Santa Anas occur when high pressure forms in the Great Basin (Western Utah, much of Nevada, and the Eastern border of California) with lower pressure off the coast of Southern California. This pressure gradient drives airflow toward the Pacific Ocean.

As air travels West from the Great Basin, orographic lift dries the air as it rises in elevation over mountain ranges. As air descends from high elevations in the Sierra Nevada, its temperature rises dramatically (~5 °F per 1000 ft decrease in elevation). A subsequent drop in relative humidity accompanies this rise in temperature. This drying/heating phenomenon is known as a katabatic wind. Relative humidity in Southern California during Santa Anas is often 10% or lower.

In Southern California, Santa Ana winds typically blow from the North/Northeast. Gusts of 50+ mph, particularly in canyons, are not unusual during Santa Anas. In the Malibu area, Santa Ana winds are channeled through Topanga, Malibu, and Corral Canyons toward the coast.

2.2 Previous estimates of Santa Ana wind speeds in Malibu Canyon

During litigation that followed the 21 October 2007 Canyon Fire, which was ignited due to structural failure of electrical assets in the East/West section of Malibu Canyon Road, expert witnesses developed estimates of wind speed at the time of ignition. Their opinions are summarized briefly here.

2.2.1 Spatial Informatics Group (SIG)

Through a combination of in situ wind measurements, analysis of historical wind observations, and simple wind modeling, Spatial Informatics Group, LLC (SIG) concluded [1]:

> ...the historical annual average maximum gust speed across the simulated ignition location points is 67 mph with a 95% confidence interval upper boundary of 69 mph. The maximum simulated wind gusts at the Malibu Canyon Fire ignition location during the logged period, which is relatively short (~15 years), are roughly 75 mph.

2.2.2 Cermak Petersen Peterka (CPP)

Dr. Jon Peterka, of CPP Inc., determined that wind gusts at the time of ignition of the Canyon Fire was significantly higher than the SIG estimate, writing [2]:

To a reasonable degree of engineering certainty, I estimate that the wind gust speed at fire site at ignition time was 114 mph with an estimated range of 101 – 130 mph for fire ignition time of 4:50 am PDT. It is highly likely that the strongest wind gusts at this time were within this range. The steep and complex geometry of Malibu Canyon at the fire ignition site combined with the strong Santa Ana winds on the day of the fire created a strong rotor (a rotating eddy wind flow with a horizontal axis aligned with the canyon axis) in the canyon. The local wind direction at the ignition site at time of ignition was from the southwest (toward the canyon bottom at the location of the poles) caused by the strong rotor within the canyon that turned winds from the northeast above the canyon to southwest at the bottom of the canyon at the pole locations.

2.3 Malibu Canyon study area

The Settlement Agreement [3] defines Malibu Canyon as "the area in the vicinity of Malibu Canyon Road between Potter Drive and Mesa Peak Tractor Way." For the purposes of this report, the "study area" refers to Malibu Canyon as defined in the Settlement Agreement. This study area is shown in red in Figure 1. The distance along Malibu Canyon Road between Potter and Mesa Peak Tractor is approximately 3.5 miles.

Figure 1. Malibu Canyon study area (red) as defined in Settlement Agreement.

2.4 Malibu Canyon topography and its effect on wind characteristics

Winds in the study area are strongly affected by topography, including canyon walls and ridges. For this reason, it is important to understand the primary topographical features that affect wind characteristics in the study area. Figure 2 shows 50 m elevation contours overlaid on an elevation raster. Another way of visualizing the terrain, known as a hillshade raster, is shown in Figure 3. This simulates the way the terrain would appear when illuminated by a light source from the Northwest.

Within the study area, Malibu Canyon Road can be divided into roughly 3 separate sections based on wind characteristics in each section (see Figure 4). The first section extends from Mesa Peak Tractor Way at the North to the first major bend in Malibu Canyon Road where its orientation changes from primarily North/South to primarily East/West. The second distinct section is the portion of Malibu Canyon Road that runs East/West. Finally, the third section runs South from the second major bend in Malibu Canyon Road to Potter Road.

In this first section (Mesa Peak Tractor Way south to the first S curve), Malibu Canyon Road parallels Malibu Creek, which runs primarily South/Southwest. The topography is such that for North/Northeast winds, as Santa Anas typically are, flow constriction, channeling, and associated acceleration are expected to occur as winds travel from the "mouth" of Malibu Canyon (near Mesa Peak Tractor Way) toward the S curves.

In the second section – the ~3/4 mi nominally East/West stretch of Malibu Canyon Road – wind characteristics during Santa Anas are affected by Piuma Ridge to the North. This ridge, with an elevation of approximately 1,400 to 1,700 feet, is approximately 1000 ft above the East/West stretch of Malibu Canyon Road (which has an elevation of approximately 500 ft). During North/Northeast Santa Anas, wind accelerates over this ridge and, as described in Section 2.2.2, a recirculation zone forms on its leeward side. This causes turbulent eddies to descend from Piuma Ridge into Malibu Canyon. This phenomenon is sometimes referred to as flow separation, recirculation, or a wind rotor. It effectively transports high velocity parcels of air from the top of Piuma Ridge to lower elevations including Malibu Canyon Road.

The third section of the study area extends from the Eastern part of the East/West section of Malibu Canyon Road South to Potter Road. This section is characterized by a progressively widening canyon as one travels further South. For this reason, wind speeds are expected to be the highest at the North end of Section 3, and lowest closer to Potter Road where the canyon opens up.

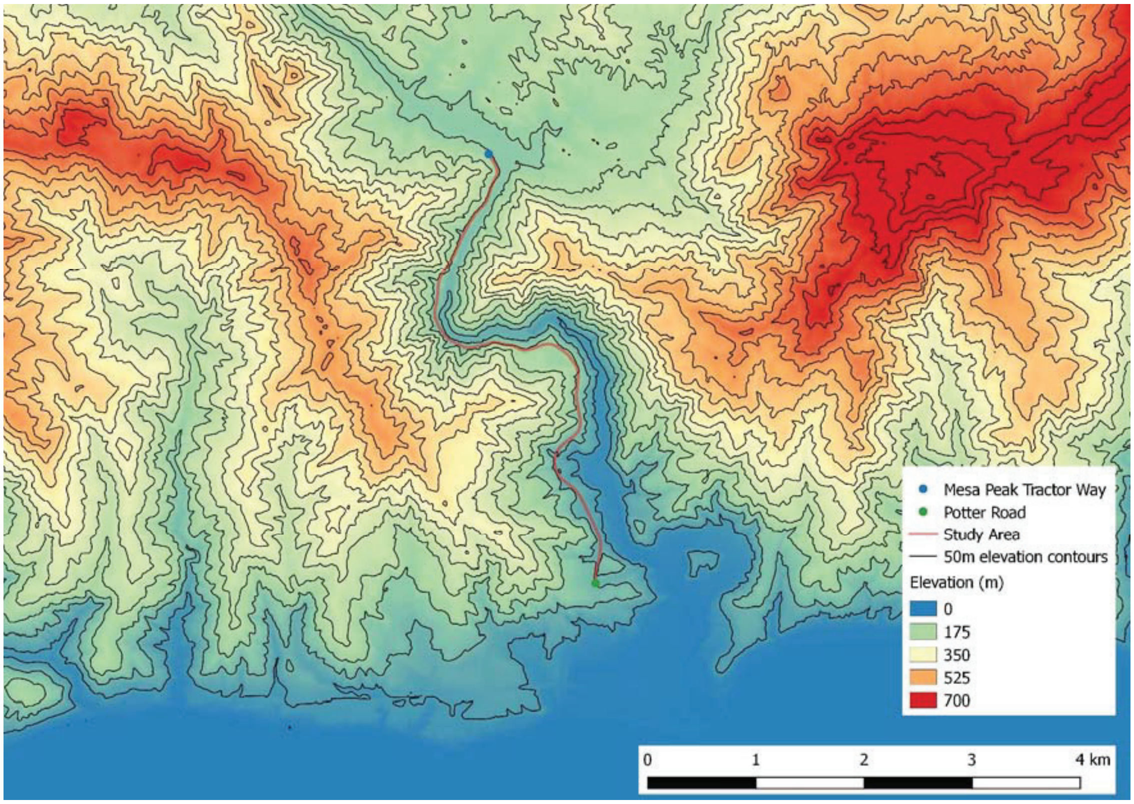

Figure 2. Malibu Canyon topography – digital elevation model and elevation contours.

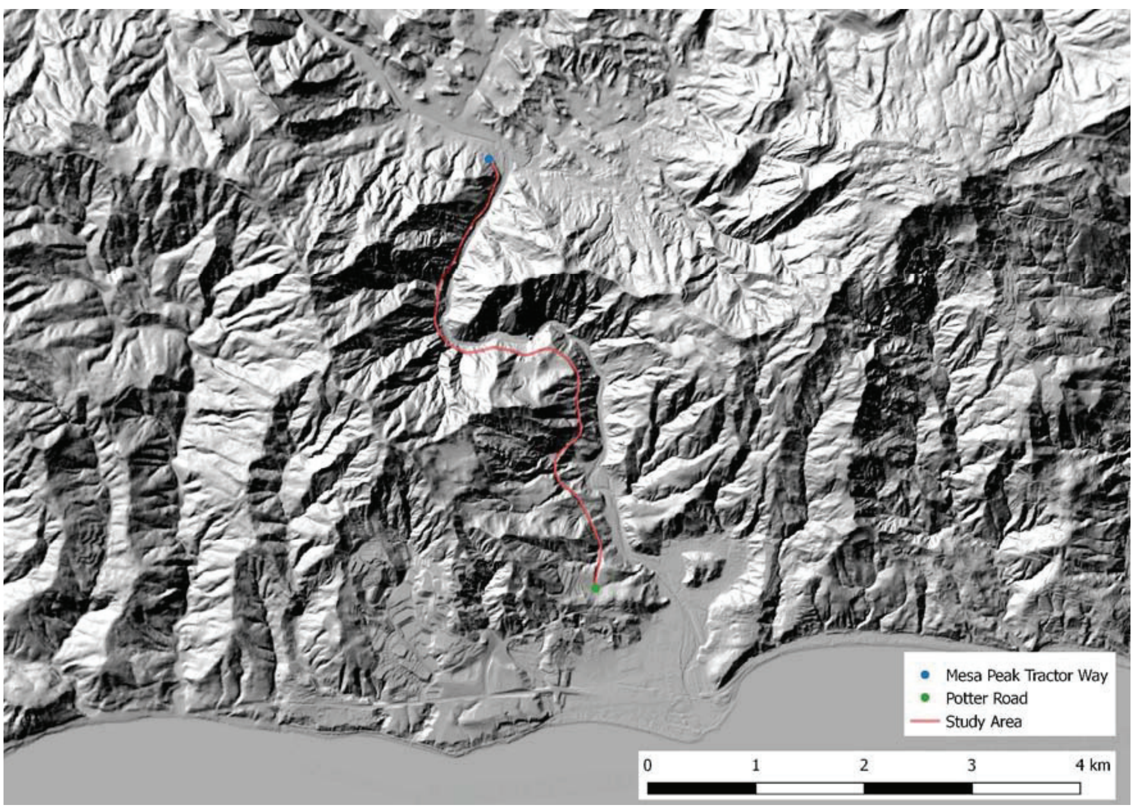

Figure 3. Malibu Canyon topography – hillshade raster.

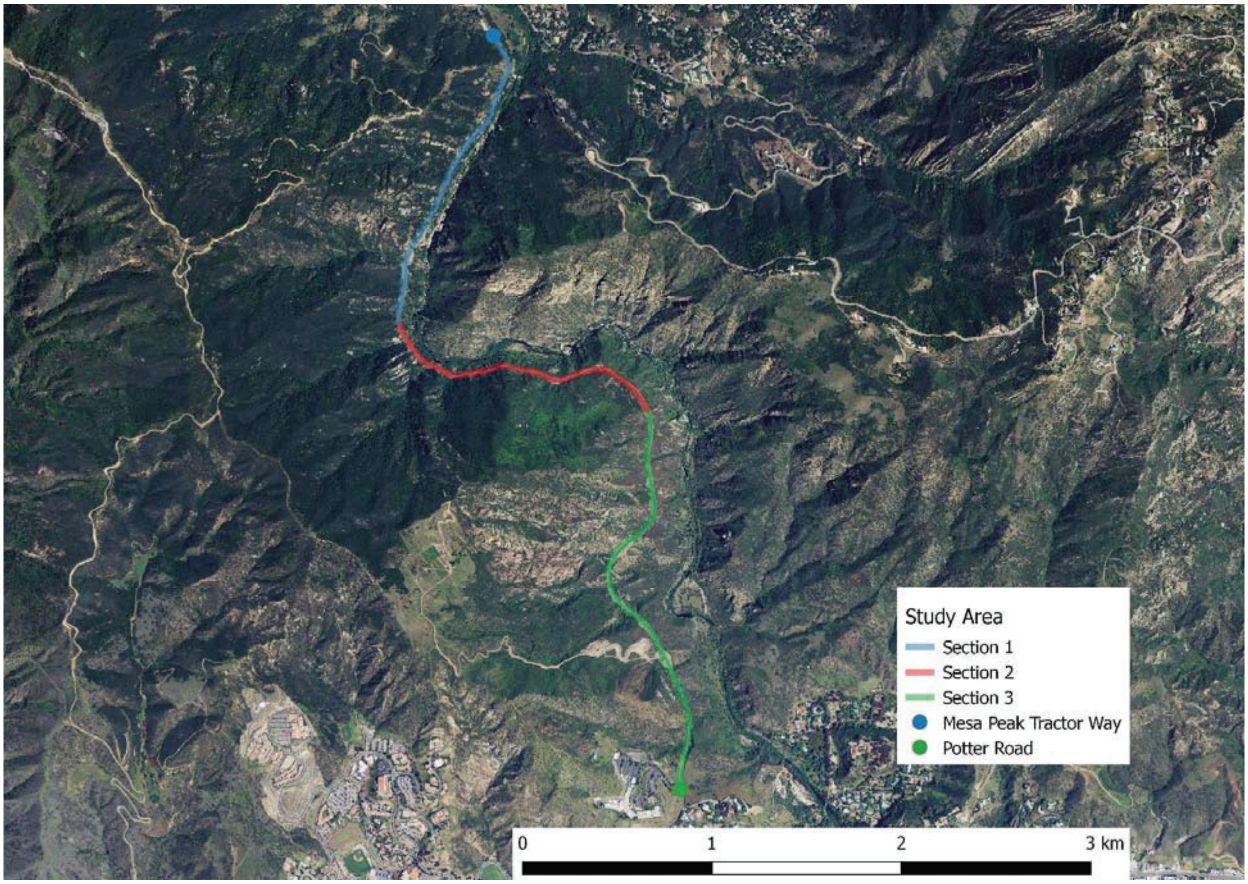

Figure 4. Three separate sections of the study area.

3.0 Wind and Weather Observations

In this study, two separate sets of weather observations were considered. These include in situ measurements made in Malibu Canyon via instrumentation installed specifically for this study (Section 3.1) and nearby Remote Automated Weather Stations (RAWS, Section 3.2).

3.1 In situ measurements

A primary component of this study involved installation of three meteorological stations in Malibu Canyon to facilitate in situ wind measurements. Station installation and monitoring were conducted by Leidos, and full details are given in the Leidos report [4] attached hereto. A brief summary of the meteorological monitoring program is provided here.

Figure 5 shows the locations of the three stations that were installed for this study. Station 1, the Northernmost station, is located just South of Mesa Peak Tractor Way and is intended to characterize winds in Section 1 of the study area (see Figure 4). Station 2 is located along the section of Malibu Canyon Road that runs East/West and is intended to characterize winds in Section 2 of the study area (see Figure 4). Finally, Station 3 is located approximately ½ mile South of the East/West stretch of Malibu Canyon Road and is intended to characterize winds in Section 3 of the study area (see Figure 4). All stations include anemometers mounted at 20 ft above ground level, and Station 3 also includes sensors for measuring air temperature and relative humidity. An annotated photograph of Station 3, looking South toward Potter Road, is presented in Figure 6.

Due to permitting and other logistical issues, the stations were not installed simultaneously. Stations 2 and 3 were installed on July 1, 2015 and Station 1 was installed on October 30, 2015. A summary of each station is presented in Table 1.

Nine separate Santa Ana events were captured between October 2015 and April 2016. A summary of the measured peak 3 second wind gusts for each of these nine Santa Ana events is presented in Table 2. These data will be discussed further in Section 5.0.

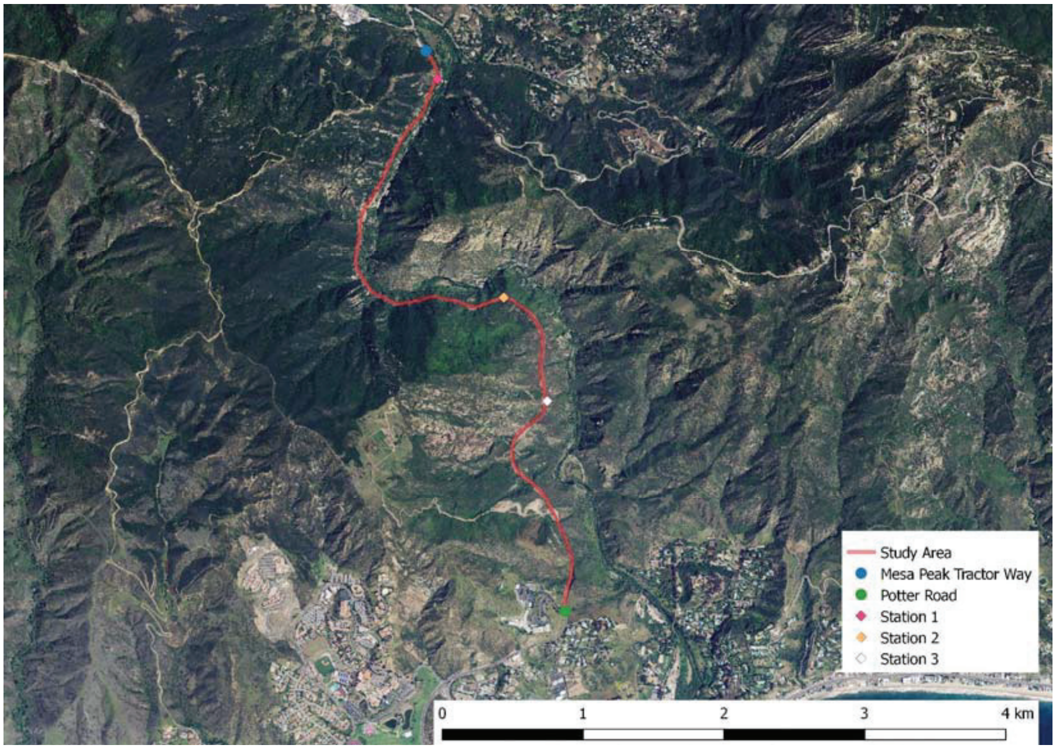

Figure 5. Locations of meteorological monitoring stations installed for this study.

