*Southern California Edison*
**WODUP A.13-10-020**

**DATA REQUEST SET A.13-10-020 WODUP ED-SCE-14**

**To:** ENERGY DIVISION
**Prepared by:** Scott Lacy, P.E.
**Title:** Project Engineer
**Dated:** 03/02/2015

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## Question ALT-27:

**Follow-up to SCE response on ALT-18a.** SCE's response to request ALT-18a states the following (emphasis added):

> A ***Project-specific meteorological study*** was performed in 2011 and resulted in design wind conditions ranging from a minimum of 12 pounds-per-square-foot (PSF) to a maximum of 18 PSF that are applied on the conductor as appropriate to different segments of the Project.

Please provide a complete copy of the referenced 2011 meteorological study.

## Response to Question ALT-27:

The information requested is included in three attachments, consisting of: 1) Meteorological Study for the West of Devers Project, dated November 18, 2011; 2) a spreadsheet showing the interpretation of the wind report for various geographical portions of the Proposed Project, applying the methodology found in ASCE Manual of Practice 74 "Guidelines for Electrical Transmission Line Structural Loading"; and, 3) a map showing the graphical translation of the portions of the Proposed Project identified in the spreadsheet.

# Meteorological Study for the West of Devers Project

***November 18, 2011***

***Submitted to:***

Mr. Fidel Martinez
Transmission Engineering
Southern California Edison
Pomona, California

Aerocomp Document 52TR31F

***Prepared and Submitted by***:

J. A. Catalano, CCM
Aerocomp
(714) 964-3985
meteorology@aerocomp.com

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# FOREWORD

This study is a long-term forecast, mostly based on past weather records. Given the nature of atmospheric processes, extremes may actually surpass the forecast or fall below, and no claims are made to the contrary. Furthermore, data used in this report originates from government (NOAA, FAA, DOI, NPS, etc.) and non-government files, which carry release of liability notices regarding their use or suitability. Therefore, this work is not a representation or warranty of Aerocomp or of any person or organization named in the report, that these findings are suitable for any general or particular use or promise freedoms that their use would not infringe privately owned rights. Anyone using this information assumes all liability from such use.

## 1.0 Project Summary

This technical report deals with weather conditions along the proposed transmission lines as follows: Devers-El Casco, El Casco-San Bernardino, Devers-San Bernardino, Devers-Vista #1, and Devers-Vista #2. Among other aspects, the report provides a forecast of 50-year maximum winds that could affect this transmission system. Line orientation of the routes are east to west-northwest, with a section running south to north from the San Bernardino Junction to the San Bernardino Substation. These will be a new design to replace existing lines in the area. The region of study is shown in Figure 1, where synoptic weather stations are noted by filled circles and remote weather sites by filled squares. The five routes are noted by one solid blue line extending for a length of approximately 48 miles: provided by SCE on Google Earth .kmz files. The constructed system will consist of double-circuit 220kV lines with conductors at an average height of 80 feet and wire diameter of 1.504 inches, OPGW about 0.69 inches. The highest elevation along the route is 3050 ft and this occurs northeast of Beaumont.

Figure 1 – The study region showing the alignments, substations, and weather monitoring sites.

In the figure, METAR/ASOS weather stations are shown by circles with their respective call letters: Ontario (ONT), San Bernardino (SBD), Riverside (RIV), Beaumont (BUO), and Palm Springs (PSP). The nearby remote sites are Clark (CLK), and BDF-Mill Creek (MLC). Data for three weather towers were additionally used in the analysis. The weather stations at Ontario, March AFB (Riverside), and Norton AFB (San Bernardino) apply to the western part of the route. Data from three weather towers and Beaumont are applicable to the Pass itself, and Palm Springs describe conditions near Devers. Prevailing wind direction and average speeds were determined from these data and wind roses for some of the locations are shown in Appendix A.

The sectors along the Right-of-Way (ROW) consist of one environment that considers line orientation, topography, land cover, and exposure. Sections of route are oriented E-W, SE-NW, ESE-NNW, and N-S. Listed in the report for these orientations are the maximum winds forecast for the lifetime of the line. Subsequent sections of the report discuss regional climate, resource datasets, technical approach, and analysis results. A short section on thunderstorm initiation aspects is given in Section 5, together with a description of thunderstorm tracks that can affect the ROW. Appendices B and C provide the supporting data displayed graphically.

## Background

The Transverse Ranges of San Gabriel and San Bernardino are oriented west to east with Cajon Pass separating the two mountain systems. San Gorgonio Pass is along the southern edge of the San Bernardino Mountains and next to the south is the peninsular range of San Jacinto, with its peak at 10,780 feet. In effect, San Gorgonio Pass divides the two mountain systems, and along this Pass, extends the power line through intermediate and low desert terrain.

The region is dominated by westerly flow, weaker in summer. Desert and coastal winds take the easiest path through canyons and passes, as currents change in response to diurnal, seasonal cycles, and pressure systems that move through the region. During Santa Ana winds (a kind of downslope flow), currents from the Mojave Desert rush down the Cajon Pass spilling into the valleys below often with destructive force.

The climate regime of the San Gorgonio Region is semi-arid with hot, dry summers and mild winters; significant precipitation normally falls from December to April, where at Beaumont the annual average is 19.3".

To obtain the 50- and 100-year winds, return periods for sustained and gust speeds were calculated from data at six locations. Return periods were calculated assuming a double-exponential distribution for the annual extremes following methods in Air Weather Service Publication 105-2 (USAF, 1977). In a statistical sense the time between occurrences of an event is a recurrence interval, and the average of these recurrence intervals is the return period, which denotes how long on average it will be between events of a given magnitude, noting that multiple events can occur in the same year, or in consecutive years, or not at all in the target years. Instead of return period, some publications prefer the term *mean recurrence interval* to convey the same concept. The probability associated with the 50-year return period is 98%; that associated with the 100-year return period is 99%. Thus, for a structure lifetime of one year, there is a 2% probability that an event equal to or greater than the 50 year return period event will occur in any year, and a 1% probability that an event equal to or greater than the 100 year return period event will occur in any year. Considering a structure lifetime of 50 years, there is a 64% probability that a 50-year load will be exceeded at least once in any 50 years, and a 39% probability of exceedance of the 100-year return period event at least once in any 100 years. Sustained-wind and gust data were summarized to obtain return periods for, among others, the 50- and 100-year targets. Graphs of these projections are given in Appendix B, where probabilities (return-period in years) are the abscissa and design speed the ordinate.

For five climate sites, daily weather summaries were analyzed to view temperature maxima and minima as a function of wind speed. Appendix C shows the graphs of peak gust for maximum and minimum temperature, also cited in the discussions by sector.

As noted by DeMarrais (1965), in the mountains and deserts of Southern California, snow and ice usually occur above 2500 ft. Since portions of the ROW exceed this elevation, an icing evaluation was performed. Weather parameters observed at Palm Springs, Ontario, Twentynine Palms, and March AFB were scanned for any occurrence of freezing rain/drizzle, snow or precursors to the formation of rime ice. Additionally, queries were made of the storm events database at NCDC looking for significant snow and ice storms in the area of the Pass from 1950-2000. Ice deposits that could be expected at elevations higher than 2500 ft are glaze, rime, wet-snow, and hoarfrost. Glaze is a continuous deposit that results from freezing rain when the ambient temperature is at or just below freezing. Rime is formed by super-cooled cloud droplets impinging on objects at subfreezing temperature; this deposit, accumulated when the conductor is in a cloud. This is the most common icing type in the SCE service territory.

Heavy winds will affect the line as synoptic systems migrate through the region from October to April, often with embedded thunderstorms. Wind direction during high winds will vary with the type of storm. Thus, prior to the passage of a front, flow will be from the southeast to south, and this will gradually shift to southwest as the front passes. Flow behind the front will likely be from southwest gradually shifting to northwest. At other times when an area of high pressure builds over the Great Basin, winds from north through northeast, will flow down the Cajon Pass, and these strong currents will produce significant line loads for sections aligned normal to them in the westernmost section of the route. In Southern California, this great katabatic wind is called "Santa Ana" and originates from the cold air over the Great Basin that flows out of high mountain valleys and down the canyons towards low pressure along the coast. Strong and gusty, these winds can exceed 100 mph.

At times in winter a band of high humidity stretches across the Eastern Pacific like a conveyor belt in what is termed "The Pineapple Express". On orographic uplift by the transverse ranges of California, convective clouds develop and torrential rains result over large areas of the State, most of which are flood-prone watersheds. These are the Atmospheric River storms (Jones, et al., 2011) or AR storms, where not only continuous rain is the problem, but also severe weather and high winds. The term "Pineapple Express" has long been used to describe this weather phenomenon, which entrains water vapor from the tropics near Hawaii and transports it to the to the U.S. west coast, much like a river does in its liquid form. In recent years, it has been determined that "Pineapple Express" episodes are no more than a subset of AR storms, of which there were 42 impacting California from 1997 to 2006.

Readily available moisture is the necessary ingredient for the development of clouds, and this reaches the project area from the Pacific Ocean: humid air comes from this primary source with the prevailing flow or with storms passing through from the west. Then from July to September, a thermal low pressure is established over the scorching Southwest, and this circulation draws moist air off Baja California and other parts of Mexico. Storms can then develop southeast of the project and move northwest across the region. They can also develop over the San Bernardino Mountains and progress along convergence zones towards the southwest. Both tracks have the potential of impacting the project's (ROW).

Sustained and gust daily maxima were obtained from Summary-of-Day (SOD) files available at the National Climatic Data Center (NCDC). Annual maxima were extracted from these files and were input to the statistical technique that yields return periods. For the NWS/FAA stations, the peak observed sustained wind is 64 mph. The calculated 50-year peak sustained wind at the 80-foot level is 84 mph. For wind gusts, the peak observed value is 80 mph; the 50-year peak gust at line level is 99 mph. Outflow from severe thunderstorms in the form of downbursts may surpass these values, but their occurrence in space or time cannot be predicted.

### Wind and ice probabilities

From Devers to Vista, the alignment extends in a general east-west direction. On the western side, the route is open to winds from all directions. Prevailing currents are from the west with a secondary prevalence from the northwest. Across the Pass, the prevailing direction is from the west, as shown by data from the DOE weather tower near Devers where 90% of the time flow is from the west. To forecast the extreme weather that may affect the line, the 48-mile alignment was divided into seven sectors by considering topography, land cover, and exposure (local flow). In general line orientation determines the magnitude of the effective load for each of four weather patterns: conditions prior to the passage of a front, during frontal passage, a post-frontal flow direction, and Santa Ana down-slope winds.