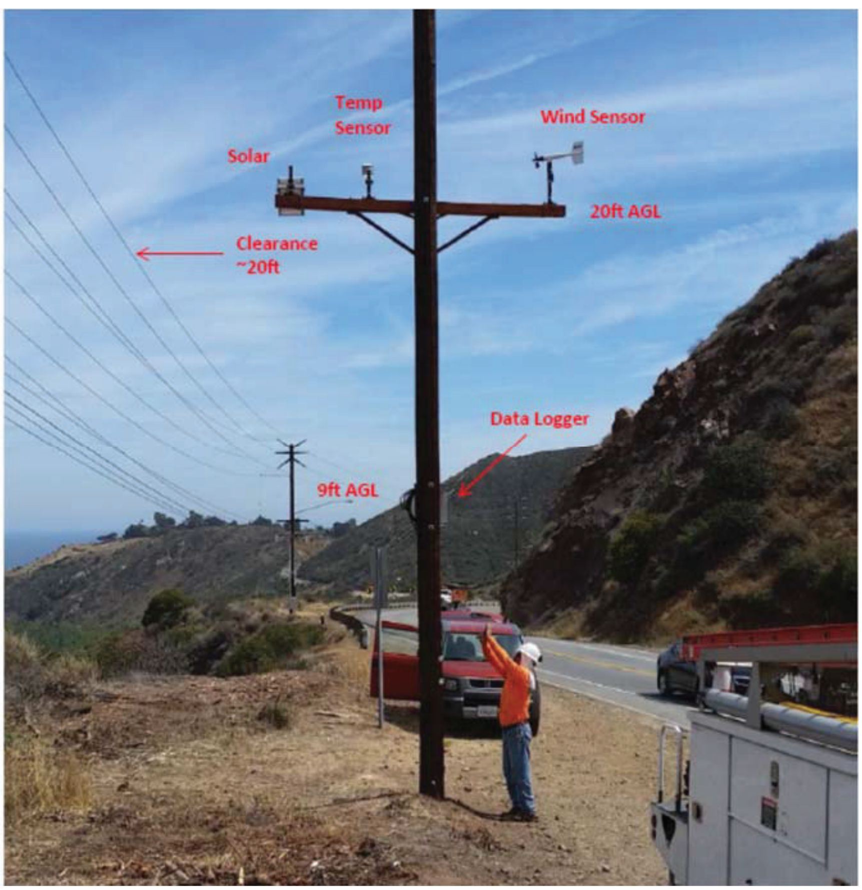

Figure 6. Station 3 looking South (courtesy Leidos).

Table 1. Summary of meteorological stations installed for this study.

Station #	Latitude	Longitude	Elevation	Install date	Sensors
1	34.07764	-118.70226	510 ft	10/30/15	wind only
2	34.06368	-118.69719	540 ft	7/1/15	wind only
3	34.05708	-118.69385	500 ft	7/1/15	wind, temperature, RH

Table 2. Measured peak 3-second wind gust (peak) during Santa Ana events.

Event #	Dates (UTC)	Station 1	Station 2	Station 3
1	10/29/15 – 10/31/15	n/a[1]	55.4	39.3
2	11/16/15 – 11/18/15	27.4	64.5	44.1
3	12/14/15 – 12/16/15	24.6	44.7	40.6
4	12/26/15 – 12/28/15	43.1	52.7	39.5
5	2/4/16 – 2/8/16	28.2	44.9	34.0
6	2/14/16 – 2/17/16	33.1	44.6	41.0
7	2/22/16 – 2/24/16	36.3	42.2	33.0
8	3/21/16 – 3/25/16	28.0	48.9	39.0
9	4/14/16 – 4/17/16	38.5	55.0	42.2

Notes:

1. n/a[1]: Station 1 was not operational until 1400 hours, 10/30/15, which was after peak winds were measured on that day at the other stations.

3.2 Remote Automated Weather Stations (RAWS)

In addition to the in situ measurements described above, weather observations from several nearby RAWS stations were also analyzed. Observations were obtained from MesoWest [5]. The stations selected for analysis include Cheesboro (CEEC1), Malibu Canyon (MBCC1), Malibu Hills (MBUC1), Topanga (TPGC1), and Leo Carrillo Beach (LCBC1). Key metadata for each station is presented in Table 3 and the locations of these weather stations relative to the study area are shown in Figure 7. Data collected from these stations These will be discussed in Section 5.0.

Table 3. RAWS metadata.

Station	Latitude	Longitude	Elevation	Availability	Notes
CEEC1	34.18658	-118.71956	1707 ft	12/2/99 – current	ridgetop N of study area
LCBC1	34.04511	-118.93599	50 ft	1/2/00 – current	E of study area near ocean
MBCC1	34.08394	-118.70345	610 ft	9/28/05 – current	ridgetop N of study area
MBUC1	34.06156	-118.64522	1575 ft	12/2/99 – current	ridgetop 3 mi E of study area
TPGC1	34.13624	-118.606	1600 ft	6/27/11 – current	ridgetop NE of study area

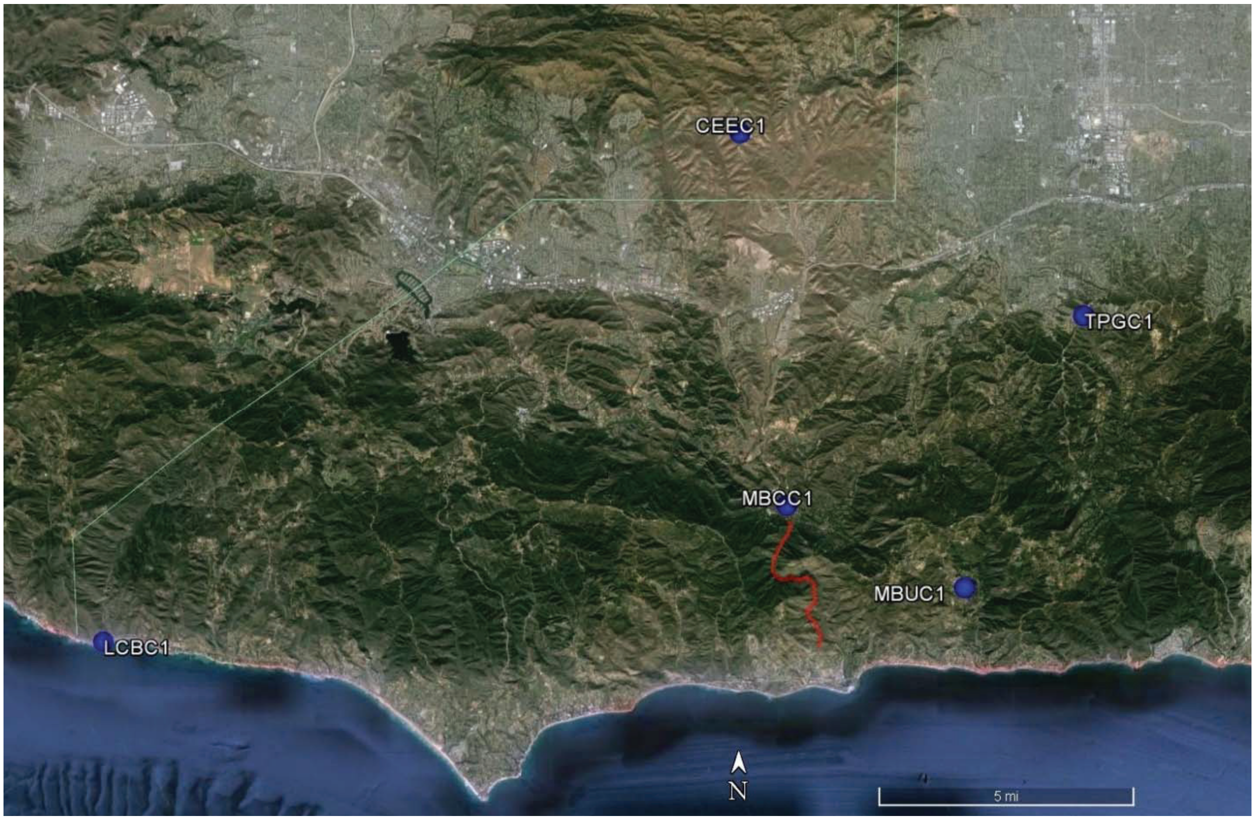

Figure 7. Locations of RAWS stations relative to study area.

4.0 COMPUTATIONAL MODELS

Several computational tools were used to supplement analysis of in situ and RAWS wind speed observations. These include Numerical Weather Prediction (NWP, Section 4.1), high resolution Computational Fluid Dynamics (CFD) wind modeling (Section 4.2), and mass-consistent wind modeling (Section 4.3). Each of these tools is discussed briefly in this section and their application to estimate maximum reasonably foreseeable wind speed is deferred to the analysis presented later in Section 5.0.

4.1 Numerical Weather Prediction (NWP)

One of the tools used in this work to quantify maximum reasonably foreseeable wind speeds in Malibu Canyon is NWP. The Weather Research and Forecasting (WRF) [6-7] mesoscale weather model, Version 3.7.1, was run in a nested configuration with three telescoping domains as shown in Figure 8. The innermost domain (d03) had a resolution of 1.2 km, while the middle (d02) and outer (d01) domains had resolutions of 3.6 km and 10.8 km, respectively. The innermost domain was 96 cells by 96 cells (115 km by 115 km). To provide a sense of the resolution of the innermost (finest) computational domain relative to the study area, Figure 9 shows the grid cells of the innermost computational domain and the locations of the three stations installed as part of this work overlaid on orthoimagery. Although 1.2 km is considered very high resolution for NWP, Figure 9 shows that Station 2 and Station 3 fall within the same computational cell, meaning the WRF analysis cannot differentiate between wind conditions at Station 2 and Station 3 (except perhaps through the use of different gust factors at each station).

For each grid cell shown in Figure 9, WRF calculates a vertical stack of meteorological data (wind speed and direction, temperature, relative humidity, etc.) at multiple heights above ground level, referred to as “vertical levels”. In this case, WRF was run with 40 vertical levels. As is common practice, meteorological data were saved at hourly intervals, although it must be understood that those hourly intervals do not represent hourly averages but rather the instantaneous state of the atmosphere in the WRF model. Historical meteorological conditions were simulated using the North American Regional Reanalysis (NARR) dataset [8] to provide initial conditions and lateral boundary conditions.

Meteorological data were generated for 30 years (1986 – 2015) for the months of October and November. These two months were selected for analysis because historically some of the most severe or damaging fires have occurred in these months, although the strongest Santa Ana winds in a given season do not necessarily occur in October or November. Additionally, meteorological data were generated for December 2015 through April 2016 to facilitate comparison of measured and modeled Santa Ana wind speeds during the time period that Santa Anas occurred while in situ observations were made in Malibu Canyon.

The WRF physics options used in this analysis are summarized in Table 4.

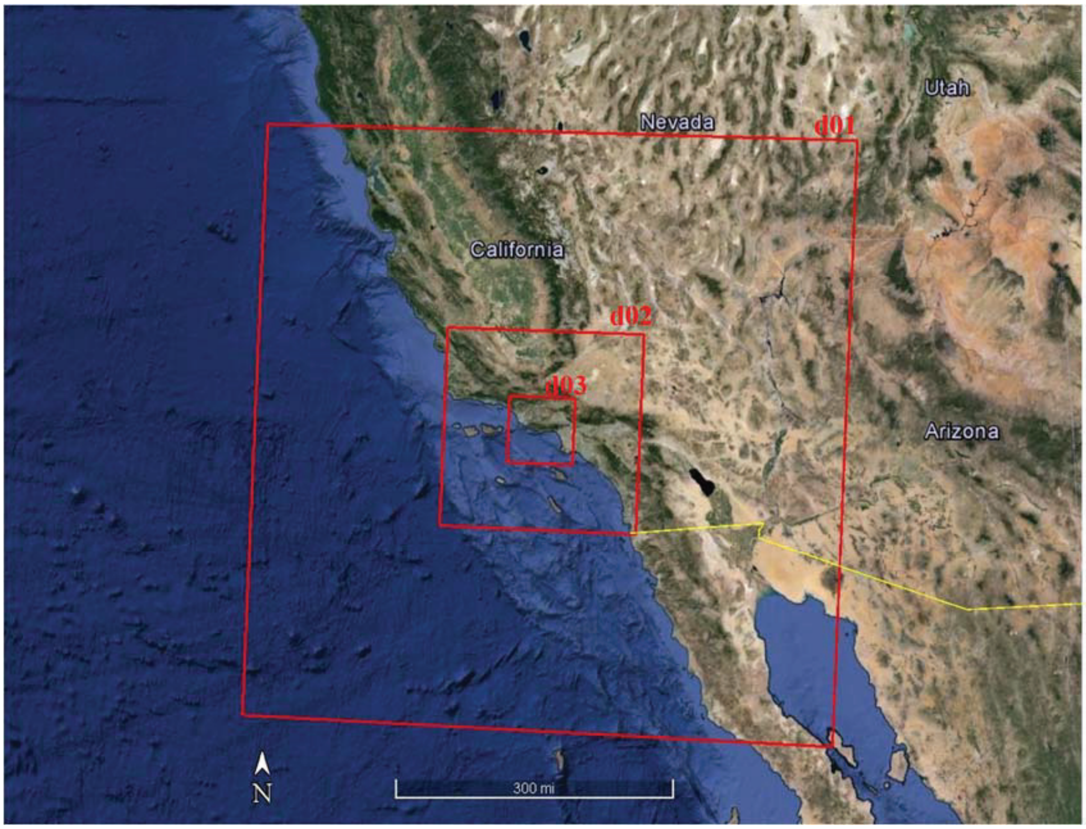

Figure 8. WRF nested domains. d03 is inner nest, d02 is middle nest, and d01 is outer nest.

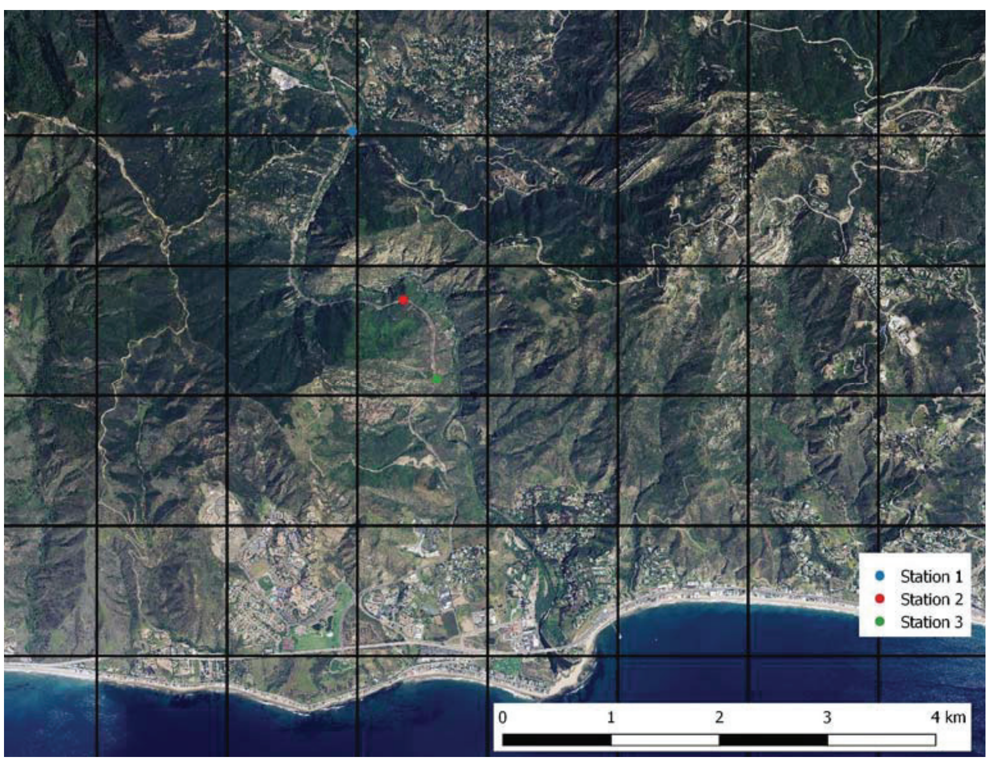

Figure 9. WRF grid cells in innermost computational domain and locations of three meteorological stations.

Table 4. Primary WRF physics options.

Physics option	Value
microphysics (mp_physics)	8: Thompson *et al*. scheme
longwave radiation (ra_lw_physics)	24: Fast RRTMG
shortwave radiation (ra_sw_physics)	24: Fast RRTMG
surface layer (sf_sfclay_physics)	5: MYNN surface layer
land surface (sf_surface_physics)	2: Noah land surface model
planetary boundary layer (bl_pbl_physics)	5: MYNN level 2.5 PBL
cumulus parameterization (cu_physics)	1: Kain-Fritsch (outer domain only)

4.2 High Resolution Computational Fluid Dynamics (CFD)

Fire Dynamics Simulator (FDS) Version 6.4.0 [9-10] was used to investigate three dimensional wind patterns in Malibu Canyon under Santa Ana conditions. FDS is a Computational Fluid Dynamics (CFD) model developed by the US National Institute of Standards and Technology (NIST). It simulates fluid flow by solving the Navier Stokes equations using a Large Eddy Simulation (LES) turbulence model. In LES, turbulent structures resolvable at the grid scale are computed directly, while subgrid-scale turbulence is modeled. LES was developed in the 1960's and 1970's to model atmospheric processes.

A 6 km by 6 km computational domain was centered on the study area. In the vertical direction, the computational domain extended to from sea level to 3,000 m (approximately 9,800 ft) above sea level. The computational domain was gridded with 32,000,000 cells, corresponding to a cubic grid spacing of 15 m. Terrain was specified from a 1/3 arcsecond digital elevation model (DEM) that was warped and upsampled to 15 m in the same Lambert Conic Conformal (LCC) projection used by WRF. 2014 National Agriculture Imagery Program (NAIP) orthoimagery was upsampled to 15 m and draped over the terrain field to facilitate visualization and identification of landmarks. Figure 10 is an isometric view of the terrain and computational domain.

Boundary conditions (air temperature, wind speed, and wind direction) were obtained from post-processed WRF data. Each 6 km face of the FDS computational domain maps to five 1.2 km WRF cells. For each WRF cell, vertical profiles of air temperature and wind speed/direction were extracted and specified as boundary conditions on two of the four vertical faces of the FDS computational domain. The remaining two faces were specified as open (zero gradient) outflow boundaries. For Santa Ana conditions, the prevailing wind direction is from the Northeast, so vertical wind and temperature profiles were specified on the North and East faces of the FDS computational domain, while the South and West faces were specified as open. The top face of the computational domain was specified as a free-slip adiabatic surface.

Using 32 computational cores, processing times are on the order of 1-2 days to simulate 1 hour of real-time wind conditions. As such, only a limited number of Santa Ana conditions were analyzed primarily to assess the degree of flow acceleration due to confinement in Malibu Canyon and analyze the recirculation pattern or wind rotor along the East/West running stretch of Malibu Canyon Road. This will be discussed further in Section 5.0.

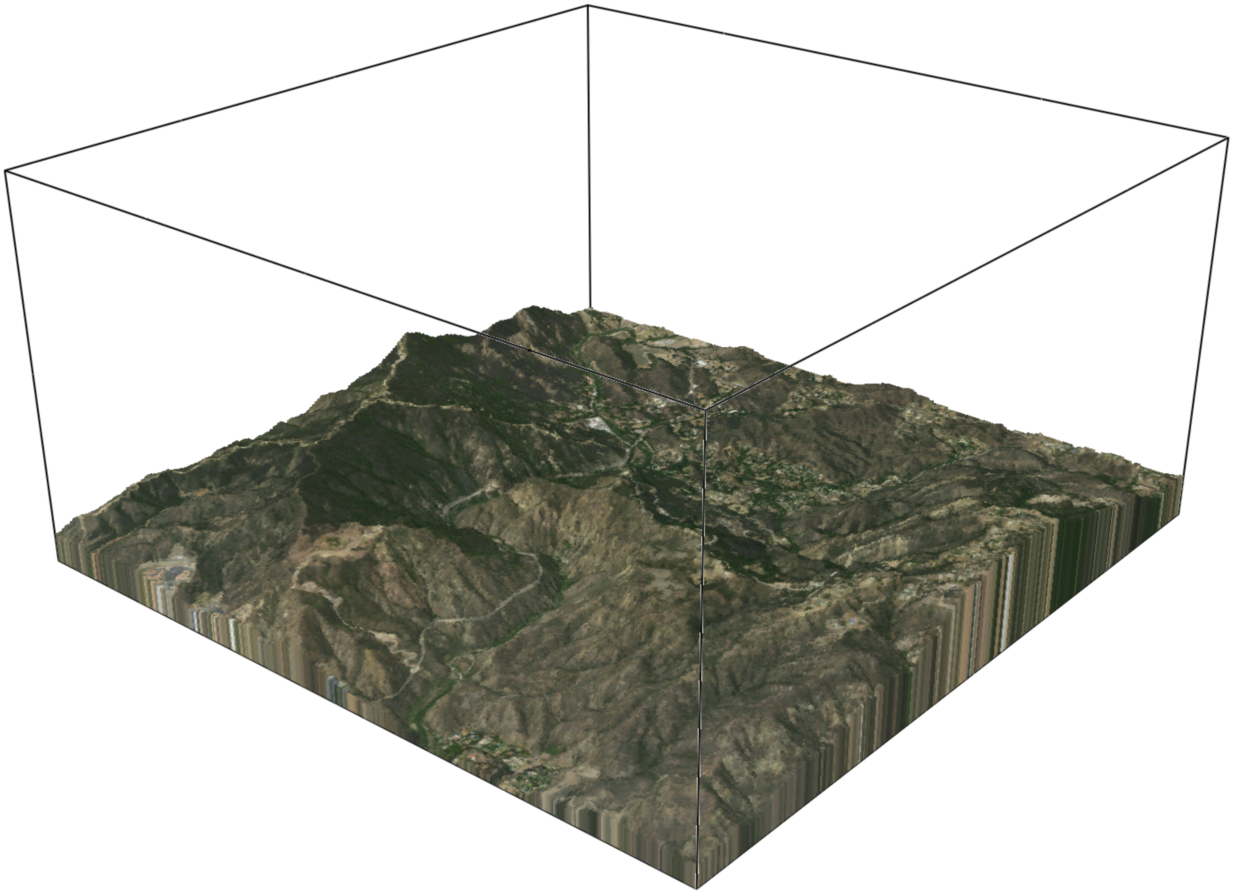

Figure 10. Isometric view of geometry and computational domain used in high resolution wind modeling analysis. Vantage point is looking approximately Northwest.