In the sector discussions that follow, wind estimates are given as normal to the conductor at the average height of 80 ft, and they apply to a return period of 50 years. Ambient temperatures, when cited, are at thermometer level in the instrument shelter -- usually 1 meter above ground; the corresponding winds in the temperature/wind graphs of Appendix C are at the average conductor height of 80 ft. High winds during maximum ambient temperatures are noted in the discussion below, as it is when the temperatures are at the lower end of the range; these data come from the five METAR sites. Because of elevation differences between the applicable weather station and sections of route, a 1°C temperature decrease is expected per 100 m of elevation increase (standard lapse rate).

Regarding severe weather, the region is affected by thunderstorms, a few of which can produce hail, high winds, downbursts, or an occasional tornado. Neither of these can be predicted, nor is there sufficient data to treat their occurrence statistically. Downbursts are capable of producing 200 mph winds (Fujita and Wakimoto, 1981); the highest wind speed associated with a downburst in the U. S. was recorded at Andrews AFB: 156 mph. In California, 104 mph were measured at nearby Twentynine Palms. Additional details on downbursts are given in Section 2.

The area is affected by an average of 6 thunderstorms per year (source: Western Regional Climate Center). Most of the storms capable of affecting the ROW progress from southeast clockwise to west, and some of these storms result from AR moisture transport from the tropics as described previously. With moisture advected from the Gulf of California and Mexico, in nearby source regions, convective clouds may start in the morning developing thunderstorms which then may progress to the north in the afternoon. Another kind of thunderstorm – known as a pulse storm – originates locally and may or may not regenerate or reach maturity near the route

As noted previously, an assessment of icing potential was performed as part of this study. Weather parameters observed at the METAR sites were scanned for occurrences of freezing rain or drizzle, snow, fog, plus precursors to the formation of snow, rime, hoarfrost, and freezing precipitation. Results show that no appreciable icing accumulation on conductors could have occurred in the last 36 years. Three cases were identified by scanning data through 2010. These were light storms, lasting at most 3 hours, and consisted of snow showers from a passing thunderstorm, moderate to light snow fall from cumulus and stratocumulus clouds, and ice pellets -- neither of which could have accumulated significant ice on conductors. Hence, the episodes were light, lasting a few hours, and at temperatures that would have quickly melted the deposit.

The long-term weather for the route is described next along with comments regarding line exposure to the various types of surface flow, plus a forecast of wind direction and speed. In these descriptions, winds relate to return periods of 50 years on conductors that are at an average height of 80 ft. Also, when extrapolated from a distant weather station, temperature values have been adjusted to account for elevation differences.

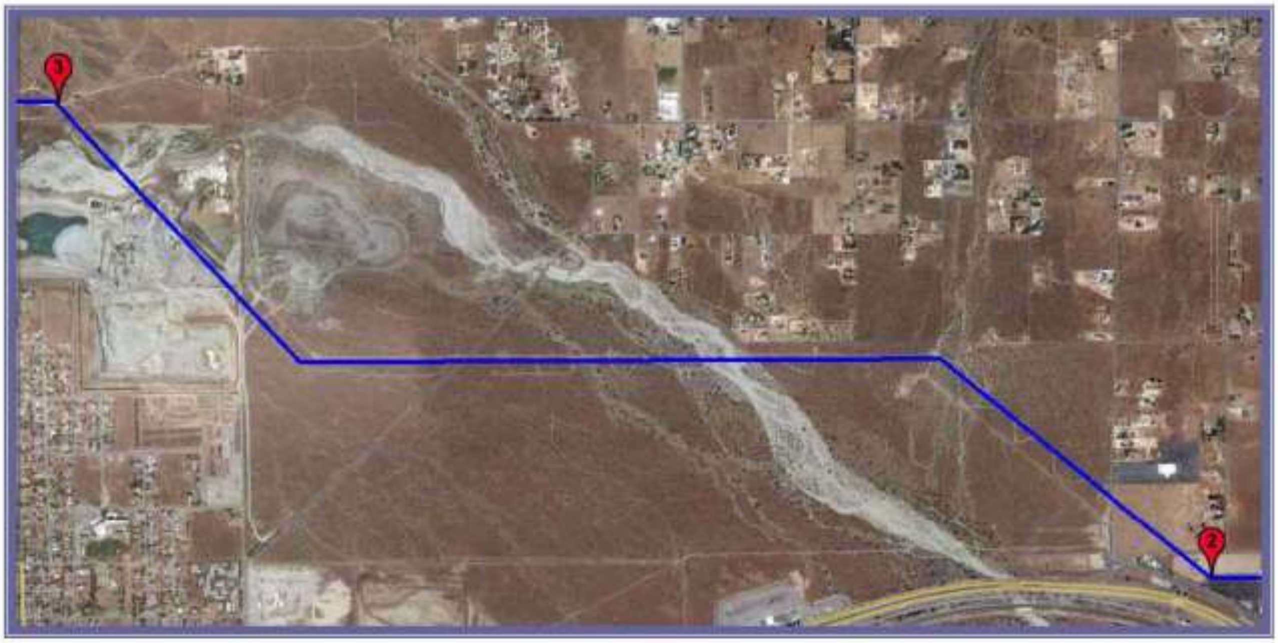
SECTOR 1

Starting at the Devers Substation, the route extends almost due west for approximately 14 miles. Elevation at Devers is 1100 ft and at the end of the sector it is 2070 ft. Just north of Devers, the Department of Energy operated a wind tower from December 1976 through September 1982. This site is shown as TW1 on the map above. The data collected show that prevailing winds are from the west about 90% of the time; the maximum speed measured by an anemometer at 150 ft was 60.5 mph. The Kenetech Corporation also collected data in the neighborhood of Devers, and these are shown as TW2, and TW3 above. At the 80-foot level, maximum speeds at these sites over the data-collection period are 61.3 and 50.5, respectively.

For the first 8 miles from Devers, past Whitewater River and to about Stubbe Canyon, effective winds during Santa Ana episodes will reach 46 mph with gusts to 64 mph. The same spans on pre-frontal storms, will be affected by winds from the southeast which will impact the line with normal components reaching 56 mph gusting of 64 mph. West of that location, past Millard Canyon and almost to Potrero Creek (end of the sector), the line is progressively sheltered by the mountain masses to the north and south. Along this half of the sector, sustained Santa Ana winds will flow parallel to the line from east to west at 70 mph, gusting to 80 mph. During the passage of fronts in winter, flow will be from west to east, with winds up to 80 mph gusting to 94 mph, which being parallel to the line, will have minimal effect on the wires.

In the past 37 years, the highest annual daily temperature at nearby Palm Springs Airport has ranged from 77 F to 129 F, minima from 13 F to 37 F. At the time of maximum gusts affecting this sector, the maximum ambient temperature is expected to be 77 F and the minimum close to 62 F.

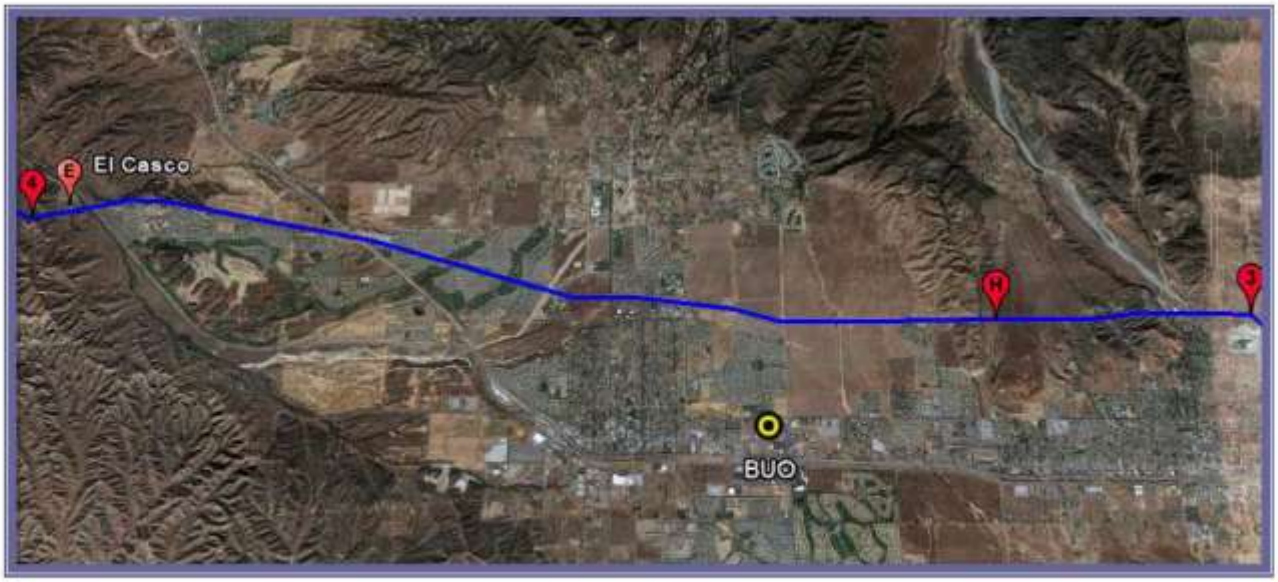
## SECTOR 2



The length of this sector is approximately 3 miles. It consists of two segments oriented SE-NW with an E-W segment located in between. Elevation at the start is 2070 ft and at the end 2545 ft. Effective winds for the slanting segments will be 56 mph gusting to 64 mph when flow is west to east -- such as during frontal storms -- and 46 mph gusting to 52 mph when flow is east to west, as during Santa Ana episodes. The sector will be protected from all other currents by the mountains on both sides. Wires on the middle segment, being parallel to the orientation of the Pass, will experience little disturbance from winds that at times will reach 80 mph gusting to 90 mph. The stress on towers, however, will have to be considered.

The ambient temperature forecast when wind gusts are at a maximum is 71 F for the maximum and 56 F for the minimum.

SECTOR 3

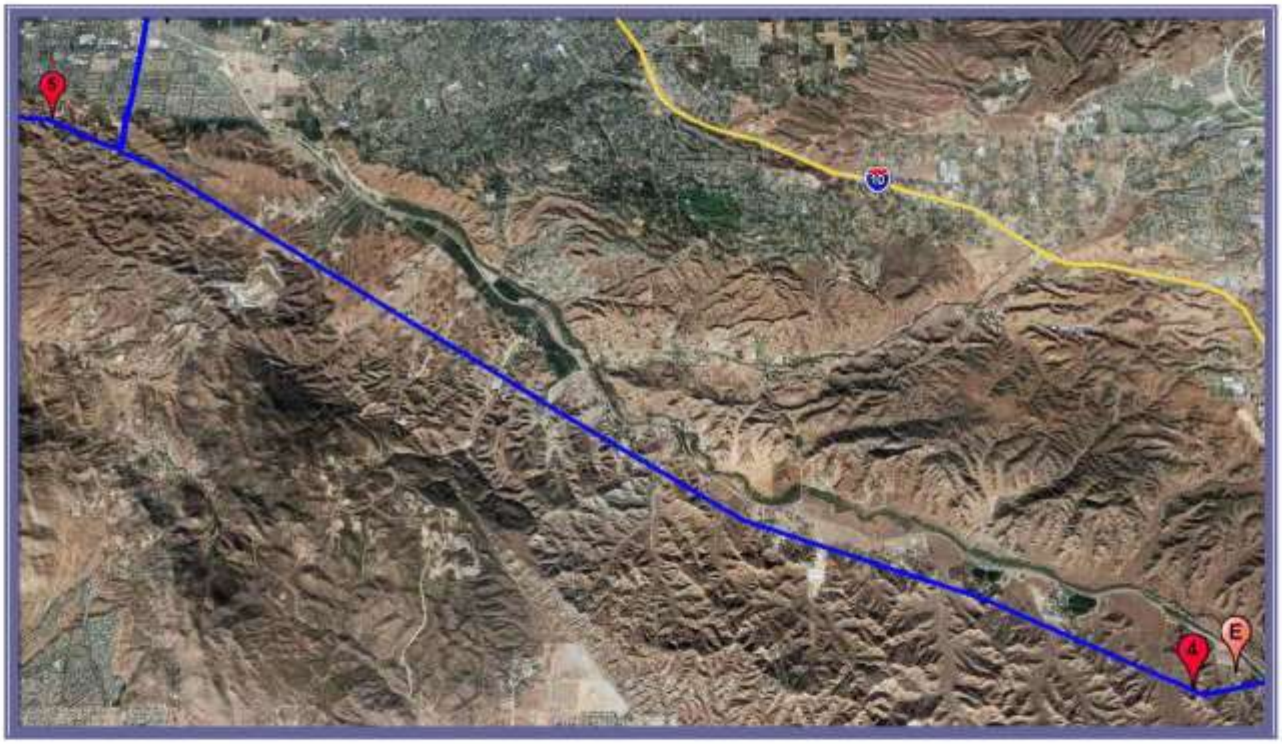


From just west of Hathaway Creek to just past the proposed Casco Substation on San Timoteo Canyon Road, this sector extends for approximately 13 miles. Just beyond Mias Canyon and San Gorgonio River, ROW elevation increases from 2550 ft to 2850 ft over a group of hills. Beyond those hills is the high point of the route at 3050 ft, which occurs by Sunset and Fraser Streets. On the map this is shown by a letter H inside a bubble; from here, elevation decreases to the end of the sector which is at 2260 ft. The ROW proceeds in a westerly direction, with the alignment turning slightly WSW for the last 1.5 miles. Pre-frontal winds will not affect the line for the first six miles of this sector because of sheltering terrain to the south. West of that point their effect will increase to a maximum effective wind of 28 mph gusting to 34 mph. For the last 1.5 miles, these will increase to 55 mph, gusting to 65 mph. Post frontal currents will likewise affect the wires beyond Beaumont Ave, and their effective magnitude will be 40 mph gusting to 54 mph. For the last 1.5 miles, these effective winds will decrease to 19 mph, gusting to 26 mph. Much of the sector will be sheltered from currents from the north through northeast by the San Bernardino Mountains. However Santa Ana currents will reach this sector from the east, as shown by data recorded in recent years at the Beaumont RAWS station, which show winds from easterly components during Santa Ana episodes. Thus, it is expected that these currents from the east will flow mostly parallel to the line at speeds up to 70 mph, gusting to 78 mph. Effective magnitudes will be slightly higher in the last 6 miles of the sector, still giving winds normal to the conductor under 15 mph.

On reaching the highest elevation of 3050 ft northwest of Banning, snow and small amounts of conductor icing are possible one mile on either side of this high point. Three cases were identified by scanning precursor data from Norton AFB, March AFB, Palm Springs, and Twentynine Palms. These were slight storms, lasting at most 3 hours, and consisted of snow showers from a passing thunderstorm, moderate to slight snow fall from cumulus and stratocumulus clouds, and ice pellets, neither of which could have accreted any significant ice on conductors. One snow storm was recorded at Palm Springs which is at an elevation of 420 ft; it is probable that in portions of the alignment above 2500 ft, the storm was more intense, but not enough data exists to quantify magnitudes. Also, on this day, the regional flow was from the SE, which through the Pass would have resulted on winds parallel to the conductor, thus minimizing the accretion.

Ambient temperatures when wind gusts are at a maximum are forecast to be 70 F for the maximum and 55 F for the minimum.

SECTOR 4



This sector starts 1.8 miles southeast of El Casco Lake at an elevation of 2280 ft, runs parallel to San Timoteo Canyon for an approximate length of 11 miles, and ends past the San Bernardino Junction at an elevation of 1520 ft. General ROW orientation is SE-NW on hilly terrain. Flow in all cases will be turbulent given the type of undulating terrain: rising and falling, with many short hills extending at most 500 ft over the valley floor. Prevailing winds over the region are from the west. On pre-frontal stormy weather, effective winds will be about 45 mph, gusting to 60 mph. After the front passes they will reach 63 mph gusting to 86 mph (flow normal to the wires). Given line orientation, the maximum impact during Santa Ana episodes will be when winds are from the northeast, these reaching 80 mph with gusts to 92 mph. As noted previously, all wind speeds given here have been calculated for a 50-year return period at the average conductor height of 80 ft.

Ambient temperatures through the sector are forecast to be 71 F for the maximum and 38 F for the minimum, both occurring at the time of maximum gusts.

SECTOR 5

The segment first extends WNW for about three quarters of a mile, turning next SSW for less than a quarter mile, then WSW for half a mile, and finally NW for not quite a half mile. Total length of the sector is about 1.75 miles. Elevations at start and end of the sector are 1565 ft and 1310 ft, respectively. As in the prior sector, the terrain is undulating, but the sporadic hills are not as high: reaching at most 400 ft above the valley floor.

The first segment will experience maximum impact with Santa Ana winds from the NNE: flow normal to the wires; these winds will be 82 mph, gusting to 94 mph. During frontal passage, flow will also hit the wires at near-normal angles, but effective speeds will be lower: 56 mph, gusting to 76 mph. For the SSW oriented sector, maximum winds will occur with post-frontal settings at 55 mph, gusting to 67 mph. Second in intensity will be Santa Ana currents at their onset speeds with a magnitude normal to the wire of 32 mph gusting to 38 mph. For the half mile spans oriented WSW, the maximum effect will occur with Santa Ana winds reaching 80 mph with gusts to 88 mph. Pre-frontal storm winds will contact the wires at 56 mph, gusting to 67 mph. For the final segment heading NW, north winds will contact the wires at an angle such that effective speeds on Santa Ana episodes will be 59 mph gusting to 64 mph. Normal to the wires will be the post-frontal winds at 63 mph, gusting to 86 mph.

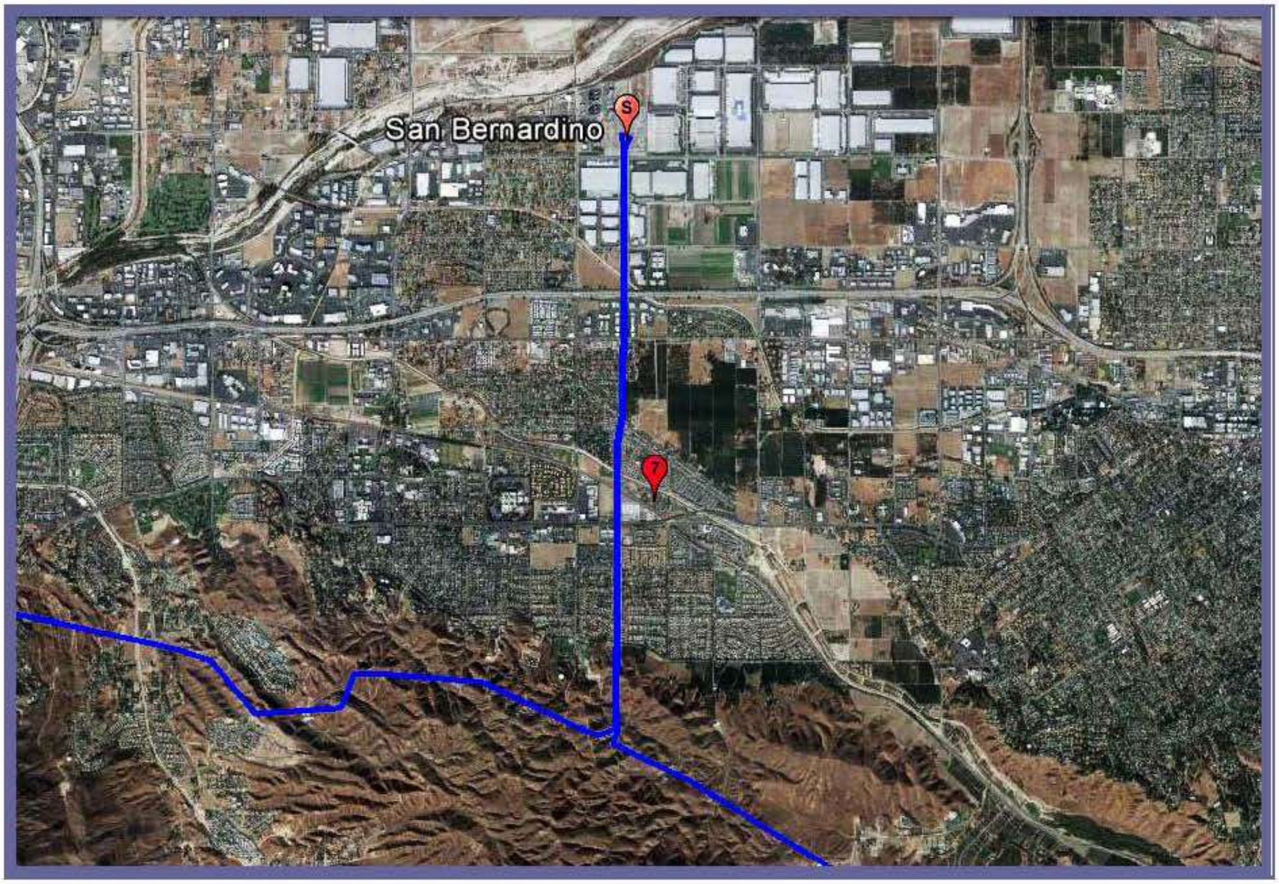
For this sector, ambient temperatures when wind gusts are at a maximum are forecast to be 73 F for the maximum and 40 F for the minimum.