4.3 Mass-consistent wind modeling

Due to the high computational cost associated with CFD-based wind modeling, a second type of wind modeling, known as a mass-consistent model, was also used. Mass-consistent wind models do not solve the Navier-Stokes (or momentum conservation) equations, but solve only conservation of mass. Consequently, their run times are on the order of seconds compared to days for CFD. Although mass-consistent wind models are not capable of simulating complex flow patterns such as recirculation eddies, they can simulate simple acceleration due to flow confinement. The mass-consistent wind model used in this work was developed by the US Department of Agriculture Forest Service [11-12]. Appliication of this model will be discussed further in Section 5.0.

5.0 Estimation of Maximum Reasonably Foreseeable Santa Ana Wind Speeds in Malibu Canyon

In this section, the weather observations and computational models described earlier in this report are synthesized to estimate the maximum reasonably foreseeable Santa Ana wind speeds in Malibu Canyon – and more specifically, the maximum 50-year return interval 3 second gust at a height of 20 ft above ground level. 50-year return interval is selected because this is the approximate lifespan of electrical infrastructure. 3 second gust is used because this gust duration is typically used in structural analyses. Finally, 20 ft above ground level is selected because this is the height at which in-situ wind measurements were made in Malibu Canyon as well as the anemometer height for RAWS data used in this analysis.

First (Sections 5.1-5.3), the in situ data from each Station are analyzed to estimate the maximum 50-year return interval 3 second gust at 20 ft above ground level at each Station. Next (Section 5.4) the computational models described in Section 4.0 are used to generalize these observations to the balance of Malibu Canyon.

5.1 Station 1

As shown in Figure 5, Station 1 is located at the North end of Malibu Canyon just south of Mesa Peak Tractor Way. At this location, there is some flow acceleration due to the canyon, but it is not as significant as in other parts of Malibu Canyon. For this reason, it was postulated that wind speeds at this location should be well-predicted with WRF. Indeed, it was found that a gust-factor of 1.66 (meaning the ratio between 3-second gust and hourly WRF wind speed is 1.66) was capable of predicting the maximum gust speed in a given Santa Ana event reasonably well. Figure 11 demonstrates the correlation between modeled and measured peak 3-second wind gust at Station 1 for each of the 8 separate Santa Ana events that were captured. Although 9 events occurred during the meteorological monitoring period, Station 1 was not yet operational at the time of the first event. The correlation coefficient (R^2 value) is approximately 0.78. Importantly, WRF with the 1.66 gust factor appears to slightly overestimate wind gust speeds above 35 mph, suggesting a degree of conservatism is built into this analysis.

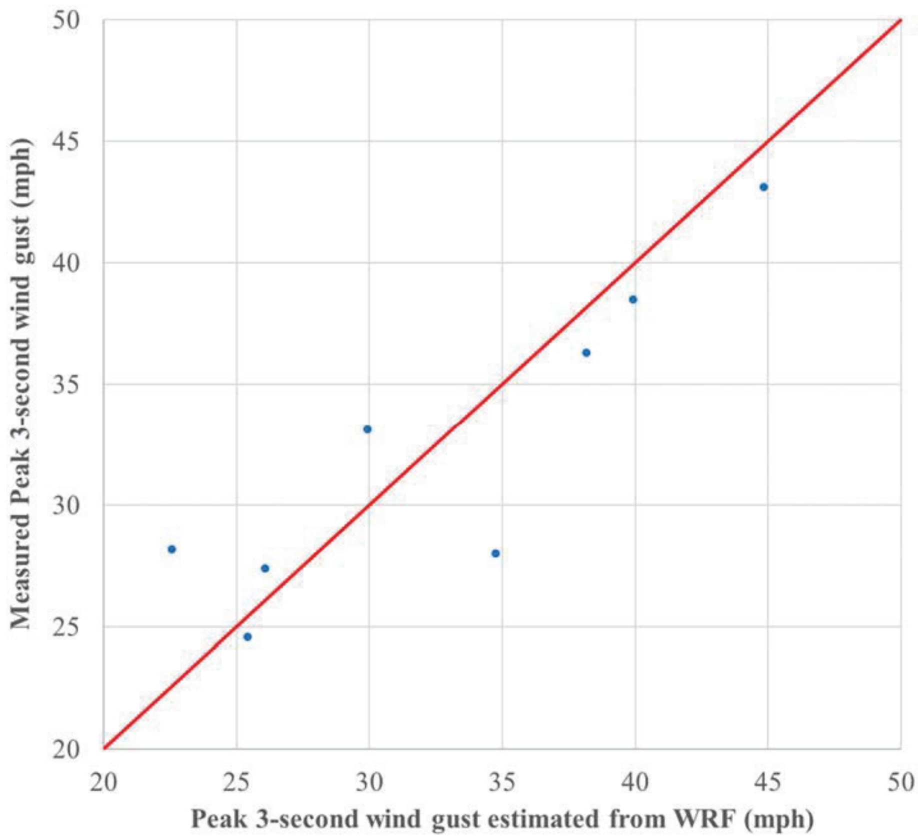

Figure 11. Station 1 correlation between 3-second gust speed estimated with WRF and peak measured 3-second gust.

From the 30 years of WRF data, the peak wind gust at station 1 is approximately 54 mph. This peak wind occurred during a Santa Ana event from October 30 – 31, 1991. On Thursday October 31, 1991 the LA Times wrote the following[1]:

> A day of cool, dry Santa Ana winds that graced Southern California with panoramic, postcard views also put firefighters to work Wednesday, stirring fears that more fires could be expected today as humidity levels remain low. A fast-moving wildfire pushed by 25-m.p.h. winds consumed 150 acres of brush-covered hills in Thousand Oaks and evoked fears of disaster before more than 275 firefighters from Ventura and Los Angeles counties contained the blaze. Elsewhere, firefighters battled smaller fires in Torrance and Lopez Canyon near the city of San Fernando, as Santa Ana conditions pushed humidity levels to lows of 10% in Burbank and San Bernardino. Normal humidity levels in those areas exceed 30% at this time of year. Winds were clocked from 20 to 40 m.p.h. throughout the region, with gusts reaching up to an estimated 60 m.p.h. in some canyons, said Steve Burback of WeatherData Inc., which provides weather information to The Times.

[1] http://articles.latimes.com/1991-10-31/news/mn-755_1_thousand-oaks

This anecdotal account provides some validation for the estimated 54 mph 3-second wind gust speed. The next step is to convert the estimated wind gust speed to a 50-year return interval. The definition of return interval (sometimes called return period or recurrence interval) is:

$$\text{return interval} = \frac{n}{m} = T \tag{1}$$

where n is the number of years in the record, and m is the number of recorded occurrences of the event being considered. In this case, although 30 years of WRF data were considered, only the months of October and November were analyzed. Since Santa Anas typically occur over a 6 month season, and only 2 months of that season were simulated with WRF, here we take n = 10 years (*i.e.*, 30 years × 2/6 = 10 years). Since we are considering the peak wind speed over that duration, m = 1 in Equation 1. ASCE 7-10 Equation C26.5-2 can be used to translate the wind speed for a particular return period to the 50 year return period wind speed as follows:

$$\frac{V_{50}}{V_T} = \frac{1}{0.36 + 0.1\ln(12T)} \tag{2}$$

where T is the return period in years, V_{50} is the 50-year return interval wind speed, and V_T is the T-year return interval wind speed. Substituting T = 10 years into Equation 2 gives V_{50}/V_{10} = 1.192. Consequently, the 50-year return interval 3-second gust at Station 1 is estimated as follows:

$$V_{50} = V_{10}\frac{V_{50}}{V_{10}} = 54\text{ mph} \times 1.192 \approx 64\text{ mph} \tag{3}$$

On this basis, the maximum 50-year return interval 3 second gust at 20 ft above ground level at Station 1 is estimated to be 64 mph.

5.2 Station 2

During the ~1 year of monitoring, the highest wind speed recorded at Station 2 was 64.5 mph. Using Equation 2, this corresponds to a 50 year return interval wind speed of 106 mph. However extrapolating to a 50 year return interval from a single year of data may be problematic if that year was not "typical". Consequently, it is desirable to extend the period of record with the use of additional observations, if possible.

Unlike Station 1, WRF is not expected to be predictive of wind gust speeds at Station 2 because gusts at that location are controlled by flow confinement and recirculation – effects not captured by WRF at a resolution of 1.2 km. During Santa Anas, the highest wind gusts at Station 2 most likely occur when high velocity parcels of air accelerating over Piuma Ridge to the North are brought down to Malibu Canyon Road by turbulent eddies that form as part of a recirculation pattern or wind rotor. For this reason, it is expected that the wind speed at Station 2 is correlated with wind speed on Piuma Ridge. Although there are no weather stations on Piuma Ridge, the

Malibu Hills RAWS station (MBUC1) is located on a ridge of similar elevation approximately 3 miles East of the study area (see Figure 7).

Since wind characteristics at MBUC1 are expected to be similar to wind characteristics on Piuma Ridge, it was hypothesized that wind speeds at Station 2 are correlated with wind speeds at MBUC1 during Santa Anas. To test this hypothesis, peak 3 second gust at Station 2 was compared to peak 3 second gust at MBUC1 for the 9 Santa Ana events shown in Table 2. It was subsequently determined that the data reported by MBUC1 during events 5 and 6 were not credible. Therefore, events 5 and 6 were removed from the data set for the purposes of this analysis. The correlation between wind gust speeds at MBUC1 and those measured at Station 2 is shown in Figure 12. The *x*-axis is the maximum hourly wind gust measured at Malibu Hills RAWS, and the *y*-axis is the corresponding maximum 3-second wind gust measured at Station 2 during the same hour.

There is considerable scatter in the data and the correlation coefficient (R^2 value) for the entire dataset is approximately 0.55. However, for wind gusts greater than 55 mph measured at Malibu Hills RAWS, the corresponding wind gust at Station 2 as shown in Figure 12 is always lower. For example, when a wind gust of 64.5 mph was recorded at Station 2, the corresponding wind gust at Malibu Hills RAWS was 83 mph. Based on this reasoning, wind gusts measured at Malibu Hills RAWS during Santa Ana wind events are considered an upper limit on wind gusts that could occur at Station 2.

The Malibu Hills RAWS data, which are available from December 1999 to current day, were subsequently analyzed to estimate the highest anticipated wind gust at Station 2 based on this ~15 year record. The highest credible wind gust speed during a Santa Ana event was found to be 97 mph. From Equation 2, $V_{50} / V_{15} = 1.137$, and the maximum 50-year return interval 3 second gust at 20 ft above ground level at Station 1 is estimated at 1.137×97 mph = 110 mph. For comparison purposes, as described in Section 2.2.2, based on wind tunnel testing it was previously estimated that the maximum wind gust at October 2007 Canyon Fire's ignition site was 114 mph at the time of ignition.

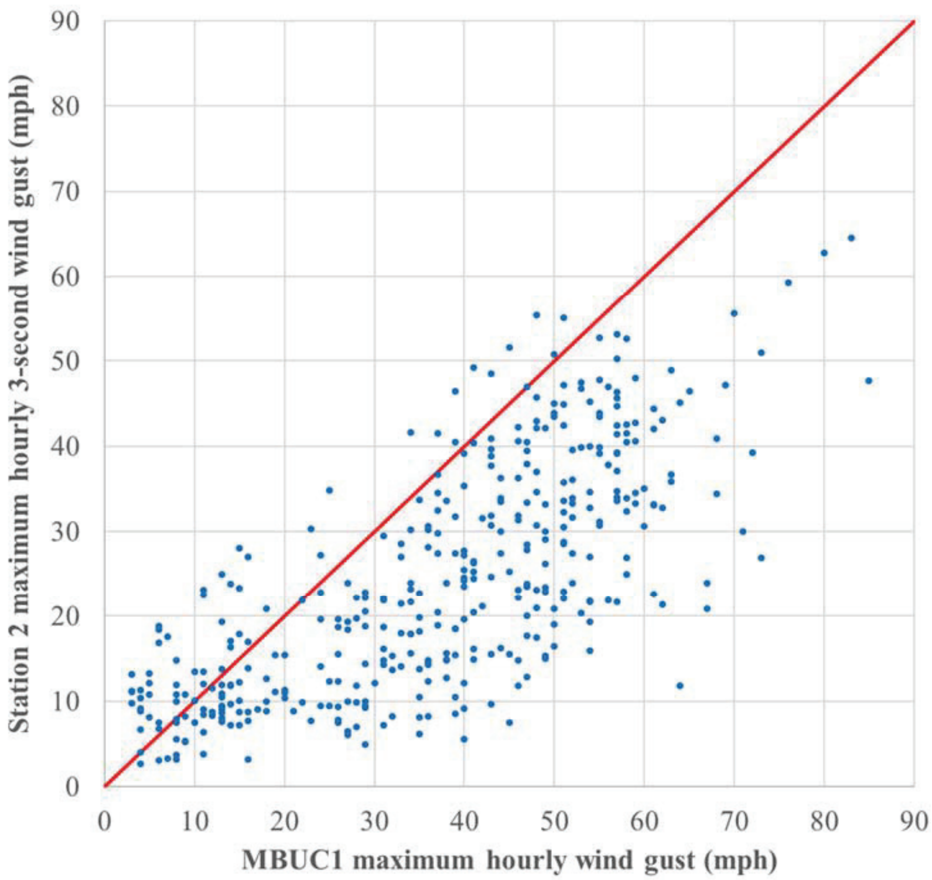

Figure 12. Comparison of maximum hourly 3-second wind gust measured at Station 2 with maximum hourly wind gust at MBUC1 raws.

5.3 Station 3

As with Station 2, wind gust speed at Station 3 is likely affected by both flow confinement and recirculation from Piuma Ridge. Therefore, it was hypothesized that the maximum wind gust speed at Station 3 is correlated with the maximum wind gust speed at Station 2. Shown in Figure 13 is the correlation between Station 3 wind gust and Station 2 wind gust. The data are fit by the linear correlation given as Equation 4 with an R^2 value of 0.72:

$$V_{s3} = 6.1 + 0.57 \times V_{s2} \text{ (mph)} \quad (4)$$

Here V_{s3} is the wind gust speed at Station 3 and V_{s2} is the wind gust speed at station 2. Substituting V_{s2} = 110 mph (50 year return interval peak 3 second gust wind gust at Station 2 as determined earlier) into Equation 4 gives V_{s3} = 69 mph. Therefore, the maximum 50-year return interval 3 second gust at 20 ft above ground level at Station 3 is estimated at 69 mph.

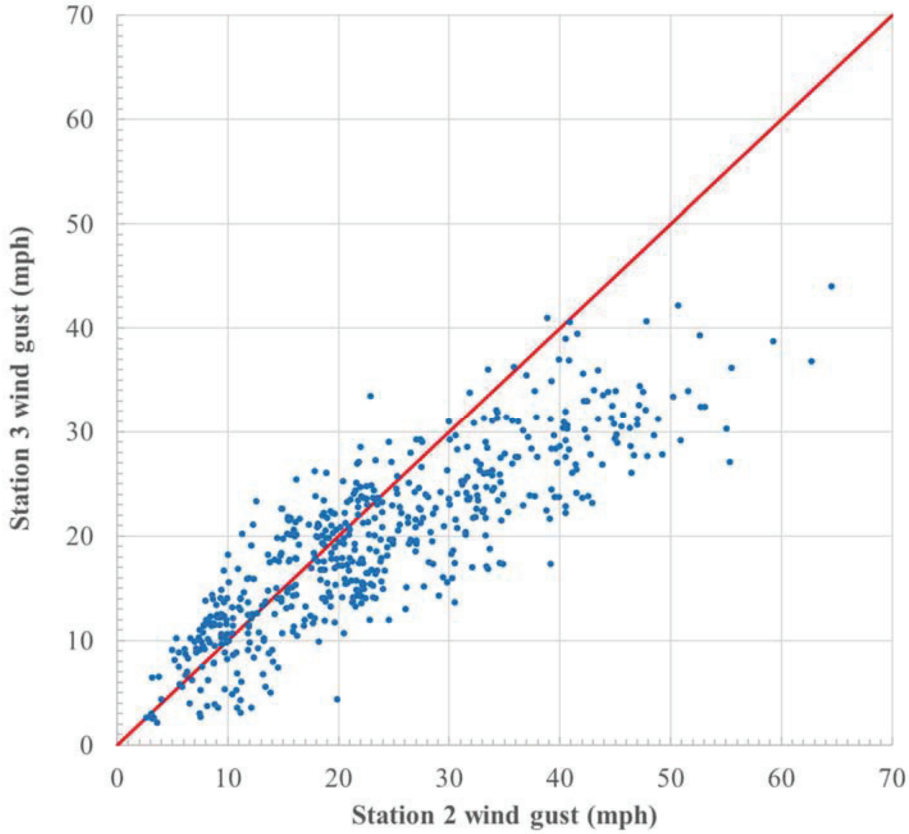

Figure 13. Correlation between wind gust at Station 3 and wind gust at Station 2.

5.4 Generalization across Malibu Canyon

The computational tools described in Sections 4.2 and 4.3 were used to qualitatively assess relative degrees of flow acceleration in Malibu Canyon. The findings for each of the three separate sections of the study area (as identified in Section 2.4) are as follows:

1. Wind observations at Station 1 include some degree of acceleration due to canyon effects, but may not necessarily correspond to peak wind speeds for Section 1. An increase in gust speed of 5 mph would not be unreasonable. This puts the estimated 50-year return interval 3-second gust at 20 ft in Section 1 at 69 mph.
2. Wind speeds in Section 2 are dominated by recirculation eddies that transport high velocity air parcels from Piuma Ridge down to Malibu Canyon Road. Therefore, the highest wind speeds in this section are not strongly affected by channeling or acceleration. Consequently, the estimated 50-year return interval 3-second gust at 20 ft determined for Station 2 (110 mph) is taken as representative of Section 2.
3. Wind speeds in Section 3 are affected by recirculation eddies blowing in from the North. Due to surface friction and widening of Malibu Canyon as one travels farther South, the peak wind speed estimate at Station 3 is considered representative of Section 3. Therefore, the estimated 50-year return interval 3-second gust at 20 ft determined for Station 3 (69 mph) is considered to be an upper limit for wind speeds in Section 3.

6.0 Conclusions

The wind speed estimates developed earlier in this report can be converted to wind loads (lb/ft^2) by squaring the wind speed and multiplying by 0.00256. Based on the analyses described in this report, the 50-year return interval peak 3 second gust wind speeds at a height of 20 ft, and associated wind loads, for the three different sections of Malibu Canyon as identified in Figure 4 are estimated as follows:

1. Section 1: 69 mph (12.2 lb/ft^2)
2. Section 2: 110 mph (31.0 lb/ft^2)
3. Section 3: 69 mph (12.2 lb/ft^2)

These results are shown graphically in Figure 14.

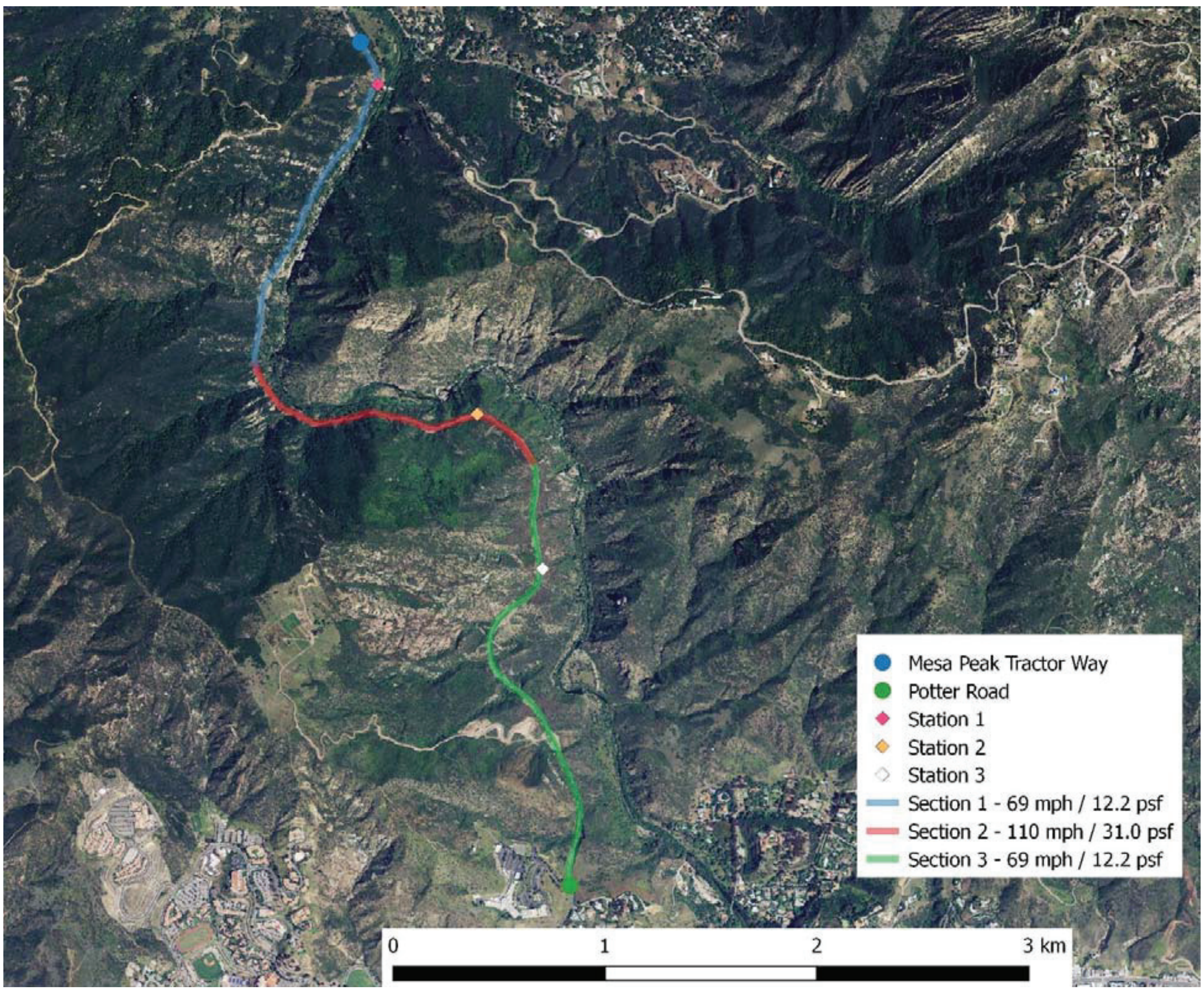

Figure 14. Estimated maximum 50-year return interval peak 3 second gust wind speeds and associated wind loads in Malibu Canyon study area.

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June 10, 2016

Malibu Canyon Wind Study
Meteorological Monitoring Program
Final Report

Santa Ana Wind Study

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1 Introduction

Reax Engineering contracted with Leidos to implement a meteorological monitoring program in Malibu Canyon regarding the settlement issues associated with NextG Network of California's (NextG) alleged involvement with the Malibu Canyon Fire in October 2007. NextG is currently owned by Crown Castle NextG West Inc. and Crown Castle is considered the prime contractor for this study. Reax Engineering has been retained by Crown Castle to determine the maximum, reasonably foreseeable Santa Ana wind speed in Malibu Canyon. One component of this study is the installation of meteorological monitoring stations at several locations in the Malibu Canyon, and subsequent analysis of these data.

In the area surrounding Malibu Canyon, Santa Ana conditions are often associated with relatively high speed northerly or northeasterly winds driven by an anomalous synoptic condition where high pressure over the Great Basin creates offshore geostrophic winds that flow roughly perpendicular to the topography (mountains) around the LA air basin. These winds generally flow downgradient to the ocean, which results in the air mass warming and having lower relative humidity. Elevated wildfire ignition and propagation conditions may occur during Santa Ana events when warm air with low atmospheric relative humidity reduces moisture conditions in both dead and live fuels to produce elevated fire danger. During these Santa Ana events, utility and power generation infrastructure may be subjected to wind load stresses leading to damage and increasing the likelihood of wildfire ignition and propagation.

The objective of this study was to measure the highest winds within the canyon during the fall and winter months, when Santa Ana events are most likely to occur. Data analysis was conducted on measurements taken at three (3) meteorological monitoring stations located in Malibu Canyon from July 1, 2015 to June 30, 2016. This report details all relevant station information in this study and provides analysis on the final quality assured and quality checked (QA/QC) data set for the three (3) meteorological monitoring stations in Malibu Canyon.

2 Meteorological Monitoring Program Design

During November 2014, staff from Reax Engineering and Leidos walked the section of Malibu Canyon Road that is part of the settlement agreement (between Potter Drive and Mesa Peak Tractor Way) to determine candidate sites for installation of pole mounted weather stations. The wind study was designed to capture measurements at three (3) geographical sections of Malibu Canyon. The locations of the three (3) monitoring stations are shown in Figure 1.

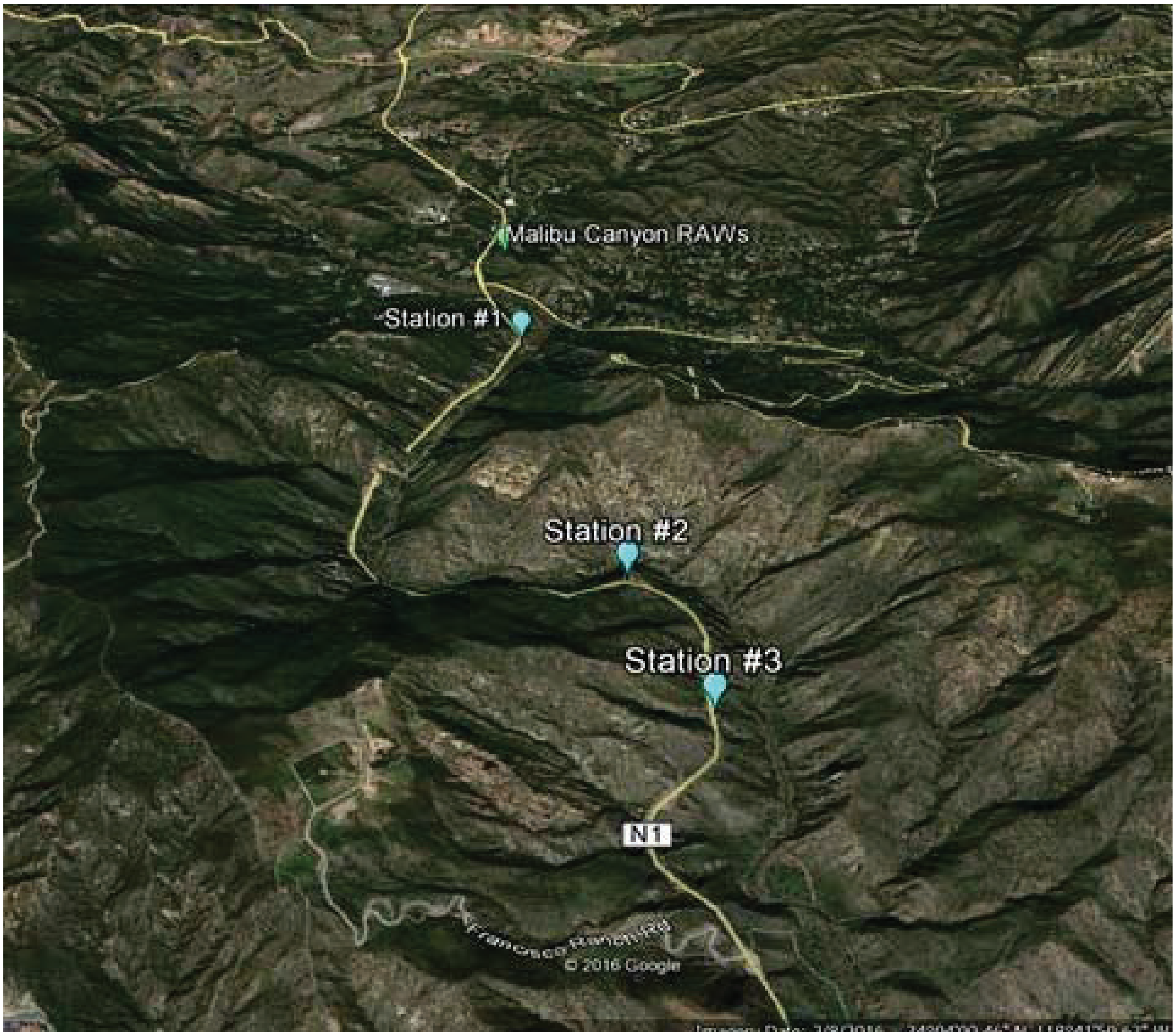
- Station 1 (pictures in Appendix 1) is located at the entrance to Malibu Canyon from the north, where northerly or northeasterly Santa Ana winds approach the canyon and prior to any topographical flow restrictions. This station was designed to capture surface wind measurements representative of the predominant synoptic forcing (Santa Ana flow), prior to reaching the topographical features that constrict airflow through the canyon. Due to logistical and LA County permitting issues, Station 1 was not installed until October 30, 2015. Therefore, data collected and analyzed from this station spanned the period from October 30, 2015 to June 30, 2016; a total of eight (8) months.

- Station 2 (pictures in Appendix 1) is located in the portion of the canyon that extends west-to-east along Malibu Canyon Road, and was designed to capture surface wind measurements due to flow restrictions and/or recirculation patterns. Station 2 was installed on July 1, 2015, and the meteorological dataset available for analysis spans 12 months from July 2015 to June 2016.

- Station 3 (pictures in Appendix 1) is located closest to the ocean in the most southerly section of Malibu Canyon. This station location was chosen to collect surface wind measurements in the portion of Malibu Canyon where the topographical features become less constrictive and allow the airflow to expand towards the coastline in a north-south direction. Station 3 was also installed on July 1, 2015, and the meteorological dataset available for analysis spans 12 months from July 2015 to June 2016.

In addition to the three (3) monitoring stations installed as part of the Malibu Canyon Wind Study, meteorological data from the geographically closest remote automated weather station (RAWS) - Malibu Canyon (MBCC) - was used for a portion of this analysis. The MBCC station is also shown in Figure 1; located approximately 0.5 miles north of the Station 1 installation site. While MBCC data is used for a portion of this analysis, it is important to note that the MBCC station is also located on a hilltop outside of Malibu Canyon. Consequently, the wind data may show somewhat different characteristics than data from the meteorological stations installed and operated as part of the Malibu Canyon Wind Study, which were designed to collect measurements within the canyon and adjacent to the power lines along Malibu Canyon Road.

Figure 2-1 Monitoring Station Locations in Malibu Canyon Wind Study



2.1 Monitoring Stations Components

Each station deployed in the Malibu Canyon Wind Study was designed to collect wind speed (WS) and wind direction (WD) measurements at a 20-foot height. The 20-foot measurement height was chosen for consistency with Remote Automated Weather Stations (RAWS). In addition to WS and WD measurements, Station 3 includes one (1) temperature (T) and relative humidity (RH) sensor to collect surface level temperature and RH readings during Santa Ana wind events. Since T and RH were not expected to show much variation over the 3-4 mile stretch of Malibu Canyon Road, only one (1) T/RH sensor was deployed for this study.

Each station was equipped with a RM Young Model 05103 propeller anemometer to measure wind speed and direction. Station 3, located in the lower section of Malibu Canyon, also had a Model 215 CSL temperature/relative humidity probe that provided additional data at that location.

Each station had a power supply system, including a solar panel and battery, to allow it to operate at remote locations. Each station was also equipped with a data logger and cellular modem, so that the data could be collected and transmitted back to Leidos headquarters in San Diego.

Each monitoring station's data logger was programmed to collect wind speed and direction measurements at 1-hour averaged intervals, while hourly averaged ambient temperature and relative humidity readings were also collected at Station 3. In addition to the hourly averaged readings, each station's data logger was configured to collect the highest 3-second wind speed gusts (WS gust) during each hour. The 3-second WS gust measurement is a shift from the "fastest MPH" that has traditionally been used to measure highest wind speeds within an hour, and is a government-mandated change to improve analysis of environmental loads on buildings and other structures (Erichsen, 2008). This WS gust measurement is more directly related to the objectives of this study, as discussed above, than average hourly wind conditions, so the focus of this analysis will be on the WS gust measurements within Malibu Canyon.

RAWS stations (such as the MBCC station used to supplement the data collected by the stations installed in this study) are often located to support operations by the National Wildfire Coordinating Group and its member agencies, and the data is in the public domain (NWCG, 2014). The RAWS stations use a variety of meteorological instrumentation, but they should be reasonably comparable to the equipment installed for this program.

The NWCG data format standard mandates a 10-minute average to be calculated for use as the station hourly average wind speed and direction. This RAWS calculation for these parameters is slightly different than the 60-minute average which is used in the hourly average calculations at the Malibu Canyon stations, but they should be reasonably close and comparable. For WS gust measurements, the NWCG data format standards require the reporting of the maximum speed within an hour from no less than 720 samples. That is, the MBCC station should be reporting WS gust measurements from no more than 5-second periods (and more likely, gusts will be reported from 3-second periods, since that is the recommended period defined as gusts). Consequently, the average wind speed and WS gust measurements at the MBCC station should be directly comparable to the data collected in this program.

3 Analysis of the Data from the Monitoring Program

The data analysis was designed to determine the relative frequency of high speed, gusty winds that could affect structures along Malibu Canyon, and to identify the intensity of those gusty winds. In addition, the study was used to compare winds at the three sites within the canyon and at the MBCC RAWS station located just outside of the canyon.

3.1 Relative Frequency of High Speed, Gusty Winds during Santa Ana Events

For the purposes of this analysis, "high speed" winds were defined as periods when WS gusts (the maximum 3-second gusts measured within an hour, as defined previously) exceeded 40 mph at any of the monitoring stations within Malibu Canyon.

During the monitoring period for this program (July 1, 2015 through June 30, 2016) periods of high speed winds, as defined above, occurred primarily during the fall and winter periods, although Santa Ana conditions with elevated wind speeds occurred twice during early spring 2016, on March 22-23rd and April 15-16th, as shown in the table below. These elevated speed winds can be attributed to Santa

Ana events, as they are readily identifiable during periods of strong northerly winds and low relative humidity measurements. Santa Ana conditions with high speed winds occurred at a frequency of slightly more than once per month, although there timing was erratic: there were two (2) Santa Ana events in December, none in January, and three (3) in February. Appendix 1 provides the meteorological monitoring data during selected periods when elevated WS gust were measured during Santa Ana conditions over the period of record (July 2015 - June 2016). Appendix 2 contains the meteorological monitoring data during selected periods when high WS gust data was measured when Santa Ana conditions were not present.

3.2 Comparison of Winds at the Malibu Canyon Monitoring Stations

Table 3-1 summarizes the wind data presented in Appendix 1, the maximum winds encountered during Santa Ana conditions. The table shows hourly average winds and maximum WS gust measurements during the peak period for each Santa Ana event at the four (4) stations analyzed for this report.

Table 3-1 Observed Winds in Malibu Canyon during Santa Ana Events

Event #	Time Period	Station 1		Station 2		Station 3		MBCC	
		Hourly Avg. Wind Speed (mph)	Max Gust (mph)	Hourly Avg. Wind Speed (mph)	Max Gust (mph)	Hourly Avg. Wind Speed (mph)	Max Gust (mph)	Hourly Avg. Wind Speed (mph)	Max Gust (mph)
1	10/30/15	n/a[1]	n/a[1]	25.0	55.4	13.5	39.3	10.0	40.0
2	11/17/15	9.8	27.4	33.4	64.5	18.1	44.1	10.0	32.0
3	12/15/15	12.4	24.6	16.2	44.7	13.9	40.6	6.0	21.0
4	12/26/15	9.6	43.1	17.7	52.7	9.3	34.0	16.0	42.0
5	02/06/16	11.8	26.5	12.4	44.9	9.9	31.9	inc.[2]	inc.[2]
6	02/15/16	14.0	29.6	13.3	44.6	13.3	41.0	inc.[2]	inc.[2]
7	02/22/16	13.9	36.3	17.9	42.2	8.9	33.0	inc.[2]	inc.[2]
8	3/23/16	9.7	28.0	18.0	48.9	14.0	39.0	inc.[2]	inc.[2]
9	4/15/16	10.6	38.5	23.5	55.0	11.6	42.2	inc.[2]	inc.[2]

Notes:

1. n/a[1]: Station 1 was not operational until 1400 hours, 10/30/15, which was after peak winds were measured on that day at the other stations.
2. inc.[2]: Data set were incomplete for the MBCC station on those days.