SECTOR 6

The initial orientation of this sector is WNW, tilting later WSW towards the Vista Substation. Sector length is about two and a half miles; elevations at start and end are 1310 ft and 1032 ft, respectively. The sector will experience maximum impact winds with Santa Ana currents from the NNE; these winds will be 84 mph, gusting to 96 mph. During frontal passage, winds will hit the wires at near normal angles, but speeds will be lower: 56 mph, gusting to 67 mph. For the WSW-oriented segment, maximum winds will occur during Santa Ana episodes at 82 mph, gusting to 94 mph. Second in intensity will be pre-frontal currents from the SSE at 55 mph, gusting to 66 mph.

For this sector, ambient temperatures when wind gusts are at a maximum are forecast to be 80 F for the maximum and 44 F for the minimum.

SECTOR 7



This sector extends towards the north for 3.3 miles, starting at the San Bernardino Junction at an elevation of 1500 ft, ending at the San Bernardino Substation at an elevation of 1115 ft. Post-frontal winds are expected to impact the conductors at a maximum effective speed of 63 mph, with gusts to 86 mph. Santa Ana winds from the NE will have effective speeds of 60 mph, gusting to 72 mph.

Ambient temperatures through the sector are forecast to be 60 F for the maximum and 44 F for the minimum, both occurring at the time of maximum gusts.

Considering line orientation irrespective of sector length, Table 1 gives the worst-case forecast of the component normal to the conductor along each sector. Because the detailed descriptions presented above are more complete, they have precedence over the summary of maximum effective winds given here.

**Table 1 -- 50-year Winds by Line Orientation**

| Sector | Conductor Bearing | Wind Direction (Deg) † | Likely Angle With Conductor (Deg) † | Wind Speed (mph) | Gust Speed (mph) | Sustained Speed Normal Component (mph) | Gust Speed Normal Component (mph) |
|---|---|---|---|---|---|---|---|
| 1 | W | SE | 45 | 80 | 90 | 56 | 64 |
| | | | | | | | |
| 2 | NW | W | 45 | 80 | 90 | 56 | 64 |
| | | | | | | | |
| 3 | WSW | S | 80 | 56 | 66 | 55 | 65 |
| | | | | | | | |
| 4 | NW | NE | 90 | 80 | 92 | 80 | 92 |
| | | | | | | | |
| 5 | WNW | NNE | 90 | 82 | 94 | 82 | 94 |
| | | | | | | | |
| 6 | WNW | NNE | 90 | 84 | 96 | 84 | 96 |
| | | | | | | | |
| 7 | N | W | 90 | 63 | 86 | 63 | 86 |
| | | | | | | | |

**† The uncertainty in direction is usually ± 22.5 degrees**

For the seven sectors at the 80-foot conductor, the maximum sustained speed normal to the wire will be 84 mph on a 50-year return period; with the same frequency, gusts normal to it will be 96 mph.

## 2.0 Meteorology of the region

Wind speed and direction are two important parameters that are used to calculate ambient loads on a transmission line. Air temperature becomes important at the lower and higher ends of the scale since wire tensions change with temperature variation. Thus, at the time of extreme winds, a temperature estimate is necessary to calculate tension on the wires.

Moving up from the earth's surface in what is termed the friction layer, speeds usually increase with height while direction turns clockwise in the northern hemisphere. At the gradient level, that is 500-1000 m above the surface (away from the influence of surface features) prevailing winds over the project domain are from west to east. And this prevalence changes in response to the varying synoptic conditions -- that is ridges and troughs that move through the region. Something else happens that is worth noting: over flat terrain the lateral wind variation from one place to another is small, more so if speeds are high. In rugged terrain that is not the case. Thus in the former situation, lateral extrapolation of winds from the observation site to the ROW can be done with some confidence, perhaps to within 22.5 degrees in wind direction. In the latter case the uncertainty is often larger.

The West-of-Devers environment is in a zone traversed by fronts in winter and affected by an average of 6 convective storms per year -- usually a summer occurrence. In the SCE service territory, icing and violent winds associated with migrating pressure cells are of concern in winter, plus thunderstorm downdrafts and an occasional small tornado in summer. Of the various types of thunderstorm downdrafts, the microburst is the most destructive. In size it is less than 2.5 miles in diameter and lasts from 5 to 15 minutes; it often comes from an isolated, single cloud, known as a "pulse storm". Associated with a small-scale cyclonic circulation in the parent cloud, most microbursts exhibit rotation and for this they sometimes are reported as tornadoes. But the pattern of destruction is that caused by straight line winds, beyond the turbulent leading edge. The vertical rush of air from the convective cloud hits the surface and spreads outward in a starburst pattern. If a touchdown point occurred a mile away from a transmission-line span, the gust front could affect 2000 ft of conductors and structures on a straight-line ROW. It is impossible to predict where the center of impact would be, but speeds in a microburst can cause damage up to F3 intensity in the Fujita tornado damage scale (Fujita and Wakimoto, 1981), which translates to winds from 158 to 206 mph, where roofs and some walls are torn off well-constructed houses, trains are overturned, most trees in a forest are uprooted, and heavy cars are lifted off the ground and scattered about. As mentioned earlier, the strongest recorded microburst in the U. S. occurred at Andrews AFB, MD on August 1, 1983. In this storm, winds were measured at 66.9 mps (149.8 mph), as described by Wakimoto (2001) and noted in a figure by Fujita (1985). At the eye of the microburst speeds dropped to 2.2 mph, only to climb to 96.8 mph on the backside, all of this occurring in a matter of minutes. Closer to the domain of this project, 104 mph winds resulted from a downburst near Twentynine Palms where two other 104 mph gusts were measured from the same thunderstorm. Other storms that could have caused wind damage near the WOD route are listed in Table 2.

**Table 2 -- Thunderstorm and high wind events near the ROW from 1950-2010 †**

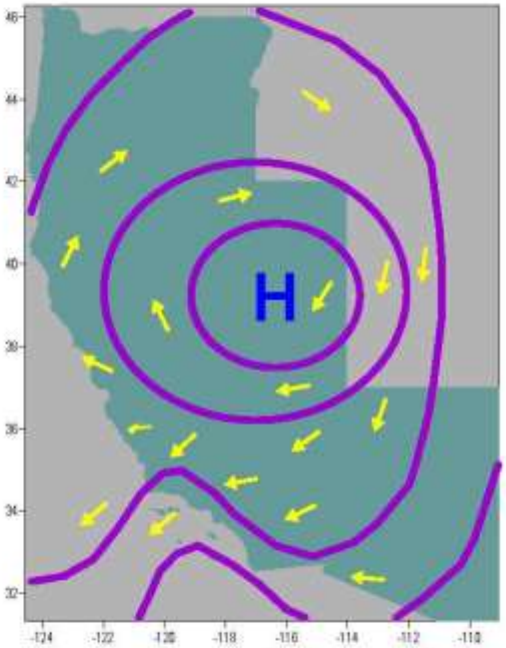
| Date | Location | Wind Magnitude | Event | Type of Damage |
|---|---|---|---|---|
| 14 Dec 1996 | Riverside, San Bernardino, Orange Counties | Winds at Rialto measured at 92 mph. Up to 96 mph elsewhere | Santa Ana | Widespread damage: overturned trucks, downed trees and power lines, damaged roofs, and freeway signs |
| 6 Jan 1997 | Riverside, San Bernardino, Orange Counties | Gusting to 99 mph at Freemont Canyon | Santa Ana | Reports of damage from Coachella Valley to San Bernardino. Close to 1M customers lost electric power |
| 29 Jan 1997 | Riverside and adjacent counties | Gusts reached 100 mph at Freemont Canyon | Santa Ana | Sustained winds at Rialto up to 50 mph gusting to 87 mph. Truck overturned on freeway; air traffic disrupted |
| 1 Sep 1997 | Twentynine Palms Airport, CA | Three gusts of 104 mph at the airport | Downburst east of the airport | None reported |
| 29 Aug 1998 | Off the San Jacinto Mountains at Sage, CA | Instruments in the area measured maximum gust at 86 mph | Downburst Thunderstorm moving NE - SW | Numerous large trees were blown down and moved by the force of the wind |
| 31 Aug 1998 | Hemet | Winds estimated at 60 mph, gusts to 70 mph | Thunderstorms moving NW to SE | Among other damage, trees down near Rialto, toppled power poles in Moreno Valley and Hemet |
| 3 Dec 1999 | San Bernardino and Riverside | Gusts up to 104 mph | Santa Ana | Highways closed in Riverside and San Bernardino counties; power lines down below the Cajon Pass in San Bernardino |
| 5 Jan 2003 | Southern California | Gusts to 90 mph reported in Riverside County | 3-day Santa Ana episode | Major disruption and damage in Southern California, including near the project area where Ontario Airport diverted flights |
| 6 Aug 2005 | Perris, CA | Reported as 61 mph. Research later showed to be from 90 to 100 mph | Microburst | Thunderstorms triggered along the Elsinore Convergence Zone: combined outflow from two cells snapped 78 power poles in Hemet and Perris, uprooted trees, ripped up freeway signs along I-215 |
| 6 Sep 2006 | San Jacinto and Hemet | 61 mph | Thunderstorm | Thunderstorms developed near the Banning Pass and Elsinore Convergence Zones. The microburst damaged trees, buildings, and power lines |
| 3 Dec 2006 | San Bernardino | Gusts to 92 mph measured at Palm Ave | Santa Ana | Most of the damage occurred in San Bernardino, including downed power poles and trees |
| 9 Jan 2009 | Riverside County Mountains | Measured gusts up to 83 mph | Santa Ana (1045 mb surface high in the Great Basin) | Overturned trucks, downed trees and power lines, damaged roofs, and freeway signs |
| 26 Aug 2010 | Hemet Airport | Winds estimated at 65 mph, gusts to 70 mph | Thunderstorms | Downed power lines and trees; localized flash flooding |

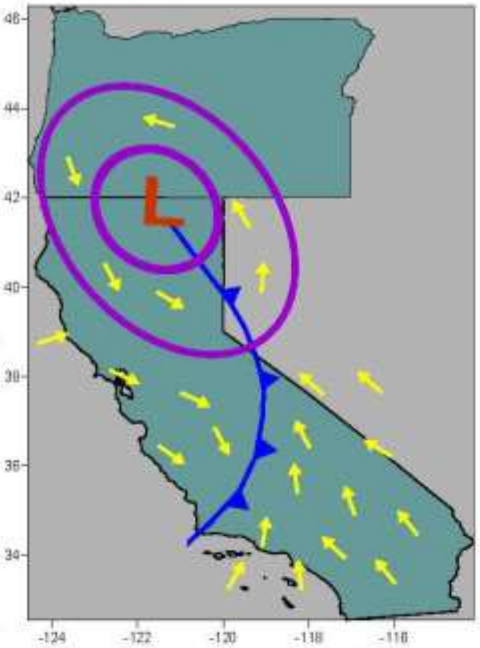
**† Source: NCDC Storm Events. In this database, the first recorded descriptions appear in 1996**

## Topography

The Transverse Ranges of San Gabriel and San Bernardino are oriented west to east with Cajon Pass separating the two mountain systems. The San Bernardino Mountain peak is at 10,680 ft. San Gorgonio Pass is along the southern edge of the San Bernardino Mountains, and to its south is the peninsular range of San Jacinto, with its peak at 11,499 ft. In effect, San Gorgonio Pass divides the two mountain systems, and along this Pass, extends the power line through intermediate and low desert terrain: land-use between agricultural and range.