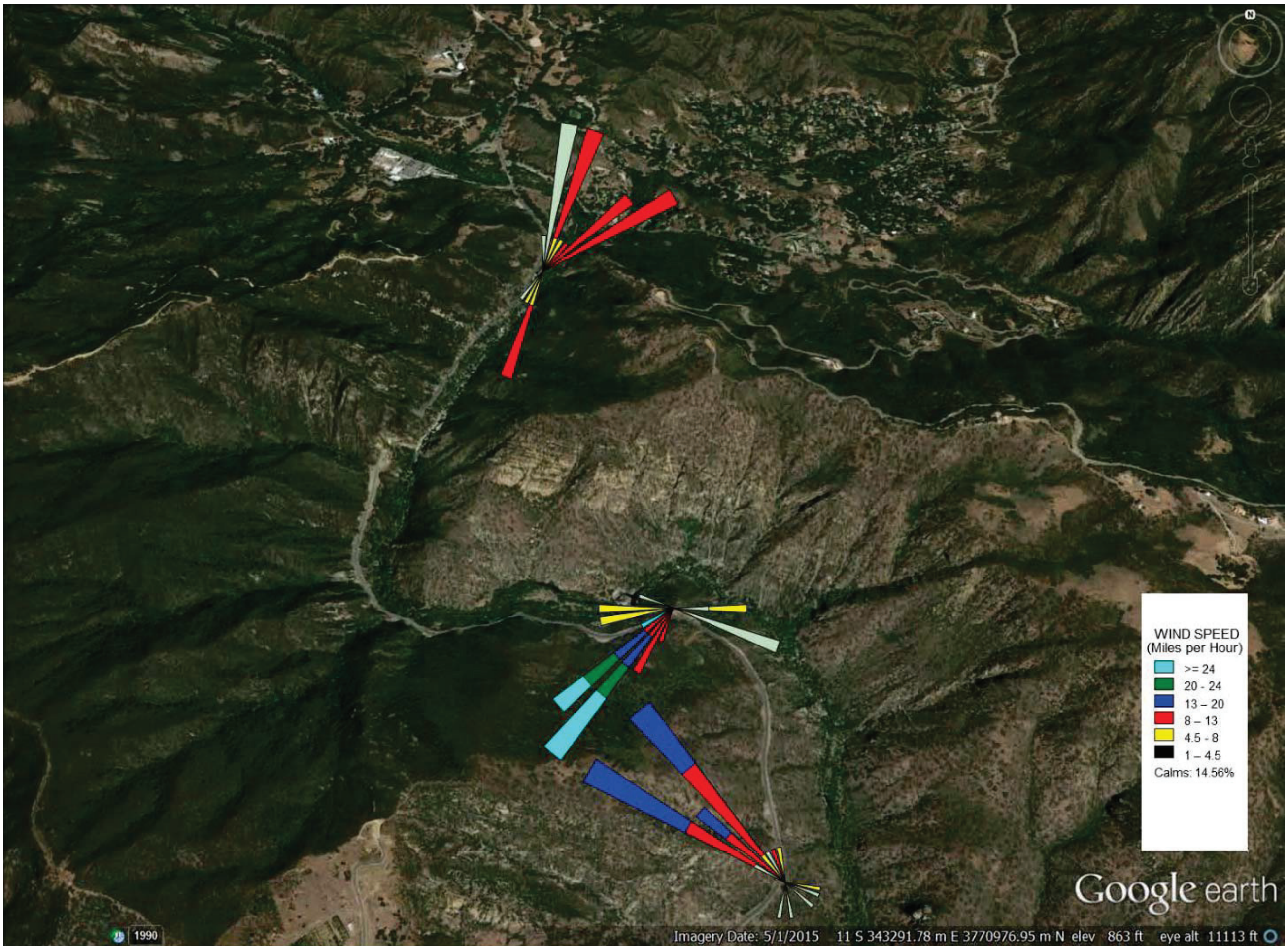
The data in Table 3-1 show the WS gust and average hourly wind speed readings at each station. The table shows some interesting features about Santa Ana winds in Malibu Canyon:

- In each Santa Ana event, the measured WS gusts were highest in the middle of the canyon, at Station 2. In the four (4) highest Santa Ana events (when winds at Station 2 were greater than 50 mph), wind gusts average 30% lower at Station 3, 35% lower at Station 1, and 33% lower at the MBCC RAWS station. Clearly, winds speeds during Santa Ana conditions develop their greatest intensity when channeled by the topographic features in the middle of the canyon.

- The highest measured WS gust during the monitoring program was 64.5 mph.

- The data in Appendix 1 also shows that relative humidity is a good indicator of Santa Ana events. For the four Santa Ana events when maximum WS gust readings at Station 2 were greater than 50 mph, RH measurements (at Station 3) on that day reached 20 percent or less. RH readings of less than 20 percent are well below typical values measured at Station 3.
- Figure 3-1 shows wind speed directions measured at the monitoring stations during a typical Santa Ana event, which occurred on November 17, 2015. These data show that synoptic winds are channeled through the canyon during Santa Ana conditions:
    - At Station 1, near the top of the canyon, winds are from the northeast.
    - At Station 2, in the middle of the canyon, the winds are most frequently from the southwest and west-southwest. This may be the combined effect of channeling and recirculation eddies due to a wind rotor.
    - At Station 3, in the lower section of the canyon, the winds are from the northwest.

Figure 3-1 Wind Rose Plots - Santa Ana Winds - November 17th, 2015



- A comparison was made between the 3-second WS gusts and the hourly wind speeds during the four (4) Santa Ana events shown in Table 1, when WS gust readings at Station 2 were greater than 50 mph. The calculation was made during the hour of the day when WS gusts were at a maximum; the results were reasonably consistent among the stations:
    - At Station 3, average hourly wind speed was 33% of the maximum WS gust.
    - At Station 2, average hourly wind speed was 43% of the maximum WS gust.
    - At Station 1, average hourly wind speed was 29% of the maximum WS gust.
    - At MBCC station, average hourly wind speed was 31% of the maximum WS gust.

3.3 High Winds occurring when Santa Ana Conditions are not present

There were two events (storms) that occurred during this monitoring period, when high winds were measured during periods when Santa Ana conditions were not present. An analysis of these events were undertaken to determine how the wind patterns compare with the patterns observed during Santa Ana events.

The resulting character or pattern of winds within Malibu Canyon is completely different than that observed during the Santa Ana events, so the results are instructive. Table 3-2 presents a summary of the wind data measured during these events, which occurred on January 5th and 31st 2016.

Table 3-2 Observed Winds in Malibu Canyon during Non-Santa Ana Events

Time Period	Station 1		Station 2		Station 3		MBCC	
	Hourly Avg. Wind Speed (mph)	Max Gust (mph)	Hourly Avg. Wind Speed (mph)	Max Gust (mph)	Hourly Avg. Wind Speed (mph)	Max Gust (mph)	Hourly Ave. Wind Speed (mph)	Max Gust (mph)
01/05/16	13.7	38.3	9.3	25.9	11.2	34.7	13.0	54.0
01/31/16	17.1	49.0	10.8	33.5	19.6	42.5	20.0	65.0

During these storms, there were high WS gusts (>50 mph), but the highest gusts were measured at the MBCC RAWS station, located on a hilltop just outside Malibu Canyon, with the second highest gusts measured at Station 1, at the top of Malibu Canyon. These two stations are the most exposed of the four (4) monitoring stations to synoptic level winds that would be associated with storms. A maximum gust of 65 mph was measured, comparable to the highest Santa Ana winds measured during the monitoring period. However, as Table 2 illustrates the lowest wind gusts (approximately 50% of the peak gusts at the MBCC station) were consistently measured at Station 2, which is located within the Malibu Canyon and is somewhat sheltered from storm-generated winds. This is in direct contrast to typical conditions during Santa Ana conditions (shown in Table 1), when measured winds by the monitoring network are consistently highest at Station 2 within Malibu Canyon.

In these cases, the storm front passes over the region and precipitation is recorded at the nearest Weather Service station in Santa Monica. During these storm events, RH readings at Station 3 were consistently greater than 95%, which is in contrast to RH readings of less than 20% measured during Santa Ana events with high WS gusts at Station 2.

4 Summary and Conclusions

This study analyzed the meteorological data collected by the 3-station network in Malibu Canyon over the period July 2015 to June 2016. In addition, meteorological data from the Malibu Canyon RAWS (Remote Automated Weather Station) site, located on a hilltop just north of Malibu Canyon, was also incorporated into this analysis.

The highest short-term wind speeds (3-second gusts) were studied because they are typically used to determine maximum wind loads on infrastructure. These high WS gust measurements primarily occurred during the fall and winter periods, when Santa Ana winds were present, but there were two instances when Santa Ana events occurred during the early spring. Almost all of the WS gust readings above a moderate-level threshold (40 mph) were found to be associated with Santa Ana events. Highest winds during Santa Ana conditions were consistently found at Station 2, located in the middle of Malibu Canyon. The highest 3-second WS gust recorded during this program was 64.5 mph.

There were two periods during this monitoring program that WS gusts above 40 mph were measured when a Santa Ana conditions were not present. Both events occurred in January 2016, when storm fronts passed over the region. Maximum WS gusts of 54.0 and 65.0 mph were recorded at the MBCC RAWS station. However during both storms, the maximum WS gust readings at Station 2 was only 50% of the WS gusts measured at the MBCC station (Table 2), illustrating that the topography of Malibu Canyon served to partially shelter the area from the storm-generated winds. This is in direct contrast to winds measured during Santa Ana conditions, when the winds are channeled through the canyon and were found to be highest in the middle of the canyon at Station 2.

5 References

Erichsen, J.R., 2008. *ANSI/TIA-222 Explained*. Tower Numerics Inc. http://www.towernx.com

NWCG, 2014. Interagency Wildland Fire Weather Station Standards & Guidelines. National Wildfire Coordinating Group, Publication PMS 426-3, October 2014. http://www.nwcg.gov.

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Appendix 1 –
Readings during Santa Ana Wind Events

Table 1.1. Hourly Meteorological Data - Event 1: 10/29/15 to 10/30/15

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
10/29/15 00:00				9.1	262.6	30.6	7.0	334.1	21.6	69.3	52.3	7.0	336.0	12.0	65.0	66.0
10/29/15 01:00				16.8	230.0	27.8	11.7	315.0	24.0	71.8	45.1	6.0	355.0	13.0	65.0	57.0
10/29/15 02:00				13.8	235.6	30.7	11.2	325.2	28.3	71.4	44.3	8.0	319.0	14.0	66.0	50.0
10/29/15 03:00				15.8	234.2	27.0	10.6	314.6	20.8	71.0	42.1	8.0	26.0	14.0	67.0	47.0
10/29/15 04:00				13.0	223.8	37.9	8.2	304.7	27.6	70.3	41.1	13.0	20.0	24.0	68.0	42.0
10/29/15 05:00				14.0	211.3	43.9	10.4	301.9	33.5	70.4	40.7	10.0	351.0	27.0	65.0	44.0
10/29/15 06:00				22.1	226.8	45.2	12.9	311.8	28.9	70.4	40.7	15.0	16.0	27.0	68.0	43.0
10/29/15 07:00				21.3	216.5	45.1	12.5	306.4	29.7	70.1	42.4	10.0	21.0	32.0	67.0	45.0
10/29/15 08:00				14.1	207.7	36.0	11.2	306.3	27.6	69.3	42.1	11.0	0.0	27.0	72.0	35.0
10/29/15 09:00				15.9	214.3	33.9	8.7	307.1	31.1	71.1	37.1	11.0	30.0	25.0	76.0	29.0
10/29/15 10:00				11.2	225.1	27.3	8.2	305.2	24.6	73.3	35.2	13.0	29.0	27.0	77.0	27.0
10/29/15 11:00				11.0	230.0	29.1	5.5	257.9	14.3	75.9	30.5	12.0	42.0	32.0	78.0	24.0
10/29/15 12:00				9.4	225.9	27.4	3.7	196.0	21.3	78.6	28.6	17.0	34.0	36.0	79.0	20.0
10/29/15 13:00				9.2	233.6	30.2	6.4	169.4	18.3	79.3	25.2	11.0	271.0	32.0	84.0	17.0
10/29/15 14:00				11.9	234.3	35.3	5.5	223.6	22.3	81.2	32.1	9.0	329.0	23.0	86.0	15.0
10/29/15 15:00				16.0	241.0	28.6	6.7	310.0	17.3	81.5	21.6	9.0	239.0	27.0	84.0	22.0
10/29/15 16:00				11.5	252.6	21.7	4.8	309.3	14.3	80.8	28.3	6.0	298.0	23.0	82.0	23.0
10/29/15 17:00				8.7	248.2	17.7	4.0	328.9	11.7	78.3	30.4	6.0	303.0	27.0	75.0	27.0
10/29/15 18:00				7.4	265.3	12.8	2.5	351.9	10.8	77.1	28.6	3.0	47.0	11.0	68.0	33.0
10/29/15 19:00				3.6	222.4	18.2	2.4	297.1	9.9	75.7	31.0	4.0	355.0	10.0	66.0	41.0
10/29/15 20:00				7.3	232.6	14.3	3.6	308.5	12.6	74.5	27.9	3.0	318.0	7.0	65.0	36.0
10/29/15 21:00				6.8	237.3	14.8	3.1	329.4	14.1	73.0	23.5	4.0	92.0	9.0	63.0	29.0
10/29/15 22:00				5.9	243.1	18.0	5.4	325.4	20.0	74.0	22.3	7.0	338.0	8.0	63.0	29.0
10/29/15 23:00				6.2	244.4	18.5	6.1	335.7	14.0	72.8	24.5	8.0	8.0	12.0	63.0	30.0

Table 1.1. Hourly Meteorological Data - Event 1: 10/29/15 to 10/30/15 - cont.

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
10/30/15 00:00				6.8	232.9	21.3	3.5	325.2	14.2	71.1	26.7	11.0	15.0	14.0	67.0	29.0
10/30/15 01:00				10.1	227.6	31.4	4.7	299.6	25.2	71.1	29.5	8.0	5.0	23.0	66.0	33.0
10/30/15 02:00				17.8	223.9	39.9	8.2	304.5	23.8	70.7	30.5	8.0	0.0	17.0	64.0	31.0
10/30/15 03:00				19.2	218.7	33.3	8.8	300.6	21.8	70.8	26.8	10.0	329.0	15.0	69.0	22.0
10/30/15 04:00				13.9	220.8	31.1	5.8	305.8	25.2	71.3	22.3	12.0	343.0	24.0	69.0	21.0
10/30/15 05:00				12.7	226.6	30.0	7.0	307.2	23.5	71.8	22.5	13.0	353.0	26.0	68.0	20.0
10/30/15 06:00				14.2	224.5	34.4	6.7	295.2	23.4	70.8	21.8	11.0	3.0	27.0	67.0	21.0
10/30/15 07:00				17.1	223.0	44.4	7.9	297.9	33.9	70.3	22.1	12.0	351.0	24.0	68.0	21.0
10/30/15 08:00				22.8	230.9	52.6	13.5	309.1	39.3	70.6	21.8	9.0	32.0	24.0	73.0	16.0
10/30/15 09:00				25.4	236.3	47.1	15.3	311.3	32.6	72.6	19.4	16.0	357.0	25.0	77.0	12.0
10/30/15 10:00				25.3	235.5	47.9	12.8	311.0	27.6	75.4	16.0	18.0	357.0	35.0	78.0	11.0
10/30/15 11:00				25.0	230.3	55.4	10.1	296.9	27.1	78.5	14.1	10.0	23.0	40.0	84.0	8.0
10/30/15 12:00				23.6	228.0	53.1	9.7	294.0	32.4	80.9	12.0	11.0	11.0	31.0	84.0	9.0
10/30/15 13:00				22.0	216.9	43.8	10.4	290.2	26.8	82.4	11.7	15.0	18.0	35.0	86.0	8.0
10/30/15 14:00	13.8	25.5	26.9	18.3	220.4	47.2	8.2	279.9	34.4	83.8	11.3	12.0	0.0	36.0	87.0	8.0
10/30/15 15:00	10.7	28.8	31.5	20.0	216.8	43.5	9.2	296.5	31.2	84.7	11.1	14.0	95.0	28.0	86.0	8.0
10/30/15 16:00	11.1	24.7	26.7	21.3	222.8	40.0	8.9	290.8	28.6	85.6	10.4	14.0	20.0	31.0	85.0	8.0
10/30/15 17:00	10.2	27.5	28.3	19.1	218.9	37.0	8.8	293.0	24.1	85.3	10.6	5.0	39.0	34.0	81.0	9.0
10/30/15 18:00	9.4	12.4	10.5	14.0	217.0	28.5	6.6	288.1	20.6	84.8	11.3	9.0	323.0	21.0	75.0	14.0
10/30/15 19:00	3.9	28.6	11.5	14.0	233.2	22.4	6.2	299.6	15.3	83.0	12.4	12.0	7.0	22.0	71.0	20.0
10/30/15 20:00	5.7	37.9	14.5	6.3	224.8	23.4	8.3	337.4	21.9	79.1	18.5	9.0	35.0	19.0	70.0	21.0
10/30/15 21:00	7.3	31.0	9.1	10.8	224.6	22.9	12.3	337.9	18.9	76.9	17.9	1.0	4.0	17.0	64.0	25.0
10/30/15 22:00	3.7	0.7	7.9	8.1	264.0	20.0	7.8	336.8	16.6	76.2	16.1	1.0	234.0	9.0	60.0	28.0
10/30/15 23:00	3.8	6.5	6.1	8.3	271.6	15.8	9.6	325.3	15.6	75.4	19.9	2.0	282.0	7.0	57.0	32.0

Table 1.2. Hourly Meteorological Data - Event 2: 11/16/15 to 11/17/15

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
11/16/15 00:00	5.8	67.1	10.5	11.2	282.4	23.5	6.5	358.5	23.0	55.8	47.3	7.0	16.0	24.0	52.0	56.0
11/16/15 01:00	5.5	34.5	13.3	10.0	249.0	23.5	7.2	349.7	18.6	55.3	47.2	11.0	310.0	21.0	53.0	45.0
11/16/15 02:00	6.1	61.2	20.8	9.0	278.3	22.1	4.1	351.8	17.8	54.4	38.5	6.0	343.0	24.0	50.0	47.0
11/16/15 03:00	5.8	65.6	16.7	9.7	275.5	24.6	4.3	3.4	19.7	54.4	40.2	10.0	321.0	30.0	50.0	41.0
11/16/15 04:00	6.9	74.5	16.7	10.0	282.8	23.9	4.3	356.4	15.6	54.0	37.9	7.0	355.0	23.0	50.0	47.0
11/16/15 05:00	6.9	65.8	13.7	9.5	280.0	25.5	4.5	355.4	21.1	53.5	40.2	8.0	318.0	22.0	48.0	41.0
11/16/15 06:00	5.2	34.8	13.0	8.6	271.0	33.5	4.1	346.2	28.4	52.4	40.0	12.0	328.0	20.0	48.0	40.0
11/16/15 07:00	5.6	52.6	16.7	11.9	258.9	41.4	4.0	338.8	26.8	52.0	37.0	10.0	354.0	21.0	51.0	34.0
11/16/15 08:00	8.1	58.9	22.1	15.5	237.7	36.7	8.6	334.8	22.9	53.3	33.2	12.0	11.0	27.0	53.0	28.0
11/16/15 09:00	8.9	43.5	17.8	15.0	225.8	40.6	6.5	311.9	22.9	54.8	29.1	13.0	127.0	39.0	55.0	24.0
11/16/15 10:00	6.5	60.6	21.9	11.9	245.1	30.0	5.2	354.1	23.0	57.1	27.3	11.0	28.0	26.0	60.0	20.0
11/16/15 11:00	7.5	45.5	21.0	14.2	228.9	34.9	6.3	311.4	17.3	58.1	24.6	7.0	52.0	29.0	62.0	19.0
11/16/15 12:00	6.7	27.8	17.2	10.6	199.6	22.2	5.6	339.0	17.4	59.2	24.4	6.0	9.0	25.0	66.0	15.0
11/16/15 13:00	6.1	23.0	16.6	5.9	209.0	11.8	3.8	337.9	15.9	61.6	22.0	7.0	42.0	16.0	64.0	15.0
11/16/15 14:00	6.2	18.2	16.1	3.3	109.3	9.9	4.7	120.4	12.0	61.9	26.8	7.0	85.0	19.0	65.0	15.0
11/16/15 15:00	6.3	12.5	13.0	3.0	107.8	9.4	4.5	122.1	12.6	62.4	29.6	6.0	293.0	21.0	63.0	15.0
11/16/15 16:00	5.4	12.6	14.3	3.1	136.3	9.4	3.5	134.9	9.6	61.4	28.2	7.0	66.0	22.0	62.0	15.0
11/16/15 17:00	6.4	19.4	18.6	2.8	207.8	11.8	3.8	159.9	9.1	60.4	31.1	3.0	28.0	16.0	53.0	22.0
11/16/15 18:00	6.6	7.8	9.9	4.0	214.9	15.6	2.7	250.6	17.8	58.9	23.6	4.0	272.0	16.0	50.0	25.0
11/16/15 19:00	1.8	351.9	5.8	4.0	244.2	21.2	6.7	310.0	15.7	57.4	20.4	5.0	332.0	8.0	52.0	22.0
11/16/15 20:00	2.2	9.5	7.6	10.4	239.4	27.4	6.4	310.7	22.5	56.1	22.8	3.0	98.0	17.0	50.0	27.0
11/16/15 21:00	2.8	353.9	25.4	8.4	236.4	45.7	7.3	305.7	31.6	55.8	27.4	16.0	21.0	15.0	54.0	29.0
11/16/15 22:00	12.1	19.7	22.6	18.1	216.6	43.5	10.6	313.5	36.0	55.9	30.2	4.0	53.0	32.0	52.0	31.0
11/16/15 23:00	9.9	20.8	14.8	15.4	218.3	47.8	15.7	321.3	40.6	55.7	31.1	15.0	318.0	28.0	52.0	31.0

Table 1.2. Hourly Meteorological Data - Event 2: 11/16/15 to 11/17/15 - cont.

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
11/17/15 00:00	7.8	73.1	20.3	29.7	242.1	59.3	19.6	319.0	38.7	55.7	31.6	15.0	352.0	31.0	52.0	31.0
11/17/15 01:00	10.8	61.9	20.8	33.4	235.5	64.5	18.1	309.3	44.1	55.8	30.7	12.0	331.0	27.0	52.0	27.0
11/17/15 02:00	9.8	46.5	27.4	32.0	223.2	62.8	14.7	297.9	36.8	56.0	23.7	11.0	352.0	27.0	53.0	19.0
11/17/15 03:00	10.4	45.5	17.8	30.4	222.6	55.5	14.2	296.7	36.2	57.8	19.1	10.0	353.0	32.0	52.0	22.0
11/17/15 04:00	10.1	47.4	19.0	29.1	226.1	50.9	13.8	297.7	29.2	57.9	17.6	18.0	313.0	22.0	56.0	14.0
11/17/15 05:00	9.3	60.2	21.6	21.6	228.0	47.7	10.4	303.3	32.2	58.6	15.5	10.0	101.0	31.0	56.0	11.0
11/17/15 06:00	8.6	58.4	25.7	18.8	225.8	39.2	11.1	314.6	34.9	59.9	12.5	14.0	329.0	32.0	56.0	11.0
11/17/15 07:00	10.0	61.1	25.1	17.6	221.0	40.5	8.0	311.6	29.2	60.9	12.0	10.0	341.0	38.0	57.0	12.0
11/17/15 08:00	9.7	43.1	14.0	19.9	218.5	44.9	10.3	304.9	29.3	61.5	12.7	4.0	324.0	34.0	63.0	10.0
11/17/15 09:00	5.9	22.9	12.5	10.4	220.6	27.0	9.6	319.0	29.2	63.7	11.7	5.0	48.0	17.0	68.0	8.0
11/17/15 10:00	6.1	28.2	18.4	10.6	212.3	37.9	13.9	323.9	31.4	66.2	10.8	8.0	46.0	15.0	72.0	8.0
11/17/15 11:00	8.6	17.7	25.4	9.8	202.0	32.8	13.6	317.8	26.8	68.8	10.8	10.0	61.0	20.0	74.0	8.0
11/17/15 12:00	11.4	19.0	20.9	12.5	232.6	34.6	9.7	301.5	25.1	71.8	11.0	5.0	56.0	26.0	79.0	8.0
11/17/15 13:00	8.8	21.1	19.7	8.2	207.7	15.3	8.0	316.8	14.6	72.3	28.8	12.0	182.0	23.0	74.0	22.0
11/17/15 14:00	10.0	197.7	17.8	4.8	87.8	7.5	5.7	98.8	9.1	66.1	35.2	11.0	350.0	22.0	77.0	8.0
11/17/15 15:00	8.3	197.6	12.3	3.2	85.6	8.8	4.3	113.6	9.5	67.2	31.1	6.0	330.0	23.0	81.0	7.0
11/17/15 16:00	6.9	203.4	13.4	2.9	105.0	7.2	3.9	129.2	8.8	65.4	49.5	2.0	159.0	18.0	76.0	19.0
11/17/15 17:00	7.9	205.3	10.2	2.2	110.1	3.9	3.3	166.9	4.0	62.8	56.7	5.0	321.0	12.0	68.0	19.0
11/17/15 18:00	3.7	223.0	7.3	1.1	105.1	13.9	1.2	194.3	18.1	61.7	56.8	7.0	9.0	10.0	64.0	18.0
11/17/15 19:00	3.0	4.9	5.3	4.2	285.4	13.1	6.2	350.1	16.7	65.7	20.3	3.0	25.0	15.0	57.0	23.0
11/17/15 20:00	2.1	356.9	8.9	4.9	273.4	14.8	9.5	334.9	12.8	66.9	22.0	6.0	70.0	9.0	53.0	28.0
11/17/15 21:00	3.4	10.6	10.6	6.1	272.2	17.4	6.9	317.2	15.1	64.4	21.4	2.0	50.0	13.0	50.0	31.0
11/17/15 22:00	3.5	6.1	6.4	7.4	257.8	17.4	4.1	295.3	8.8	63.9	30.7	1.0	31.0	11.0	48.0	34.0
11/17/15 23:00	4.1	9.7	5.8	7.3	257.1	16.8	2.6	331.9	12.5	61.9	24.8	1.0	24.0	5.0	46.0	36.0

Table 1.3. Hourly Meteorological Data - Event 3: 12/14/15 to 12/15/15

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
12/14/15 00:00	4.8	45.7	7.8	10.0	275.0	21.6	7.1	350.8	15.7	53.3	54.9	7.0	356.0	16.0	47.0	67.0
12/14/15 01:00	3.6	4.8	6.4	8.7	281.1	19.0	6.5	0.3	15.5	52.4	52.2	7.0	336.0	18.0	48.0	62.0
12/14/15 02:00	2.9	8.0	6.1	8.9	275.9	20.3	4.5	350.8	17.9	51.8	47.8	4.0	324.0	15.0	42.0	71.0
12/14/15 03:00	3.8	356.0	7.0	7.6	278.9	16.2	5.9	359.4	17.9	50.6	49.0	6.0	21.0	9.0	43.0	66.0
12/14/15 04:00	4.5	355.0	7.6	5.2	290.6	11.8	6.3	345.5	11.5	48.9	50.4	3.0	257.0	10.0	39.0	71.0
12/14/15 05:00	3.9	1.0	5.3	4.2	276.5	14.8	6.0	337.1	13.7	47.9	47.5	2.0	249.0	6.0	35.0	84.0
12/14/15 06:00	3.2	4.2	5.2	3.7	256.1	10.5	5.6	326.8	8.6	47.0	52.6	2.0	291.0	4.0	34.0	90.0
12/14/15 07:00	3.7	2.2	6.4	4.6	256.9	12.7	3.2	293.6	9.3	46.0	52.6	1.0	327.0	4.0	32.0	100.0
12/14/15 08:00	3.8	3.8	6.2	7.0	259.6	14.0	3.9	301.8	9.1	45.1	54.6	1.0	28.0	4.0	33.0	100.0
12/14/15 09:00	4.0	9.7	8.5	7.1	261.6	12.1	3.9	318.4	12.1	46.3	52.0	2.0	49.0	4.0	43.0	76.0
12/14/15 10:00	4.6	350.5	9.2	3.3	279.7	20.8	5.4	344.3	17.2	47.2	49.8	5.0	314.0	12.0	54.0	38.0
12/14/15 11:00	4.1	17.1	13.7	8.9	227.3	28.6	6.7	344.6	22.1	52.2	37.8	8.0	329.0	26.0	58.0	31.0
12/14/15 12:00	6.5	81.7	17.5	14.7	257.4	28.8	6.3	1.0	22.7	56.0	31.4	9.0	261.0	27.0	59.0	27.0
12/14/15 13:00	6.0	76.1	17.5	12.1	260.2	40.5	5.4	2.3	22.2	57.7	29.9	10.0	343.0	31.0	60.0	23.0
12/14/15 14:00	6.7	60.5	21.4	17.3	237.5	33.4	8.2	333.0	24.7	58.1	26.7	11.0	356.0	26.0	58.0	22.0
12/14/15 15:00	6.8	42.5	21.3	14.9	239.9	33.9	8.8	332.7	26.3	58.1	26.0	9.0	244.0	31.0	60.0	19.0
12/14/15 16:00	7.9	57.2	17.8	17.4	240.6	26.3	9.5	323.0	21.9	57.5	23.3	9.0	18.0	26.0	55.0	26.0
12/14/15 17:00	6.6	45.7	19.1	10.5	247.8	19.7	6.2	330.8	22.1	56.3	30.3	7.0	39.0	16.0	50.0	34.0
12/14/15 18:00	11.1	6.2	16.2	8.4	241.0	24.6	6.4	294.0	29.0	54.0	33.6	7.0	25.0	14.0	45.0	39.0
12/14/15 19:00	8.3	10.2	17.0	9.8	206.8	27.4	11.7	306.5	29.2	51.8	34.3	11.0	25.0	13.0	44.0	44.0
12/14/15 20:00	10.7	1.0	20.6	8.5	280.5	31.9	16.8	321.3	33.8	51.1	33.6	6.0	21.0	18.0	42.0	44.0
12/14/15 21:00	13.3	352.4	19.4	12.0	214.5	33.5	11.9	300.6	26.0	50.7	33.3	7.0	56.0	19.0	46.0	38.0
12/14/15 22:00	11.5	351.2	15.6	12.8	219.2	33.2	10.5	293.9	31.4	50.8	32.0	5.0	348.0	18.0	44.0	39.0
12/14/15 23:00	7.4	6.5	17.0	16.1	217.0	34.6	10.3	292.2	27.5	50.4	35.4	10.0	339.0	16.0	45.0	35.0

Table 1.3. Hourly Meteorological Data - Event 3: 12/14/15 to 12/15/15 - cont.

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
12/15/15 00:00	8.5	21.5	16.2	18.1	216.8	32.4	9.5	294.8	21.9	50.2	32.8	6.0	320.0	19.0	45.0	36.0
12/15/15 01:00	5.7	40.6	22.1	17.8	233.8	35.9	8.0	297.7	36.3	49.8	34.3	11.0	51.0	17.0	45.0	38.0
12/15/15 02:00	12.4	6.0	24.6	15.6	213.7	40.9	13.9	301.0	40.6	50.3	34.3	6.0	335.0	21.0	44.0	42.0
12/15/15 03:00	10.4	19.9	12.6	16.2	214.3	44.7	15.4	307.5	32.5	50.0	35.9	7.0	4.0	16.0	43.0	46.0
12/15/15 04:00	8.1	30.5	11.0	18.4	215.8	35.0	15.6	318.8	27.9	49.2	38.3	6.0	351.0	12.0	40.0	51.0
12/15/15 05:00	5.2	19.4	6.6	12.7	215.9	22.6	14.6	322.1	23.0	48.6	39.9	2.0	309.0	8.0	38.0	58.0
12/15/15 06:00	3.8	6.5	6.6	8.5	229.3	21.0	14.7	336.5	20.2	48.1	41.2	3.0	43.0	6.0	33.0	69.0
12/15/15 07:00	3.8	10.5	6.1	8.5	255.1	15.9	12.5	327.8	20.6	47.8	40.2	2.0	33.0	4.0	31.0	76.0
12/15/15 08:00	4.0	6.2	7.7	9.6	257.5	23.1	13.1	320.0	23.7	47.5	44.7	2.0	289.0	5.0	32.0	74.0
12/15/15 09:00	4.7	14.3	8.1	11.7	252.3	32.2	13.3	331.5	30.8	47.8	35.7	4.0	327.0	8.0	47.0	46.0
12/15/15 10:00	5.4	23.0	17.2	14.6	206.6	40.5	15.3	310.6	27.6	50.2	35.2	9.0	31.0	19.0	56.0	26.0
12/15/15 11:00	7.9	26.5	23.1	16.0	214.1	30.7	9.3	299.2	24.0	53.1	29.5	6.0	41.0	21.0	58.0	21.0
12/15/15 12:00	9.4	16.5	15.3	10.6	213.2	21.6	6.3	305.9	14.8	55.9	24.8	6.0	23.0	16.0	60.0	18.0
12/15/15 13:00	5.2	25.5	14.0	7.9	213.0	9.1	3.9	324.6	12.2	58.3	30.6	5.0	251.0	16.0	64.0	13.0
12/15/15 14:00	4.9	18.0	12.9	3.1	111.8	7.8	4.8	140.7	11.4	58.1	30.8	9.0	214.0	18.0	64.0	22.0
12/15/15 15:00	4.9	232.1	13.5	2.5	112.2	7.0	4.0	138.4	9.9	58.2	30.6	9.0	198.0	17.0	63.0	22.0
12/15/15 16:00	8.0	206.9	11.9	2.7	98.7	5.0	3.9	114.7	9.1	57.8	34.5	3.0	195.0	15.0	57.0	30.0
12/15/15 17:00	5.6	206.7	11.0	2.0	113.1	20.6	2.9	125.0	12.1	56.3	36.5	7.0	2.0	14.0	54.0	18.0
12/15/15 18:00	3.6	9.4	12.4	7.1	230.0	28.1	3.1	282.8	18.1	56.3	20.2	5.0	338.0	18.0	51.0	21.0
12/15/15 19:00	5.9	19.8	8.0	13.9	227.8	29.8	6.9	287.2	21.2	55.5	21.0	8.0	319.0	14.0	49.0	22.0
12/15/15 20:00	3.6	27.4	9.4	14.9	227.5	29.4	9.6	303.1	19.8	54.7	21.8	8.0	316.0	17.0	50.0	22.0
12/15/15 21:00	3.5	5.9	8.3	13.6	242.1	24.6	9.3	309.4	20.7	54.0	22.0	6.0	327.0	13.0	45.0	24.0
12/15/15 22:00	4.7	353.3	11.0	13.8	243.7	23.4	10.1	312.0	23.2	53.5	21.9	8.0	15.0	13.0	45.0	26.0
12/15/15 23:00	5.5	5.8	8.3	11.4	216.6	19.2	10.2	310.7	25.9	52.9	21.8	1.0	63.0	12.0	41.0	28.0

Table 1.4. Hourly Meteorological Data - Event 4: 12/26/15

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
12/26/15 00:00	6.7	22.6	9.2	15.5	218.6	34.1	9.7	301.9	24.6	49.3	36.4	8.0	344.0	11.0	41.0	48.0
12/26/15 01:00	6.1	23.3	11.6	17.4	229.5	39.5	11.5	311.0	23.8	48.8	38.1	6.0	2.0	16.0	43.0	47.0
12/26/15 02:00	8.0	34.1	14.4	16.9	214.5	34.6	9.6	299.4	25.9	48.3	42.2	6.0	14.0	13.0	42.0	51.0
12/26/15 03:00	9.7	17.3	15.9	13.6	217.3	24.0	8.5	296.8	22.3	47.8	41.6	7.0	355.0	19.0	44.0	46.0
12/26/15 04:00	8.7	10.1	11.6	8.0	217.2	24.9	6.2	298.1	19.7	47.6	41.1	6.0	20.0	13.0	39.0	52.0
12/26/15 05:00	5.6	16.9	11.4	10.4	213.4	31.9	6.4	304.0	23.7	47.3	41.8	5.0	19.0	13.0	39.0	52.0
12/26/15 06:00	6.9	14.3	8.1	7.4	203.1	24.2	4.2	283.0	16.7	46.5	43.9	6.0	14.0	9.0	38.0	56.0
12/26/15 07:00	5.5	4.8	8.8	10.2	217.2	22.7	6.4	312.1	16.4	46.2	43.5	7.0	11.0	10.0	38.0	56.0
12/26/15 08:00	5.4	9.2	9.3	11.7	218.7	23.8	5.9	300.1	17.6	45.8	40.6	7.0	14.0	16.0	40.0	52.0
12/26/15 09:00	4.5	10.8	24.9	10.2	227.7	39.5	5.5	323.4	29.7	46.6	29.7	12.0	19.0	23.0	51.0	18.0
12/26/15 10:00	9.6	24.5	43.1	16.1	225.6	41.5	7.1	312.3	26.4	50.5	18.7	18.0	30.0	40.0	54.0	14.0
12/26/15 11:00	17.0	17.0	42.2	15.3	216.3	34.7	6.5	265.8	21.5	53.7	16.9	21.0	19.0	44.0	55.0	13.0
12/26/15 12:00	20.5	17.3	36.1	7.5	228.0	21.9	6.9	169.3	27.1	55.7	16.4	14.0	3.0	41.0	57.0	11.0
12/26/15 13:00	14.3	25.0	30.5	6.2	240.8	33.3	6.5	145.5	20.1	57.4	14.7	18.0	11.0	42.0	59.0	10.0
12/26/15 14:00	11.4	35.1	31.7	10.6	218.4	33.2	5.3	193.2	22.5	58.6	12.0	11.0	38.0	40.0	61.0	8.0
12/26/15 15:00	16.7	14.7	34.9	12.4	226.8	51.6	6.5	200.8	34.0	59.8	10.5	18.0	14.0	33.0	60.0	7.0
12/26/15 16:00	14.0	20.4	40.6	17.7	219.8	52.7	9.3	285.1	32.4	59.6	9.0	16.0	18.0	42.0	56.0	8.0
12/26/15 17:00	15.4	25.3	33.6	21.4	221.5	46.7	9.0	295.1	27.7	58.7	9.5	15.0	11.0	33.0	56.0	7.0
12/26/15 18:00	12.4	29.4	29.7	18.0	218.1	42.5	8.5	293.3	23.8	58.3	8.3	15.0	5.0	33.0	55.0	7.0
12/26/15 19:00	11.9	30.6	24.8	14.3	220.2	39.2	6.2	292.7	17.3	56.9	9.0	17.0	353.0	35.0	54.0	8.0
12/26/15 20:00	11.6	40.0	31.1	10.9	216.5	22.9	5.3	243.2	15.4	56.1	9.5	14.0	355.0	32.0	52.0	8.0
12/26/15 21:00	10.3	44.4	26.2	4.5	175.4	30.5	3.7	246.2	17.4	55.2	10.0	11.0	14.0	32.0	51.0	8.0
12/26/15 22:00	10.2	40.7	21.4	8.2	161.8	33.9	5.3	254.6	25.8	54.7	9.6	7.0	330.0	25.0	50.0	8.0
12/26/15 23:00	7.9	36.4	19.9	9.0	218.9	33.5	7.1	281.5	16.9	54.8	9.5	6.0	354.0	25.0	51.0	8.0

Table 1.5. Hourly Meteorological Data - Event 5: 02/06/16

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
02/06/16 00:00	4.9	7.9	7.1	11.8	244.9	21.6	12.7	326.1	25.1	65.6	18.8					
02/06/16 01:00	5.3	7.9	7.5	10.5	246.8	26.4	14.3	321.8	25.1	65.8	18.6					
02/06/16 02:00	5.4	8.8	9.1	11.3	230.3	22.0	15.3	320.1	28.5	65.7	17.9					
02/06/16 03:00	5.9	7.4	8.8	10.0	235.0	21.7	16.3	319.0	27.0	65.4	18.8					
02/06/16 04:00	5.7	9.5	7.1	9.3	243.0	22.5	15.9	322.8	24.8	64.3	19.9					
02/06/16 05:00	5.3	9.0	8.0	10.5	253.8	23.4	14.9	324.4	27.3	63.4	19.9					
02/06/16 06:00	5.8	10.4	7.6	9.7	252.5	18.9	13.1	318.3	20.5	63.4	20.7					
02/06/16 07:00	5.3	13.0	7.6	10.3	252.6	22.2	12.4	328.6	21.3	62.6	23.2					
02/06/16 08:00	5.8	6.3	7.8	10.2	247.6	24.4	12.7	329.4	18.9	62.7	21.0					
02/06/16 09:00	5.6	11.0	7.1	10.7	244.7	18.7	11.0	325.9	22.2	63.6	22.3	1.0	279.0	5.0	53.0	42.0
02/06/16 10:00	4.8	22.9	6.6	9.8	246.9	22.0	10.9	332.6	24.7	64.7	21.1	6.0	317.0	6.0	67.0	25.0
02/06/16 11:00	3.6	39.8	15.7	10.8	234.5	26.3	11.9	318.9	21.3	67.4	20.2	8.0	24.0	16.0	75.0	13.0
02/06/16 12:00	7.5	23.0	19.2	10.5	204.8	26.5	10.1	313.8	19.5	71.0	16.0					
02/06/16 13:00	8.7	22.3	19.6	13.2	217.8	26.5	6.7	301.3	19.7	73.9	14.3					
02/06/16 14:00	5.8	35.5	18.6	12.7	231.6	23.4	7.3	317.7	14.1	75.1	13.7	13.0	27.0	19.0	78.0	11.0
02/06/16 15:00	8.9	21.3	22.0	10.7	230.2	24.6	4.6	171.7	12.0	75.7	17.9	11.0	19.0	27.0	76.0	12.0
02/06/16 16:00	10.7	18.2	24.0	12.4	226.4	44.9	4.4	204.2	30.8	75.8	15.7					
02/06/16 17:00	11.8	18.2	26.5	17.5	209.6	40.5	9.9	293.8	31.9	75.4	14.9					
02/06/16 18:00	9.9	17.6	16.7	15.9	206.6	34.3	12.7	303.3	31.9	74.6	15.1					
02/06/16 19:00	6.9	16.0	8.7	14.8	214.4	35.7	12.2	305.7	27.0	72.9	16.3					
02/06/16 20:00	4.2	17.0	6.7	15.3	223.9	24.8	12.0	309.6	27.1	71.5	15.7					
02/06/16 21:00	3.8	3.4	6.2	11.3	219.4	19.0	13.8	314.4	21.7	71.4	15.1					
02/06/16 22:00	4.6	6.8	6.5	9.3	248.0	22.7	12.3	318.4	20.2	70.8	16.5					
02/06/16 23:00	4.8	6.6	7.3	10.1	252.6	22.9	12.4	324.9	33.5	69.8	16.9					