## Climate





Winds in the region are determined by the location and strength of the semi-permanent Pacific High and a thermal Low over the southwestern desert. Two primary types of weather patterns cause wind and icing storms in Southern California. The Santa Ana's which are associated with a high pressure system over the Great Basin, producing north to east winds, and the other -- causing both wind and ice – occurs when a low pressure system migrates southeastward through Oregon and California into Nevada and Arizona; the circulation around this pressure center is counterclockwise and, as the high pressure cell moves east, the flow over the region shifts from southeast to south to northwest. In the lower levels, moisture is entrained from the ocean on the western side of the low pressure and is advected in the south to southwest flow over the region. The strength of the storm is related to pressure differences (thermal gradients) between this low and other pressure centers in the nearby synoptic scale. A cold front usually extends southeast from the low, turning next to the south, and eventually southwest. On the upper levels, the 500 millibar chart displays a trough oriented NNE-SSW bringing cold air from Canada on its western side; this then curves over the surface low, resulting in winds from the west and southwest over the region. As this system moves east, a high pressure cell usually approaches from the west into the Great Basin, causing a clockwise circulation to develop, which over Southern California is known as the Santa Ana winds. These are downslope currents in which air accelerates as it heats adiabatically on its descent to the coastal plain. The Santa Ana winds often begin from 24 to 36 hours after the passage of the cold front (DeMarrais, 1965). The schematic views above show the idealized settings, which are common in the late fall and winter. The ROW will be subjected to pre- and post-frontal storms, usually accompanied by strong winds, low clouds, drizzle, light snow, or other precipitation. North to east winds will typically follow, the cycle being repeated with some regularity from November to March.

A third source of weather activity along the alignment are thunderstorms that occur from July to September and can move into the area from directions northeast through south. DeMarrais (1965) notes that summer thunderstorms are typically associated with the thermal Low over the desert areas; moisture to supply these storms is advected from the Gulf of Mexico or the waters off Baja California. In addition to orographic lifting, forcing mechanisms according to Small, et al. (2000) can be arcs, convergence zones, and thunderstorm outflow. The thunderstorm cells produce high, often destructive winds, that are localized with directions and speeds that vary erratically depending on intensity and stage of the thunderstorm. Lightning and heavy rain often accompany the high winds. As noted before, an average of six thunderstorms per year occur over the area (WRCC statistic). This can vary radically during an AR storm, where many more thunderstorms can occur in a few days to a few weeks. Frontal precipitation occurs from November through April, and account for ¾ of the total amount, the remaining ¼ being from summer rainfall. Richmond (1989) gives the average annual precipitation at Banning 21.4 " and snow depth of 6.7". He also provides the average number of thunderstorm days at Palm Springs and Banning as 9 and 7, respectively.

However, convective storms can occur at any time of year. Outflow from thunderstorms can reach speeds over 50 mph. Lifting of the air up the mountain slopes plays a part when cool, moist air arrives after a prolonged dry, hot spell. Similarly, this orographic lifting can engender strong convection when persistent high humidity air arrives with AR events. Besides the 6 or 7 thunderstorms occurring per year, downbursts have also been reported in the region but at a much lesser frequency: the last downburst observed in the area was near Perris and Hemet on 6 August 2005. Funnel clouds and an occasional tornado are also spotted from time to time.

It should be noted that during an AR storm, the number of events hammering an area will be numerically larger than during a regular year, but the intensity of individual storms will not necessarily be greater just because the moist air arrives in a narrow channel from the Tropical Pacific – only the number of storms being triggered will be larger.

Portions of the line west of Beaumont will be open to winds from all directions. Thus pre-frontal, frontal, post-frontal, and Santa Ana winds will affect the line with various degrees of force. Strong winds are expected to follow the passage of fronts and be from the southwest to northwest. Wires will also be affected by north to east flows blowing down canyons and passes, and these will be more intense. During a Santa Ana storm progression, speeds decrease as their direction turns more to the east.

## 3.0 Resources

### Datasets in the study

The project aim is to characterize the meteorology along the transmission line route extending in a general east to west direction for approximately 48 miles. There are several locations where meteorological parameters have been observed for several years. Because a primary analysis objective is to develop robust statistics, the longer the period of record and the higher the frequency of observations, the better the analysis and the more reliable the results. Thus hourly data are preferred over 3-hourly or daylight-only observations. The table below shows the datasets analyzed to provide information on extreme conditions, whether these are caused by pre-frontal weather, frontal passage, post-frontal effects, Santa Ana, or other systems. In addition to wind, the persistence of parameters conducive to the formation of ice (precursors) were examined; these include cloud type and ceiling height, visibility, precipitation type and amount, air temperature, and dew point (a measure of water vapor in the air).

Winds observed at the weather station are either instantaneous gusts (usually lasting less than 20 seconds) or they represent an average which is assigned to the entire hour. With the automated equipment in current use (ASOS), averaging for sustained winds is done over 2 minutes. Prior to the 1990's, however, this averaging was done visually by a weather observer who was busy with station tasks to spend the required 2 or 3 minutes looking at the speed and direction dials just before the hour. Often was the case that a mental average was formed by the observer throughout the hour, and just before the reporting time, the dials were checked for a minute or less. Gusts in the hourly record are reported whenever they occur in the 10 minutes preceding the reporting time; they are the instantaneous speed in that period if there is a difference of 10 knots (11.5 mph) or more between peaks and lulls. For sustained speeds and gusts, the accuracy of the measurement is generally within 5 ° for direction and 10% for speed.

Worth noting is that the shorter the averaging time of the measurement, the higher is the speed. Thus gusts, which typically last a few seconds, are of higher magnitude than winds averaged over an hour. Several researchers have developed relationships to link speeds from one averaging time to another. For example, Durst (1960) gives curves that go from short-duration gusts to the hourly average, and viceversa. According to his formula, a multiplier of 1.29 applied to a 2-minute average speed approximates the 3-sec gust.

Table 3 presents the datasets used in the study to provide information on extreme conditions, whether these are caused by frontal passage or other weather phenomena. As mentioned previously, in addition to wind, the persistence of parameters conducive to the formation of ice (icing precursors) was examined. Table 3 lists stations in the region that include in their reports these parameters: wind, precipitation, temperature, humidity. Most are located at airports, hence their primary purpose is to support air traffic.

## Table 3 – Climate Sites in the Analysis Region

| Station | Period of Record | Service/System | Remarks |
|---|---|---|---|
| Norton AFB | 01/01/61–12/31/92 | Military | SOD sustained winds 1943-1993; gusts 1973-1993 |
| March AFB | 01/01/74-12/31/10 | Military | SOD sustained winds 1933-2010; gusts 1971-2010 |
| Ontario International | 01/01/71-12/31/09 | METAR/ASOS | Hrly data missing for 2010. SOD sustained winds 1943-2009; gusts 1973-2009; SOD year 2000 missing |
| Riverside Municipal | 01/01/77-12/31/10 | METAR/ASOS | Incomplete periods, 1977-1999 |
| Chino Airport | 01/01/84-12/31/08 | METAR/ASOS | SOD winds 1998-2010 |
| Beaumont | 01/01/73-12/31/99 | COOP | SOD sustained winds 1948-1953, 1973-1999; gusts 1973-1999 |
| Palm Springs | 01/01/73-12/31/10 | METAR/ASOS | Hrly: large number of outliers and irregular record. SOD sustained winds 1943-1946, 1973-2010; gusts 1973-2010 |
| Twentynine Palms | 01/01/90-12/31/03 | Military | Irregular record; many outliers |
| San Gorgonio Pass | 12/01/76-09/07/82 | DOE Tower Data | Complete dataset, particularly at 30 ft; max speed at 80 ft 55 mph |
| San Gorgonio Pass | 05/16/91-02/14/94 | Kenetech Tower M1104 | Winds at 80 ft; max speed 61 mph |
| San Gorgonio Pass | 02/07/92-02/14/92 | Kenetech Tower M1105 | Winds at 80 ft; max speed 50 mph |
| Beaumont | 08/01/03-08/31/11 | RAWS | Vector frequency and wind rose |
| Millcreek BDF | 02/01/98-08/31/11 | RAWS | Vector frequency and wind rose |
| Clark Center | 01/01/00-08/31/11 | RAWS | Vector frequency and wind rose |
| Converse | 01/01/97-08/31/11 | RAWS | Vector frequency and wind rose |
| Rock Camp | 06/01/03-08/31/11 | RAWS | Vector frequency and wind rose |
| Devore | 10/01/90-08/31/11 | RAWS | Vector frequency and wind rose |

The Palm Springs hourly record is complete beginning March 1998; prior to that period, observations were taken only at certain times of the day. Data for Twentynine Palms are missing for 4 entire months and incomplete for others. The Chino hourly file is complete from June 1999, and the same applies to Riverside Municipal. The data collected by RAWS are generally hourly with some missing periods due to equipment failure or lack of calibration. At RAWS sites, gust data are generally not available before 1995. Values found to be out-of-range (outliers) were removed during the analysis; overall, these data allow good characterization of wind flow in relation to conductor orientation. The data from the meteorological towers near Devers were quality controlled as part of DOE studies. The maximum speed recorded at the 3 towers (80-foot level) was 61.3 mph.

Summary-of-the Day (SOD) reported-winds for the noted periods were used to generate sustained wind and gust return periods. These daily data for the weather stations were obtained from the National Climatic Data Center (NCDC) at Asheville, NC. RAWS data came from files at the Western Regional Climate Center, Reno, NV. The remote data (RAWS) are generally hourly with some missing periods due to equipment failure or lack of calibration.

Additionally, land cover data were extracted from USGS files in digital form; digitized terrain data came from USGS SRTM files at a resolution of 30 meters. Both terrain and land cover influence wind variations and this, in turn affects ice and wind loadings. The use of actual wind data for the analysis incorporates the effects of terrain and land type around the observation site.

### Potential for ice formation

As noted earlier, icing generally occurs above 2500 ft in the mountains and deserts of Southern California, with rime and snow being the primary deposits in the SCE service territory. Considering that the high point of the route is just over 3000 ft, it is unlikely that any significant ice would form on conductors or towers. Nevertheless, the potential for icing was examined through review of past winter storm reports from NCDC files and additionally through scanning past surface observations at Palm Springs, extrapolated to the high point of the line.