Table 1.6. Hourly Meteorological Data - Event 6: 02/14/16 to 02/15/16

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
02/14/16 00:00	5.6	12.5	7.5	9.6	236.9	20.0	7.5	345.8	17.2	68.1	22.5					
02/14/16 01:00	6.0	3.7	8.2	10.3	249.5	23.6	10.4	327.6	23.7	73.5	19.7					
02/14/16 02:00	6.4	10.7	8.4	7.5	227.2	24.8	11.3	340.2	22.9	73.8	18.8					
02/14/16 03:00	6.3	11.7	8.0	9.2	242.1	21.6	13.4	340.6	24.4	74.6	13.4					
02/14/16 04:00	6.1	8.8	8.6	8.3	256.7	21.5	10.6	329.5	19.3	75.1	25.2					
02/14/16 05:00	5.0	6.3	7.7	8.2	249.7	13.1	7.0	329.0	13.4	71.6	17.7					
02/14/16 06:00	6.0	10.5	7.6	7.5	257.8	11.1	6.8	327.1	14.0	70.8	82.7					
02/14/16 07:00	6.1	9.6	8.2	4.8	270.0	14.5	2.2	140.7	7.5	50.9	77.0					
02/14/16 08:00	5.1	12.2	8.1	5.6	257.6	22.1	1.9	210.8	14.3	51.8	52.4					
02/14/16 09:00	6.1	9.7	8.4	7.0	249.9	29.5	3.3	8.3	20.9	58.2	50.3					
02/14/16 10:00	5.6	20.5	6.5	12.2	241.1	28.3	5.0	344.8	20.4	67.5	19.9					
02/14/16 11:00	3.0	32.0	16.4	10.1	230.7	18.8	5.7	285.8	11.9	71.5	79.0					
02/14/16 12:00	6.1	27.9	24.8	5.0	236.8	21.0	4.9	138.2	17.9	65.1	81.0					
02/14/16 13:00	11.9	14.6	25.1	2.9	64.5	13.7	4.6	129.9	18.2	63.2	59.2					
02/14/16 14:00	13.3	13.6	28.9	3.8	64.6	20.5	6.9	158.1	19.8	64.8	76.5					
02/14/16 15:00	13.8	16.7	28.3	4.7	44.4	25.5	6.5	149.3	22.8	66.0	60.1					
02/14/16 16:00	13.9	20.6	33.1	5.4	337.3	31.5	7.2	177.5	20.2	71.6	58.3					
02/14/16 17:00	13.7	18.4	24.9	11.5	222.1	40.6	5.9	281.7	30.3	76.5	15.0	4.0	335.0	19.0	78.0	11.0
02/14/16 18:00	9.0	15.9	11.2	17.8	224.2	25.7	7.1	294.8	22.2	82.9	14.0	7.0	343.0	11.0	75.0	12.0
02/14/16 19:00	4.0	16.2	8.0	11.8	225.4	32.6	7.3	301.0	23.4	83.1	12.0					
02/14/16 20:00	4.9	23.8	13.8	17.2	224.0	39.2	9.0	300.8	24.5	81.6	12.9					
02/14/16 21:00	8.7	23.5	16.2	17.3	216.8	35.2	9.6	298.4	31.4	80.4	12.8	5.0	313.0	12.0	73.0	14.0
02/14/16 22:00	7.5	10.4	6.3	16.5	221.2	34.3	11.3	298.8	31.4	80.1	14.5					
02/14/16 23:00	3.8	1.1	9.1	11.3	211.6	31.6	13.2	314.5	24.1	79.9	15.6	6.0	310.0	13.0	77.0	15.0

Table 1.6. Hourly Meteorological Data - Event 6: 02/14/16 to 02/15/16 - cont.

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
02/15/16 00:00	5.1	358.9	16.2	14.4	220.6	40.7	9.4	303.2	30.6	80.0	16.5	7.0	338.0	19.0	76.0	16.0
02/15/16 01:00	8.0	16.8	17.2	19.0	220.6	37.4	12.5	301.9	28.4	80.2	17.4					
02/15/16 02:00	8.0	21.0	12.1	19.8	221.8	40.3	11.1	298.5	30.3	79.9	18.4	6.0	313.0	16.0	74.0	19.0
02/15/16 03:00	6.1	19.9	12.8	15.4	218.2	30.0	12.0	303.6	31.0	79.5	19.8	6.0	329.0	18.0	72.0	22.0
02/15/16 04:00	5.9	21.2	9.1	14.7	216.2	32.4	14.0	310.4	24.7	79.0	20.6					
02/15/16 05:00	4.4	16.4	8.2	15.4	230.6	32.2	10.9	308.7	21.8	78.5	21.4					
02/15/16 06:00	4.7	1.1	8.2	16.0	230.8	32.4	11.4	310.6	27.2	78.2	21.8	7.0	342.0	13.0	69.0	28.0
02/15/16 07:00	5.4	7.9	9.4	16.6	223.1	31.2	14.3	315.4	24.9	77.3	22.7					
02/15/16 08:00	5.0	358.1	7.5	15.9	231.8	27.6	14.2	314.5	29.0	76.6	23.5	8.0	3.0	12.0	81.0	19.0
02/15/16 09:00	4.2	359.7	9.8	12.6	226.5	29.2	15.9	319.8	24.2	76.9	23.2	13.0	11.0	29.0	83.0	16.0
02/15/16 10:00	5.3	22.1	22.1	13.3	210.8	44.6	14.2	316.4	31.4	78.8	22.1					
02/15/16 11:00	10.4	19.5	26.7	15.8	202.4	38.9	13.3	307.1	41.0	81.2	21.0					
02/15/16 12:00	14.0	13.4	29.6	15.6	211.8	40.8	12.8	307.6	36.9	82.7	19.8					
02/15/16 13:00	16.2	12.3	27.4	18.1	214.6	33.0	9.8	282.6	22.4	83.9	19.2					
02/15/16 14:00	16.4	14.5	27.8	17.2	220.9	32.1	6.2	269.1	17.0	85.7	18.6					
02/15/16 15:00	14.6	17.8	29.5	12.5	230.1	30.5	5.0	248.8	13.7	87.4	17.5					
02/15/16 16:00	14.0	15.3	21.9	10.9	230.2	27.0	3.7	191.9	21.6	88.3	21.4					
02/15/16 17:00	10.8	21.7	19.7	10.3	222.6	31.6	6.1	290.9	25.7	86.9	18.1	7.0	3.0	19.0	79.0	19.0
02/15/16 18:00	9.2	18.5	16.6	13.0	220.7	29.8	8.2	295.7	15.6	85.9	18.3	6.0	11.0	12.0	72.0	24.0
02/15/16 19:00	7.5	5.3	12.6	13.3	225.4	33.3	5.7	294.3	29.0	83.8	19.6					
02/15/16 20:00	4.8	23.6	8.0	17.3	224.0	33.5	11.3	306.9	26.1	82.9	19.9					
02/15/16 21:00	4.1	8.5	7.5	14.4	221.6	37.3	14.9	316.6	23.9	82.1	20.1					
02/15/16 22:00	4.2	7.6	7.2	10.2	230.5	15.5	11.4	316.1	21.5	81.3	20.8					
02/15/16 23:00	4.9	5.9	7.2	5.5	240.5	12.6	12.9	315.8	23.3	80.8	19.0					

Table 1.7. Hourly Meteorological Data - Event 7: 02/22/16

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
02/22/16 00:00	4.9	7.0	6.5	11.1	251.8	20.0	8.9	309.7	19.4	66.9	24.0					
02/22/16 01:00	4.8	6.6	6.6	12.7	252.7	23.1	9.6	308.2	15.3	67.1	20.3					
02/22/16 02:00	5.1	11.5	6.9	13.1	263.1	24.0	6.4	309.2	14.9	68.6	16.7					
02/22/16 03:00	5.1	9.2	6.4	13.9	252.0	19.7	7.3	324.1	15.3	67.7	21.0					
02/22/16 04:00	5.0	13.0	6.3	11.1	260.8	19.9	5.3	319.8	4.4	57.4	56.0					
02/22/16 05:00	4.9	13.4	6.6	11.2	262.9	22.1	1.5	171.0	13.6	48.4	56.6					
02/22/16 06:00	4.9	11.0	7.1	12.3	255.4	22.8	4.2	335.3	12.0	54.7	25.0					
02/22/16 07:00	4.9	10.3	7.5	11.5	258.2	20.5	2.6	59.6	10.7	51.0	53.9					
02/22/16 08:00	5.1	12.7	7.6	10.7	261.7	22.1	3.0	26.0	15.6	48.8	31.0	2.0	281.0	4.0	53.0	60.0
02/22/16 09:00	5.0	12.5	8.6	11.6	256.5	22.9	6.5	356.2	24.8	55.1	24.1					
02/22/16 10:00	5.5	24.2	12.9	12.0	248.0	36.2	6.4	346.0	31.0	64.7	17.0					
02/22/16 11:00	6.4	14.5	35.2	16.2	223.4	40.8	9.0	304.7	28.3	76.0	16.9					
02/22/16 12:00	13.9	17.1	36.3	17.9	215.8	42.2	8.9	293.1	33.0	78.1	15.8	12.0	24.0	35.0	84.0	10.0
02/22/16 13:00	16.3	12.7	30.0	15.4	217.2	40.3	8.3	296.0	30.9	79.9	14.2					
02/22/16 14:00	15.3	16.0	28.1	12.5	230.4	34.6	6.1	239.5	17.4	79.9	20.1					
02/22/16 15:00	13.2	15.8	28.8	11.1	229.3	32.4	5.8	209.0	22.6	81.7	12.9	9.0	18.0	27.0	84.0	10.0
02/22/16 16:00	10.4	23.6	20.5	14.6	227.5	30.3	5.2	255.3	18.6	82.9	12.4					
02/22/16 17:00	9.3	17.9	21.0	13.3	220.7	29.5	5.5	273.9	16.1	82.6	12.8	7.8	244.0	19.0	71.3	14.8
02/22/16 18:00	7.6	15.4	10.8	12.6	219.4	21.9	5.6	282.6	14.8	81.2	13.4					
02/22/16 19:00	3.2	16.6	8.5	11.0	226.9	23.3	6.6	303.1	16.4	79.8	14.5					
02/22/16 20:00	3.2	2.0	5.8	9.2	243.4	23.8	5.9	315.9	19.7	76.8	15.2					
02/22/16 21:00	3.4	3.1	5.5	9.6	232.7	27.0	11.6	326.3	19.6	74.1	14.8					
02/22/16 22:00	3.8	4.0	8.3	8.1	254.2	22.5	11.7	323.1	16.4	72.2	14.8					
02/22/16 23:00	5.0	357.9	9.4	10.4	247.1	23.1	7.6	320.5	14.2	71.6	12.6					

Table 1.8. Hourly Meteorological Data - Event 8: 03/22/16 to 03/23/16

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
03/22/16 00:00	3.1	12.1	4.7	5.7	263.1	11.8	4.4	309.2	10.7	58.0	68.1					
03/22/16 01:00	3.0	8.5	7.4	5.5	258.0	9.9	3.9	306.0	8.3	56.9	67.1					
03/22/16 02:00	4.2	16.3	6.9	3.5	257.4	9.9	2.6	309.9	9.8	56.6	68.9					
03/22/16 03:00	4.0	11.4	6.6	3.6	273.0	14.4	3.0	296.6	15.0	56.2	72.3					
03/22/16 04:00	4.0	9.5	8.4	4.7	276.0	13.7	7.3	322.2	14.8	55.7	70.9					
03/22/16 05:00	4.5	12.9	7.2	3.9	260.1	14.6	5.8	331.2	17.5	55.4	76.6	1.0	24.0	7.0	48.0	97.0
03/22/16 06:00	4.4	10.6	7.7	4.7	355.8	9.6	7.2	331.2	16.7	55.5	68.5	2.0	352.0	6.0	47.0	94.0
03/22/16 07:00	3.9	10.2	7.6	3.2	252.0	13.8	6.2	324.9	17.5	55.2	75.2					
03/22/16 08:00	4.0	7.3	5.9	5.1	264.1	11.3	8.7	331.9	20.2	54.7	69.1	1.0	316.0	5.0	55.0	75.0
03/22/16 09:00	2.8	19.3	6.1	3.2	263.8	12.2	7.7	348.0	12.6	57.2	62.0	2.0	12.0	5.0	64.0	54.0
03/22/16 10:00	2.8	40.1	11.8	5.8	209.6	11.9	4.3	345.3	11.5	60.5	57.8					
03/22/16 11:00	3.6	41.1	14.5	4.8	209.5	9.1	4.1	34.1	12.5	63.0	56.3	9.0	53.0	14.0	68.0	30.0
03/22/16 12:00	5.8	19.4	18.7	3.6	90.9	11.0	5.7	104.6	13.2	63.1	49.1	6.0	35.0	19.0	71.0	27.0
03/22/16 13:00	6.0	16.4	15.4	3.2	87.7	11.1	5.5	105.6	14.1	64.2	50.0					
03/22/16 14:00	5.6	16.8	15.6	3.9	89.7	10.0	4.5	119.9	18.2	65.6	42.0	7.0	61.0	22.0	70.0	25.0
03/22/16 15:00	4.6	170.3	14.0	3.2	114.3	15.4	6.0	128.4	14.9	65.3	40.8					
03/22/16 16:00	6.2	191.1	13.4	4.1	180.5	9.4	5.3	136.7	14.1	65.7	51.0					
03/22/16 17:00	5.9	190.7	12.7	3.8	101.5	7.7	5.9	112.0	10.8	65.0	55.4	5.0	207.0	14.0	69.0	34.0
03/22/16 18:00	5.2	207.4	8.0	2.7	104.7	5.3	3.8	130.0	10.2	62.8	54.0					
03/22/16 19:00	3.6	200.5	5.5	1.9	158.0	9.4	2.3	243.8	14.8	62.3	28.1					
03/22/16 20:00	1.7	263.4	5.3	3.1	264.8	18.8	3.8	328.8	16.8	63.2	25.6					
03/22/16 21:00	2.2	2.6	5.5	6.6	254.1	14.8	8.8	328.4	18.1	62.1	28.5					
03/22/16 22:00	2.8	11.8	6.4	5.0	251.2	24.0	5.5	323.2	20.8	60.4	31.7					
03/22/16 23:00	3.5	6.4	9.6	9.2	233.8	33.5	7.8	318.5	36.0	59.8	30.8					

Table 1.8. Hourly Meteorological Data - Event 8: 03/22/16 to 03/23/16 - cont.

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
03/23/16 00:00	5.8	8.4	18.0	14.6	219.3	40.6	14.0	313.1	39.0	60.0	29.7	5.0	324.0	21.0	54.0	37.0
03/23/16 01:00	8.4	29.6	14.8	18.0	216.7	48.9	17.1	319.2	31.3	60.0	34.6					
03/23/16 02:00	8.4	34.6	13.8	22.2	226.1	42.7	13.9	308.7	27.8	59.5	35.4	10.0	10.0	16.0	52.0	47.0
03/23/16 03:00	8.4	29.3	11.8	22.1	218.2	42.5	14.0	305.6	29.4	59.5	34.5	8.0	341.5	15.0	52.5	40.0
03/23/16 04:00	5.9	30.7	11.7	22.0	229.7	42.0	10.2	294.9	23.7	59.4	32.9					
03/23/16 05:00	7.6	32.0	16.4	20.1	224.4	47.0	11.0	302.5	31.2	60.0	29.7	9.0	353.0	17.0	55.0	32.0
03/23/16 06:00	8.3	39.7	18.3	22.8	220.7	46.3	14.3	300.0	30.3	59.9	30.8	11.0	314.0	23.0	56.0	31.0
03/23/16 07:00	6.9	60.8	13.2	22.6	237.3	43.0	13.1	305.7	34.1	59.7	29.3					
03/23/16 08:00	5.8	64.3	16.6	20.2	246.2	46.4	13.4	315.1	28.6	60.0	25.7	9.0	312.0	23.0	63.0	21.0
03/23/16 09:00	6.4	58.8	19.1	21.4	239.7	39.2	12.7	311.1	31.3	62.5	21.8	10.0	352.0	18.0	66.0	17.0
03/23/16 10:00	7.0	40.8	23.9	18.9	240.7	39.2	12.0	310.8	28.4	64.8	19.4					
03/23/16 11:00	9.7	34.7	28.0	17.7	217.8	47.0	12.3	309.5	30.7	67.2	16.9	10.0	42.0	29.0	74.0	12.0
03/23/16 12:00	14.1	17.4	25.1	17.8	217.2	37.7	9.0	287.8	23.8	69.7	14.5	9.0	47.0	33.0	75.0	11.0
03/23/16 13:00	12.8	13.8	25.3	13.4	224.1	27.7	5.9	257.2	15.2	72.4	13.9					
03/23/16 14:00	8.7	13.6	18.1	11.4	232.6	20.5	4.7	191.4	15.9	74.5	11.7					
03/23/16 15:00	4.5	24.0	14.5	8.6	226.8	20.8	3.7	290.7	15.5	76.2	12.3					
03/23/16 16:00	4.5	30.1	11.4	5.5	206.6	8.7	3.3	51.5	14.0	77.1	15.1					
03/23/16 17:00	3.7	7.2	7.7	2.8	78.9	8.8	3.9	139.6	11.5	75.4	16.3					
03/23/16 18:00	2.7	63.2	8.5	2.1	264.1	8.8	3.1	183.8	7.9	70.9	39.0	6.0	349.0	19.0	66.0	20.0
03/23/16 19:00	4.2	52.1	9.4	1.8	264.5	15.6	2.4	341.5	21.6	69.3	23.4					
03/23/16 20:00	4.2	19.2	8.3	5.8	44.5	18.7	11.7	350.6	23.4	67.6	25.4	3.0	267.0	12.0	56.0	34.0
03/23/16 21:00	3.7	352.0	5.3	6.2	237.7	17.9	14.0	343.1	23.8	65.3	27.4	2.0	334.0	8.0	52.0	46.0
03/23/16 22:00	3.3	8.0	6.0	6.6	278.0	23.2	14.3	346.7	21.8	64.2	26.8					
03/23/16 23:00	4.1	11.7	6.0	6.7	243.3	18.5	14.0	342.5	22.0	63.7	27.0					