When icing occurs at the higher elevations, the deposits can be glaze, rime, wet-snow and hoarfrost.

- Glaze is a continuous deposit that results from freezing rain or freezing drizzle when the wet bulb temperature is less than 0° C. These conditions occur when warm moist air overrides a cold air mass and rain falls into the freezing layer below.

- Rime, the most common deposit in the SCE service territory, is a granular deposit which results from freezing droplets and minute air bubbles trapped with the ice; it develops when the conductor is in a supersaturated environment as occurs in a cloud when temperatures are below 0° C. Fog and light freezing drizzle are conducive to rime formation, or when the winds blow clouds into the high terrain traversed by the transmission line.

- Wet-snow accumulates on conductors when temperatures are near freezing, the wet-bulb temperature is greater than 0° C, and heavy snowfall persists in the area. For wet-snow to accumulate on the wire, wind speeds are usually low, 5 mph or less. At times, snow on the conductor may turn into glaze when the wet-snow accretion is followed by a temperature decrease, or the snow liquefies and refreezes as ambient temperatures increase during the day and then decrease at night.

- Hoarfrost, the second most common deposit in the service territory, results from direct phase transition from vapor to ice. Producing the least iceload, hoarfrost is composed of interlocking ice crystals deposited on wires and towers; for this to occur, the temperature of the befrosted surface must be below freezing; cold temperatures and high winds favor the formation of hoarfrost. The deposit has a low density and strength and hence does not result in significant load on structures.

For each deposit the density ranges from minimum to maximum. Maxima are as follows: 0.9 $gm/cm^3$ (56 $lb/ft^3$) for glaze, 0.6 $gm/cm^3$ (37 $lb/ft^3$) for rime, 0.5 $gm/cm^3$ (31 $lb/ft^3$) for wet-snow, and for hoarfrost the density is 0.1 $gm/cm^3$ (6 $lb/ft^3$).

Ice forms on a structure when super-cooled raindrops, cloud droplets, snow particles, or water vapor collide with it. Water vapor forms the hoarfrost deposit, which contribution to the total ice load is minimal as previously noted. On the other hand, raindrops, cloud droplets, and snow particles contribute significantly to the iceload. Raindrops have diameters larger than cloud droplets and hence their terminal velocity is greater. Both of these are found in a cloud, but in fog only droplets exist. The ice accumulation per unit area of conductor or ground wire depends on the mass concentration of the particles and their velocity relative to the object. The rate of icing accumulation is then obtained as the product of these two quantities, times the cross sectional area of the object, times the three efficiencies: collision, collection, and accretion. As discussed below, each efficiency is a correction factor which varies from 0 to 1, with 1 representing 100% effectiveness.

The efficiency of collision relates to the number of particles that hit the object in relation to the total number available in the flow; larger particles -- acted upon by inertia -- tend to hit the object, whereas smaller particles, following the air flow, are deflected from a collision with the object. The second correction is the efficiency of collection which relates to that portion of particles that hit the object and stick to it -- not bouncing away. Liquid water droplets in general do not bounce, so their collection efficiency is near 1. Snow particles may bounce, and their collection efficiency can vary from 0, for dry snow, to near 1 for wet-snow.

Lastly, the efficiency of accretion is the ratio of the rate at which icing accumulates to the mass flux of particles that stick to the surface of the conductor or ground wire. When there is a film of water on the surface, a portion of the particles are lost by run-off; then the accretion efficiency is less than 1. But because freezing still takes place below the liquid film, the growth is termed "wet" and results in glaze ice. Rime ice, on the other hand, grows when there is no liquid-water film and consequently no run-off; the accretion efficiency is then near 1, and the growth rate is termed "dry". Put differently, if the amount of water particles hitting the surface of the object is less than the rate at which they freeze, i.e., each droplet freezes before the next one hits the same location, the ice growth is called "dry" (forming rime, a deposit with air bubbles). If the amount of water particles hitting the surface is rapid, the ice growth is called "wet" because the droplets do not have time to freeze before the next one hits their location (forming glaze, a solid and clear deposit).

The maximum amount of accreted ice depends on air humidity, temperature and the duration of the episode. Factors that influence the ice accumulation are the shape of the exposed object and its orientation relative to the wind direction. Height of the conductor, whether single or double circuit, has little significance on the total ice accumulation.

## 4.0 Analysis and Results

Data for the analysis were assembled from the climate sites. Parameter editing was performed first by tabular and graphical depiction of the parameters in each hourly record. As available from NCDC, wind roses were downloaded for climate sites in the area. These vector summaries give the prevailing flow direction affecting the alignment; however, they must be cautiously interpreted in light of instrument exposure, as terrain features near the monitoring site greatly affect the observed direction and magnitude.

In addition to statistics of wind speed and direction, the climate sites yielded values of precipitation type and amount plus temperature and dew point. Observed weather parameters were scanned for occurrences of freezing rain or drizzle, snow, fog, and other precursors to the formation of snow, rime, hoarfrost, or freezing precipitation. The method used is described below. Results show that no appreciable icing accumulation on conductors could have occurred in the last 36 years. During this period, reports of snow, ice pellets, and snow showers are found in the weather records for Palm Springs, Twentynine Palms, and Norton AFB, but the episodes are light, lasting a few hours, and at temperatures that would quickly melt the deposit.

Parallel to wind vector interpretation, long term wind records at the climate sites were used to calculate return periods by the extreme-value statistical approach that uses the double-exponential distribution (the most widely used theoretical distribution for extreme values). The design wind speed was next graphically displayed for various return periods including 25, 50, and 100 years.

### Data scanning for possible icing

The possibility of icing along the higher terrain in Sector 3 was done by a persistence analysis scheme, where precursors and actual reports of freezing precipitation are the measures of persistence. Actual precipitation reports plus precursors such as ceiling height, visibility, temperature, dew point, cloud type, and winds were examined hour by hour. In this scheme, if criteria are met for the occurrence of rime, freezing rain/drizzle, wet snow, or hoarfrost at a predetermined wind speed, then the hour is placed in the persistence chain. This chain can be broken the succeeding hour if criteria are not met. In this fashion, only the worst cases emerge, and these are examined in detail to assign hourly rainfall rates and adjust beginning and ending hours to the storm. On the basis of persistence of the precursor parameters, light snow or drizzle events were possible: snow or drizzle could deposit on wires one mile on either side of the high point. But these deposits are expected to melt quickly given that average temperatures are above freezing: Beaumont, for example, at an elevation of 2600 ft averages 40 F in the coldest months.

### Prevailing winds

Wind frequencies were obtained by direction and speed. These vector summaries or wind roses give the prevailing flow that affects the alignment; representative weather sites are shown in Appendix A. In these graphs, directions are given for 22.5° compass sectors showing the bearing where the wind comes from and speeds in some cases are color-coded with their magnitude as given in the legend. Terrain features affect both direction and speed, such that an identical gradient-level current (i.e., the wind above the friction layer) can be substantially different at a surface location, as modified by the local terrain. Additionally, the interpretation of wind roses must be consistent with site exposure; Ontario, for example, is open to flow from all directions with sustained winds prevailing from the west. Across sites and time periods, the highest observed sustained wind at anemometer height (33 ft) was 64 mph at Ontario.

Directional exposure for the route has been considered for the types of conditions that can affect the ROW among Santa Ana wind episodes, pre- and post-frontal activity, or isolated thunderstorm winds.

### Return periods

After wind vector summarization, daily wind speeds for the climate sites were used to calculate return periods assuming the double-exponential statistical distribution. First, speeds were normalized to the conductor height of 80 ft by applying an adjustment factor (power-law profile) that considers the anemometer height, 33 ft at the ASOS sites and 20 ft at the RAWS stations. The analysis approach is based on methods by the U.S. Air Weather Service (1977) and yields expected values for various years (from 1.1 to 200 or beyond), along with the probability of their occurrence. For the ASOS sites, input to this process, were the daily wind maxima from NCDC Summary-of-the-Day (SOD) files. The design wind speed was next graphically displayed for various return periods including 10, 25, 50, and 100 years and these are plotted in Appendix B. For the six sites, Table 4 gives these values at the observation point, as well as those adjusted to conductor height.

**Table 4** –Sustained (SU) and gust (GU) Speeds (mph) adjusted to 80 ft for return periods of 50 and 100 years

| LOCATION | 50 Y AR | | | 100 EAR | | |
|---|---|---|---|---|---|---|
| | Obs Point | | 80 ft | Obs Point | | 80 ft |
| Beaumont (SU) | 66.5 | | 75.5 | 73.7 | | 83.6 |
| Chino (SU) | 55.4 | | 62.9 | 59.7 | | 67.8 |
| Ontario (SU) | 74.2 | | 84.2 | 80.2 | | 91.0 |
| Palm Springs (SU) | 70.4 | | 80.0 | 75.7 | | 86.0 |
| Riverside - March AFB (SU) | 49.0 | | 55.5 | 52.2 | | 59.3 |
| San Bernardino - Norton AFB (SU) | 50.2 | | 57.0 | 53.3 | | 60.5 |
| | | | | | | |
| Beaumont (GU) | 68.8 | | 78.0 | 74.6 | | 84.6 |
| Chino (GU) | 75.8 | | 86.0 | 80.9 | | 91.8 |
| Ontario (GU) | 87.0 | | 98.7 | 93.7 | | 106.4 |
| Palm Springs (GU) | 79.2 | | 89.9 | 85.5 | | 97.0 |
| Riverside - March AFB (GU) | 58.6 | | 66.5 | 62.2 | | 70.6 |
| San Bernardino - Norton AFB (GU) | 68.1 | | 77.3 | 72.8 | | 82.6 |

Wind and ice loads have probabilities of occurrence that increase with the structure's design life. A 2 % chance of a wind exceeding a certain high value is sometimes referred to as the 50-year wind. This means that a given segment of line has a 2 % chance of experiencing a wind equal to or exceeding that value in any one year. Thus, a 50-year load has a 2% probability of being equaled or exceeded if the design life is one year. This does not mean that heavy winds cannot occur more often – just that the probability of that happening is not high. Over a longer period, a section of line has a 64% chance of being exposed to those winds over a 50-year design life of a structure. The 100-year load has a 1% chance of being equaled or exceeded if the design life is one year and a 39% chance of being equaled or exceeded if the design life is 50 years.

Moreover, in the calculation of extreme values, sampling errors are due to estimating the return period with a small sample in relation to the number of years being projected. The size of these errors can be estimated by the standard deviation of the sampling errors and a confidence interval. The latter are displayed below, following the method outlined by Simiu and Scanlan (1996). These values provide confidence on the accuracy of the 50-year speeds. Sample sizes were 45 years (SU) and 37 years (GU) of annual maxima at Ontario.