Table 1.9. Hourly Meteorological Data - Event 9: 04/15/16 to 04/16/16

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
04/15/16 00:00	4.1	8.2	6.9	8.3	261.4	26.5	15.0	333.7	28.0	64.6	26.6					
04/15/16 01:00	4.7	18.0	7.4	10.3	233.8	25.3	17.1	331.0	25.7	63.7	33.7					
04/15/16 02:00	5.2	15.8	6.7	7.7	339.0	36.2	17.1	337.1	27.6	62.2	37.8					
04/15/16 03:00	4.5	16.4	8.0	14.2	216.2	42.2	16.8	331.3	30.2	60.9	40.4					
04/15/16 04:00	6.1	23.4	10.4	19.5	224.3	37.0	17.7	319.3	35.5	59.7	43.7					
04/15/16 05:00	6.3	24.6	12.0	14.9	212.3	42.1	18.6	322.2	35.7	58.8	43.4	0.0	0.0	0.0	0.0	0.0
04/15/16 06:00	5.6	54.0	13.7	21.0	232.7	47.5	18.2	322.6	33.9	58.0	44.6	10.0	320.0	13.0	53.0	51.0
04/15/16 07:00	5.1	68.0	17.5	22.8	238.1	35.7	20.2	323.6	31.1	58.2	42.7					
04/15/16 08:00	6.2	60.8	25.6	17.2	233.5	50.7	11.8	316.7	42.2	58.8	41.0	9.0	342.0	25.0	57.0	43.0
04/15/16 09:00	10.4	31.5	21.2	20.8	218.1	39.9	14.2	312.0	37.0	60.5	38.3	16.0	3.0	31.0	65.0	30.0
04/15/16 10:00	8.5	40.7	31.9	19.4	224.6	45.0	14.9	321.6	34.0	63.0	32.0					
04/15/16 11:00	10.9	33.7	32.7	21.8	222.1	45.6	13.7	314.6	30.5	64.8	31.3	12.0	352.0	28.0	65.0	29.0
04/15/16 12:00	10.6	34.7	38.5	23.5	226.9	55.0	11.5	301.2	30.3	66.2	23.5					
04/15/16 13:00	14.9	32.5	38.1	26.6	225.3	50.2	10.6	288.6	33.4	69.5	15.5					
04/15/16 14:00	14.9	28.1	35.4	20.9	224.6	42.9	8.5	261.1	23.2	72.0	15.8					
04/15/16 15:00	13.6	26.8	25.1	15.0	216.5	38.8	6.4	264.9	22.4	74.6	15.0					
04/15/16 16:00	10.8	41.5	24.7	18.0	222.1	49.3	7.3	296.5	27.8	75.2	15.5					
04/15/16 17:00	10.9	46.4	25.2	21.1	225.4	41.5	8.8	292.4	24.1	75.5	12.4					
04/15/16 18:00	10.0	41.5	21.6	19.8	224.1	31.8	9.0	301.3	23.5	75.2	13.0					
04/15/16 19:00	9.7	38.3	20.2	16.7	226.4	23.9	8.3	303.7	17.9	73.9	13.3					
04/15/16 20:00	7.3	36.5	9.4	7.1	215.4	14.8	4.7	310.2	18.4	72.0	16.4					
04/15/16 21:00	6.0	11.2	9.5	5.6	209.7	8.5	3.6	299.1	11.4	70.1	19.4					
04/15/16 22:00	5.8	0.2	6.9	2.2	186.2	8.1	2.4	310.0	11.8	68.6	22.1					
04/15/16 23:00	4.1	357.0	7.9	1.4	217.5	6.2	2.9	323.7	6.7	66.9	24.0					

Table 1.9. Hourly Meteorological Data - Event 9: 04/15/16 to 04/16/16 - cont.

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
04/16/16 00:00	4.0	4.7	8.6	1.5	258.2	5.6	1.6	288.9	8.8	65.0	23.2	9.0	349.0	11.0	61.0	24.0
04/16/16 01:00	4.6	355.2	10.5	1.5	219.1	8.2	2.3	328.5	10.2	66.2	18.8					
04/16/16 02:00	6.3	29.4	11.5	1.8	231.1	8.2	2.2	285.5	6.2	67.2	18.6					
04/16/16 03:00	4.6	23.6	11.8	2.0	288.2	9.9	2.3	292.7	10.6	67.2	16.7					
04/16/16 04:00	5.7	8.6	18.4	1.5	67.3	7.5	3.1	298.4	5.3	66.7	16.6					
04/16/16 05:00	8.0	33.7	14.8	1.6	217.4	12.4	1.5	305.6	8.4	65.3	17.0	9.0	354.0	20.0	64.0	14.0
04/16/16 06:00	3.9	50.6	11.3	4.1	237.3	27.3	2.6	294.7	22.7	65.5	16.7	9.0	290.0	17.0	64.0	14.0
04/16/16 07:00	4.5	34.1	17.0	11.5	234.8	29.8	8.7	319.4	26.3	67.5	16.9					
04/16/16 08:00	9.3	54.0	24.3	13.5	226.0	39.6	8.7	310.2	28.4	68.4	16.7	12.0	348.0	19.0	67.0	15.0
04/16/16 09:00	9.8	46.2	27.0	20.1	222.7	48.5	9.5	304.6	29.7	71.4	15.2	14.0	3.0	28.0	71.0	12.0
04/16/16 10:00	9.8	46.5	29.2	23.5	226.4	46.5	11.1	304.4	26.1	73.9	13.7					
04/16/16 11:00	11.8	32.4	30.3	19.9	225.3	39.1	7.2	288.5	21.6	77.0	12.3					
04/16/16 12:00	12.7	25.0	25.0	14.6	222.2	33.7	5.3	269.3	18.8	79.6	11.7	14.0	28.0	38.0	80.0	9.0
04/16/16 13:00	10.0	33.7	25.9	8.5	246.9	24.0	6.9	159.0	23.2	79.4	18.8					
04/16/16 14:00	12.0	23.2	28.1	6.5	247.0	14.3	6.9	143.7	17.8	80.3	19.7					
04/16/16 15:00	11.1	19.8	23.7	4.3	55.6	16.2	7.9	150.7	15.3	76.9	33.7					
04/16/16 16:00	8.9	53.1	15.1	5.3	330.3	18.9	5.4	149.6	13.7	77.4	26.7					
04/16/16 17:00	6.2	83.8	13.4	6.4	276.9	19.6	4.0	5.7	18.3	82.5	14.2					
04/16/16 18:00	5.8	56.0	13.7	6.1	259.4	19.7	9.6	351.0	21.7	79.0	15.5					
04/16/16 19:00	5.3	49.2	12.1	6.6	210.4	19.9	11.1	340.3	25.9	76.9	17.1					
04/16/16 20:00	7.2	23.6	13.9	6.0	7.4	24.3	12.4	349.2	25.9	74.4	20.2	9.0	29.0	21.0	70.0	19.0
04/16/16 21:00	5.4	358.8	7.7	11.6	20.5	24.7	12.5	351.6	25.4	72.8	23.8	4.0	320.0	16.0	64.0	25.0
04/16/16 22:00	4.5	3.1	6.9	9.0	0.4	17.7	13.5	346.9	25.0	72.6	27.0					
04/16/16 23:00	3.9	15.7	6.2	6.0	320.2	14.0	11.1	335.3	21.0	72.4	29.9					

Malibu Canyon Wind Study
Meteorological Monitoring Program

Appendix 2 –
Readings during Non-Santa Ana Wind Events

4161 Campus Point Court / San Diego, CA 92121 / 858-826-2732

Table 2.1. Hourly Meteorological Data - 01/05/16

	Station 1			Station 2			Station 3					MBCC				
Time	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
01/05/16 00:00	3.4	7.3	4.2	4.0	265.7	8.2	0.9	123.9	2.7	52.9	74.7	1.0	207.0	3.0	45.0	85.0
01/05/16 01:00	3.0	10.4	4.1	3.5	258.4	6.9	0.6	11.6	3.5	52.6	76.6	1.0	109.0	3.0	46.0	83.0
01/05/16 02:00	3.0	6.2	4.7	2.8	256.6	5.6	0.5	359.8	4.5	53.4	76.3	1.0	327.0	4.0	48.0	82.0
01/05/16 03:00	3.2	19.7	4.7	2.2	256.4	6.3	0.7	307.8	2.3	55.3	79.4	3.0	38.0	4.0	47.0	81.0
01/05/16 04:00	2.4	8.0	4.7	2.8	259.8	8.7	0.3	55.3	8.6	54.4	84.2	2.0	323.0	5.0	49.0	82.0
01/05/16 05:00	2.7	11.8	8.9	2.4	79.6	12.8	3.6	163.9	13.7	56.3	86.5	5.0	148.0	14.0	54.0	90.0
01/05/16 06:00	1.8	51.9	8.0	5.5	91.4	14.0	7.3	138.3	18.3	57.1	84.8	7.0	118.0	19.0	54.0	92.0
01/05/16 07:00	1.9	72.1	8.9	5.6	92.6	13.3	8.3	142.8	21.1	57.1	87.9	10.0	149.0	24.0	52.0	92.0
01/05/16 08:00	2.3	70.6	11.3	5.6	94.6	15.6	6.8	158.1	23.3	55.6	90.7	6.0	343.0	23.0	52.0	100.0
01/05/16 09:00	2.9	83.0	24.3	5.9	95.7	21.2	9.9	160.4	31.4	54.3	94.1	7.0	241.0	36.0	54.0	100.0
01/05/16 10:00	6.8	216.4	36.1	9.3	93.1	25.9	13.6	149.1	29.7	55.3	97.7	17.0	169.0	39.0	57.0	100.0
01/05/16 11:00	13.7	222.9	38.3	10.6	84.1	24.8	11.2	121.2	34.7	56.7	98.4	13.0	188.0	54.0	55.0	100.0
01/05/16 12:00	13.2	226.1	37.5	8.6	86.6	17.6	14.4	112.2	25.1	57.3	96.7	14.0	206.0	47.0	55.0	97.0
01/05/16 13:00	9.4	214.0	14.6	6.1	80.7	10.5	8.1	109.6	12.6	56.5	97.3	5.0	177.0	28.0	54.0	100.0
01/05/16 14:00	5.5	190.1	12.1	3.0	92.4	9.6	3.4	108.2	16.7	53.9	97.4	9.0	343.0	15.0	56.0	95.0
01/05/16 15:00	3.9	138.5	11.8	2.8	168.2	21.7	3.0	355.8	19.7	55.2	87.9	7.0	325.0	31.0	57.0	76.0
01/05/16 16:00	4.4	56.3	10.2	6.7	252.6	16.7	7.5	350.5	15.5	57.9	71.0	6.0	356.0	15.0	55.0	78.0
01/05/16 17:00	3.9	22.7	8.3	3.9	304.1	20.2	5.5	350.9	15.6	56.7	76.8	3.0	319.0	13.0	53.0	78.0
01/05/16 18:00	2.1	37.3	7.3	5.5	282.4	14.1	4.8	341.3	17.0	56.4	71.2	2.0	79.0	9.0	51.0	89.0
01/05/16 19:00	1.2	324.6	6.5	2.2	265.6	12.5	2.4	327.4	6.5	55.6	77.3	3.0	334.0	8.0	50.0	91.0
01/05/16 20:00	1.8	2.9	8.9	2.7	259.4	10.1	1.9	306.1	12.6	54.7	75.3	5.0	58.0	11.0	49.0	88.0
01/05/16 21:00	3.7	10.3	7.2	2.4	234.2	12.1	3.5	320.7	13.2	53.6	75.1	2.0	359.0	8.0	45.0	99.0
01/05/16 22:00	2.3	8.7	4.9	3.1	259.3	5.7	4.5	322.1	8.1	52.8	81.8	2.0	8.0	5.0	44.0	100.0
01/05/16 23:00	2.1	12.9	6.4	2.1	264.3	11.0	3.1	297.8	13.5	52.0	78.1	2.0	5.0	5.0	42.0	100.0

Table 2.2. Hourly Meteorological Data - 01/31/16 to 02/01/16

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
01/31/16 00:00	1.9	14.3	4.6	2.3	252.4	4.4	0.6	304.1	2.3	56.1	92.1					
01/31/16 01:00	2.8	10.1	7.7	2.0	251.7	3.9	0.2	248.6	2.5	54.7	93.1					
01/31/16 02:00	2.9	8.1	5.8	0.9	322.5	4.7	0.6	143.4	5.3	54.3	92.9					
01/31/16 03:00	3.4	21.5	5.1	1.7	254.9	5.6	1.3	160.6	6.8	55.4	93.7	2.0	30.0	4.0	46.0	100.0
01/31/16 04:00	3.1	13.7	6.0	1.7	270.4	4.7	1.3	154.5	10.9	54.9	91.4	3.0	221.0	5.0	46.0	100.0
01/31/16 05:00	3.1	25.4	5.8	2.2	30.0	8.6	3.1	124.6	13.4	54.9	91.6	6.0	211.0	15.0	53.0	91.0
01/31/16 06:00	2.3	250.2	12.3	3.4	89.6	6.4	3.9	147.3	8.9	55.6	87.3	10.0	177.0	15.0	53.0	89.0
01/31/16 07:00	6.2	190.4	18.6	2.2	96.1	11.4	2.4	135.7	11.5	55.2	87.7	8.0	198.0	23.0	54.0	93.0
01/31/16 08:00	8.5	212.0	29.5	3.4	88.4	14.7	5.4	156.7	22.3	55.3	90.4	14.0	203.0	34.0	53.0	100.0
01/31/16 09:00	11.5	219.4	30.5	6.0	88.1	20.2	8.1	152.1	26.0	53.9	97.2	14.0	178.0	35.0	53.0	100.0
01/31/16 10:00	13.5	217.2	30.6	6.7	86.4	18.3	7.7	123.6	30.6	54.0	98.1	19.0	170.0	36.0	55.0	100.0
01/31/16 11:00	12.6	209.4	33.3	8.4	84.0	23.2	9.7	110.4	33.2	55.0	94.6	16.0	296.0	38.0	55.0	100.0
01/31/16 12:00	13.6	210.1	45.6	8.2	78.7	28.6	14.0	110.1	37.9	55.4	97.6	21.0	177.0	48.0	56.0	100.0
01/31/16 13:00	17.1	219.2	49.0	10.8	86.4	33.5	19.6	111.4	42.5	56.4	94.9	20.0	205.0	65.0	56.0	100.0
01/31/16 14:00	19.6	207.4	32.4	12.0	79.7	28.1	17.4	108.1	34.3	56.6	98.2	13.0	286.0	54.0	54.0	79.0
01/31/16 15:00	5.9	188.5	24.8	7.4	267.9	22.1	5.3	117.4	16.7	56.7	85.4	7.0	287.0	40.0	52.0	76.0
01/31/16 16:00	4.4	64.3	13.4	4.6	316.1	26.5	3.7	72.7	18.7	54.3	78.4	10.0	332.0	26.0	54.0	67.0
01/31/16 17:00	4.4	45.9	21.3	5.5	306.6	31.4	3.3	2.9	28.1	53.8	69.7	15.0	346.0	44.0	51.0	59.0
01/31/16 18:00	7.7	56.4	15.1	13.2	270.8	33.4	8.0	356.2	24.0	54.6	55.4	12.0	318.0	35.0	50.0	57.0
01/31/16 19:00	3.8	57.1	13.9	14.9	275.8	33.5	4.5	358.0	20.6	52.3	55.4	21.0	301.0	30.0	50.0	52.0
01/31/16 20:00	5.4	63.4	14.8	11.8	268.8	26.2	5.0	359.3	22.1	51.4	47.9	14.0	314.0	40.0	49.0	52.0
01/31/16 21:00	2.9	52.2	7.8	11.4	266.0	25.4	4.3	348.2	20.3	50.6	51.5	17.0	309.0	35.0	49.0	56.0
01/31/16 22:00	3.0	69.7	16.6	11.6	270.8	27.9	4.0	351.2	23.6	50.0	50.7	17.0	308.0	39.0	47.0	58.0
01/31/16 23:00	5.2	65.7	16.8	10.8	271.6	25.4	3.3	354.2	22.4	49.7	53.4	14.0	309.0	38.0	47.0	53.0

Table 2.2. Hourly Meteorological Data - Event 6: 01/31/16 to 02/01/16 - cont.

Time	Station 1			Station 2			Station 3					MBCC				
	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	WS mph	WD Deg	WS gust mph	AT Deg F	RH %	WS mph	WD Deg	WS gust mph	AT Deg F	RH %
02/01/16 00:00	5.3	59.2	19.5	9.9	267.5	27.8	4.5	357.4	18.6	49.7	50.0	13.0	306.0	36.0	48.0	53.0
02/01/16 01:00	6.1	61.2	14.0	11.6	267.5	27.0	4.8	0.5	23.4	49.7	49.0	17.0	311.0	39.0	47.0	49.0
02/01/16 02:00	5.5	69.6	19.4	12.2	265.9	29.4	3.7	350.8	21.0	49.5	45.1	7.0	339.0	36.0	47.0	54.0
02/01/16 03:00	7.0	67.4	9.3	10.5	275.5	22.4	5.3	351.4	16.2	49.6	50.9	7.0	10.0	21.0	44.0	49.0
02/01/16 04:00	4.7	30.6	11.6	10.0	257.3	31.9	6.4	343.4	22.0	49.0	47.0	2.0	38.0	20.0	44.0	58.0
02/01/16 05:00	4.7	32.9	9.2	10.4	252.9	14.2	6.3	331.1	10.6	48.2	51.3	5.0	345.0	21.0	45.0	46.0
02/01/16 06:00	2.5	11.9	7.6	3.6	258.1	8.2	2.3	286.0	8.6	46.8	46.4	2.0	119.0	13.0	43.0	54.0
02/01/16 07:00	2.4	331.3	8.0	2.9	260.4	15.7	3.1	327.2	12.5	48.3	43.4	5.0	110.0	12.0	42.3	53.3
02/01/16 08:00	4.1	357.6	13.8	5.2	253.2	32.0	5.6	333.0	28.9	48.2	40.6	8.0	338.0	18.0	46.0	39.0
02/01/16 09:00	6.6	23.2	19.0	11.9	243.7	37.0	8.3	341.8	30.0	49.4	35.4	7.0	9.0	26.0	50.0	33.0
02/01/16 10:00	6.7	81.8	11.8	10.8	254.9	25.7	5.4	349.6	15.7	51.9	35.5	7.0	295.0	22.0	54.0	29.0
02/01/16 11:00	5.6	84.8	16.6	10.9	246.5	19.2	4.3	15.3	17.9	53.6	32.2	7.0	283.0	23.0	57.0	23.0
02/01/16 12:00	4.9	72.6	12.8	9.6	252.5	19.3	4.7	9.5	14.4	55.1	28.3	7.0	20.0	17.0	58.0	20.0
02/01/16 13:00	5.3	57.6	10.9	7.0	243.6	15.4	3.2	3.8	15.4	57.0	27.2	6.0	111.0	18.0	61.0	20.0
02/01/16 14:00	4.0	24.4	15.5	4.0	180.6	12.6	3.4	98.5	16.3	57.7	32.6	8.0	190.0	18.0	60.0	23.0
02/01/16 15:00	6.6	16.2	15.6	3.3	90.5	8.7	4.5	116.2	13.7	56.8	31.2	7.0	97.0	22.0	60.0	25.0
02/01/16 16:00	5.4	18.9	13.7	2.7	103.9	5.5	4.2	132.0	9.2	56.2	34.4	4.0	266.0	19.0	56.0	25.0
02/01/16 17:00	7.1	23.6	16.5	1.8	163.4	15.4	2.7	162.3	6.8	55.2	35.2	6.0	65.0	18.0	52.0	29.0
02/01/16 18:00	6.6	7.0	10.8	4.9	226.1	18.0	2.1	256.4	16.7	54.1	31.0	3.0	39.0	12.0	47.0	40.0
02/01/16 19:00	3.1	2.9	4.7	6.7	225.2	16.5	7.4	314.1	13.1	52.9	32.5	1.0	337.0	6.0	42.0	53.0
02/01/16 20:00	1.3	1.3	6.1	6.6	236.5	16.7	3.8	302.3	16.3	51.4	31.1	2.0	226.0	5.0	42.0	54.0
02/01/16 21:00	2.5	2.8	5.8	7.5	247.2	13.9	6.5	322.7	13.2	51.2	30.5					
02/01/16 22:00	2.4	4.1	5.8	6.2	248.6	12.3	4.3	309.9	21.6	50.2	32.0					
02/01/16 23:00	3.3	5.6	7.2	5.6	256.6	22.7	8.1	323.6	23.0	49.9	28.0					