**Table 5** – **Confidence intervals for the 50-year wind: sustained (SU) and gust speeds (GU) Ontario, California**

| Retur years | 68 % ph) | 99 % h) |
|---|---|---|
| 25 (SU) | 3.4 | 10.1 |
| 50 (SU) | 4.0 | 12.0 |
| 100 (SU) | 4.7 | 14.0 |
| 25 (GU) | 4.0 | 12.0 |
| 50 (GU) | 4.8 | 14.4 |
| 100 (GU) | 5.6 | 16.7 |

Histograms of temperature maxima and minima versus wind gusts were generated for comparison with National Electric Safety Code (NESC) specifications. At the climate sites sites, daily weather observations were summarized to obtain temperature statistics as a function of wind speed. Appendix C presents these graphs of annual temperature maxima/minima and corresponding gusts at line level. From the graph, at Norton AFB on the day a peak gust of 72 mph occurred, the maximum temperature would have been 60 F and the minimum 44 F. Extrapolated to the high point of the ROW, these temperatures are approximately 49 and 34 F, respectively.

### 5.0 Thunderstorm occurrences in the region

The project is located in a region with elevated terrain to the north and east having peaks to about 11,500 ft (San Jacinto), mountains to the southwest with peaks to around 5700 ft (Santa Ana Mountains), and hilly terrain in between. This topography can trigger storms through orographic lifting or through convergence zones which form at certain times of year. Presently it is not possible to forecast a location where a thunderstorm will reach maturity nor with much certainty its movement afterwards. Convection processes by their turbulent nature are random. It is possible, however, to identify settings where convection could get initiated through flow convergence, orographic lifting, or differential heating, and then forecast plausible paths that the storm could take. In this section, we identify these sectors of likely deep moisture convection (resulting in a cumulonimbus cloud) which could later move to intersect the West-of-Devers ROW. DeMarrais et al. (1965) identify several convergence zones when westerly winds cover the region. Small, et al. (2000) identify convergence zones and arcs (convective activity downwind from the passes) when southeasterly flow reaches the area. In this region of complex topography, in addition to the mountain slopes, several other forcing mechanisms exist. In summer, two convergence zones develop in the immediate vicinity of the project: Elsinore and Banning. In the monsoon months from July to September (when moist air arrives from the south or southeast), storms typically develop and propagate along these convergence zones. Moreover, thunderstorm outflow from these initial storms, create additional convergence zones, which then trigger new storms. These in turn propagate in the direction of the upper-level flow or, if those winds are week, the storm motion tends to follow the line of convergence. In winter, the mountain slopes serve as forcing mechanism, but moisture is often the missing ingredient for strong convection. During AR episodes however, moisture is plentiful. Also, since currents in AR events turn clockwise with height from southeast to west, convergence zones such as Elsinore would play a role in thunderstorm development, as they do with other westerly flow.

### Mechanisms

As air ascends through forcing mechanisms as noted above, moist instability is released. The vertical profile of temperature and dew point (the latter a measure of moisture content) determine the degree of instability and layer overturning that will result in a convective cloud. When this release happens over a deep layer of atmosphere, the result is a cumulonimbus or thunder cloud which at maturity produces heavy winds, rain and even severe weather such as downbursts or tornadoes. Severe storms can happen anywhere, but elevated terrain features -- under the right flow conditions -- serve as a trigger to initiate the convection. In the study region, at certain times of the year, clouds predictably form near topographic features. For example, during the monsoon months in Southern California, clouds initiate in the morning hours either on the lee or windward sides or to the flank of some mountains. These later mature, regenerate and move into the valley if the following occurs:

- the synoptic situation permits it,
- there is adequate moisture in the lower levels, and
- the stability of the atmosphere allows air parcels to reach the level of free convection (LFC).

### Cumulo-genesis location near the ROW

Considering the above factors, there are two thunderstorm genesis areas that can affect the ROW. One is the Banning-Elsinore convergence zone created by west winds and monsoonal currents maneuvered by the terrain. Storms can develop and propagate along the convergence zone to intercept the ROW. Small et al. (2000) describe three episodes of severe thunderstorm in the mountains of San Bernardino 11-14 July 1999. In one case, a thunderstorm developed over the mountains and propagated to the southwest along a convergence zone from Big Bear through Beaumont and all the way to Lake Elsinore. Second, on southerly flow, the San Jacinto slopes can provide the orographic lifting for clouds to develop so that – with a finite LFC and adequate moisture supply – a thunderstorm can develop by early afternoon. By late afternoon or evening, this storm can affect structures on the western portion of the ROW. Under post-frontal conditions storms can also move from the southwest, as it occurred in some cases described in Table 2. In all episodes, winds were in excess of 50 mph; for example, Storm Events database of NCDC list 70 mph winds associated with a thunderstorm over the San Jacinto Valley on 12 August 1998 and one of similar intensity near Rialto on 31 August 1998.

## 6.0 Acknowledgements

Senior Line Patrolmen Mr. Steve Williams, and Mr. David Gott from Devers plus Mr. Walt Boysha and Mr. John Rinaldi from the Moreno Valley SCE office provided information on winds and icing occurrences along their respective patrol beats. Their experience of many years confirmed the findings of this study, particularly in regard to icing on conductors. Mr. Marc Swartz and Mr. George Scott of the U. S. Department of Energy provided meteorological data for the San Gorgonio DOE tower and two Kenetech towers near Devers.

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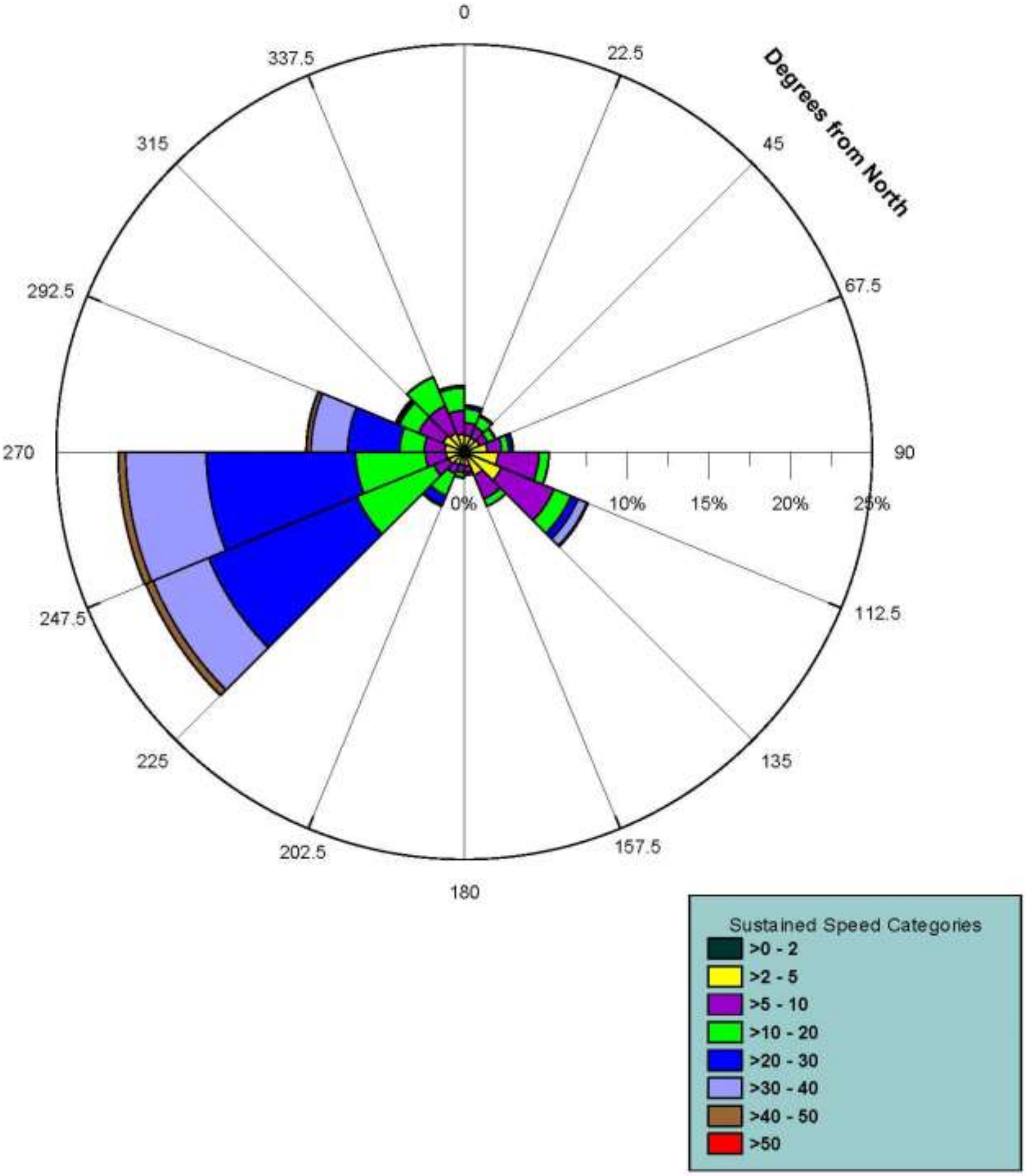
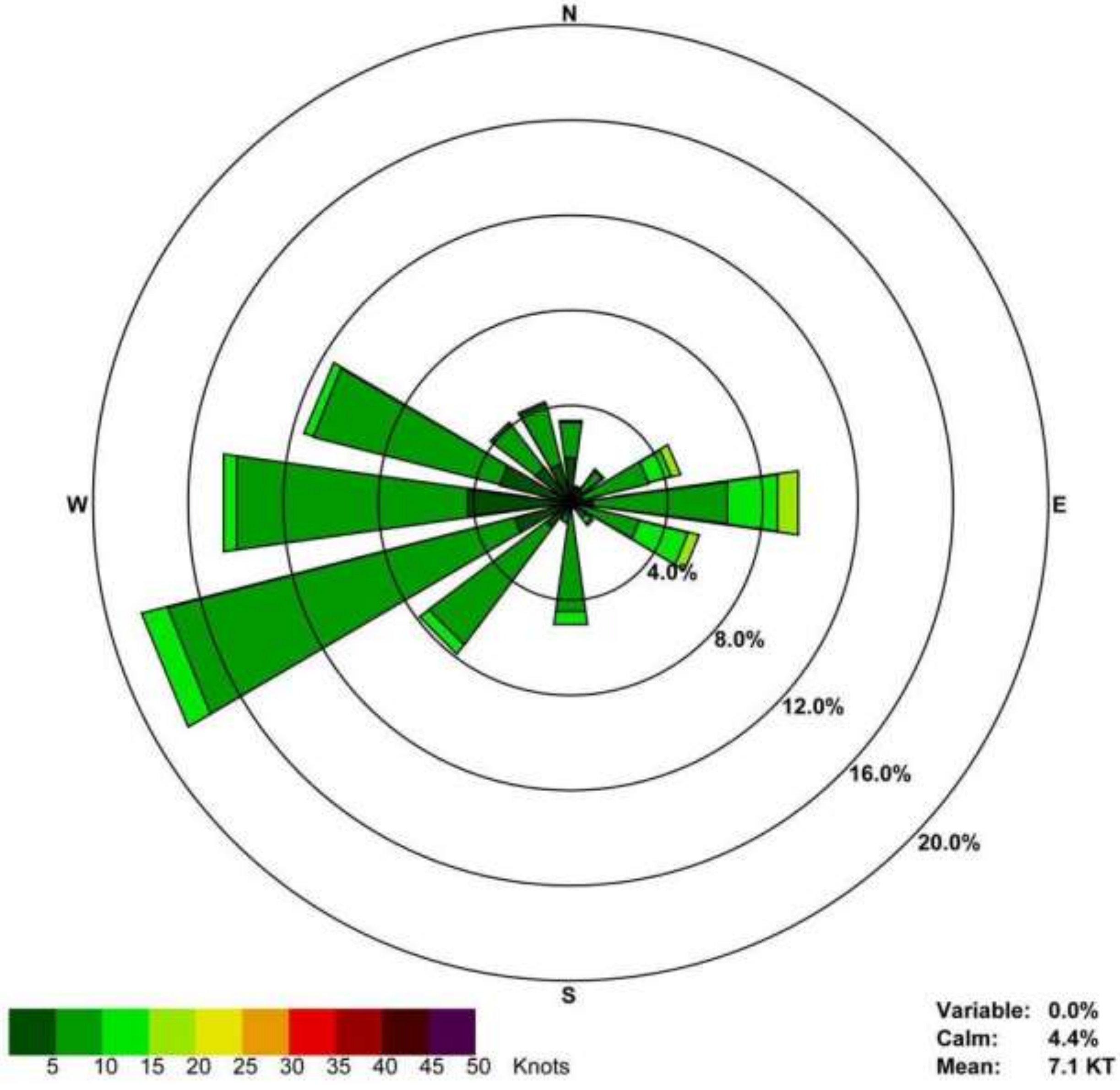
# Appendix A -- Wind Roses at Selected Weather Sites Near the ROW



**Hourly Average Wind Distribution**
**DOE Tower Data Adjusted to a Height of 80 ft (MPH)**
**Station: San Gorgonio Pass - Period: 12/1/76 - 9/7/82**

# BEAUMONT

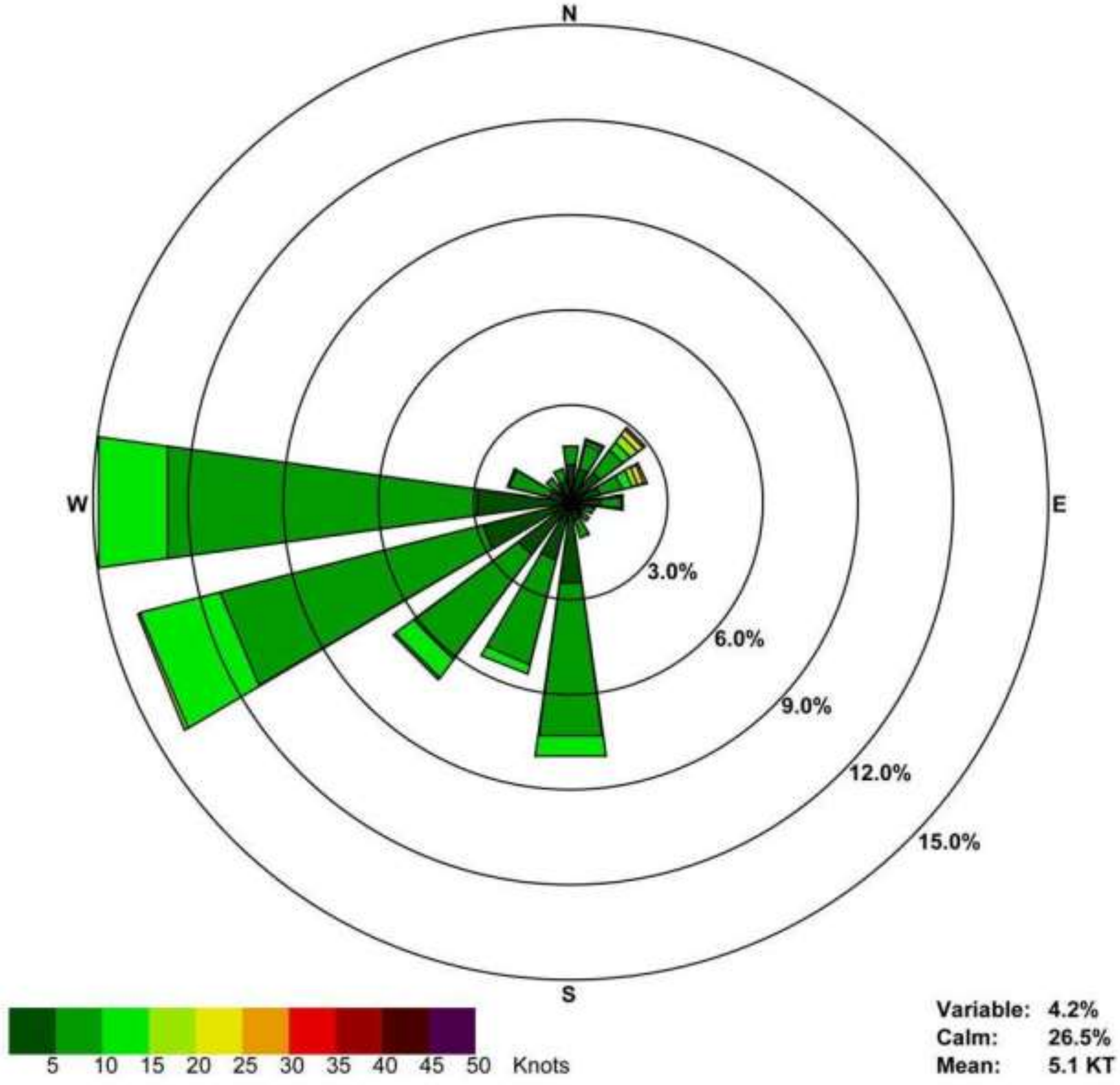
27-year summary: 1973 - 1999



Variable: 0.0%
Calm: 4.4%
Mean: 7.1 KT

# ONTARIO INTL ARPT

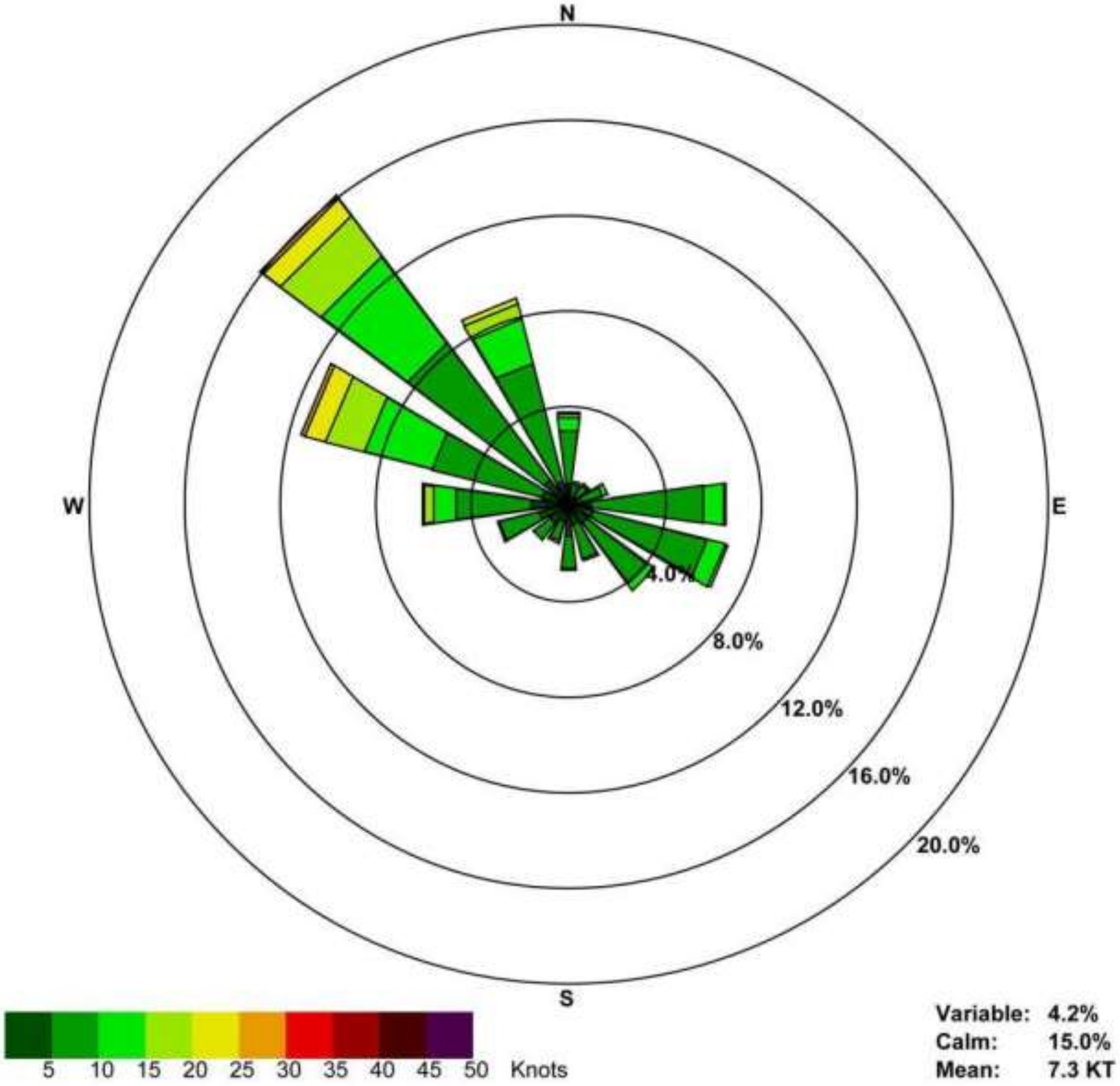
30-year summary: 1980 - 2009



Variable: 4.2%
Calm: 26.5%
Mean: 5.1 KT

# PALM SPRINGS INTL

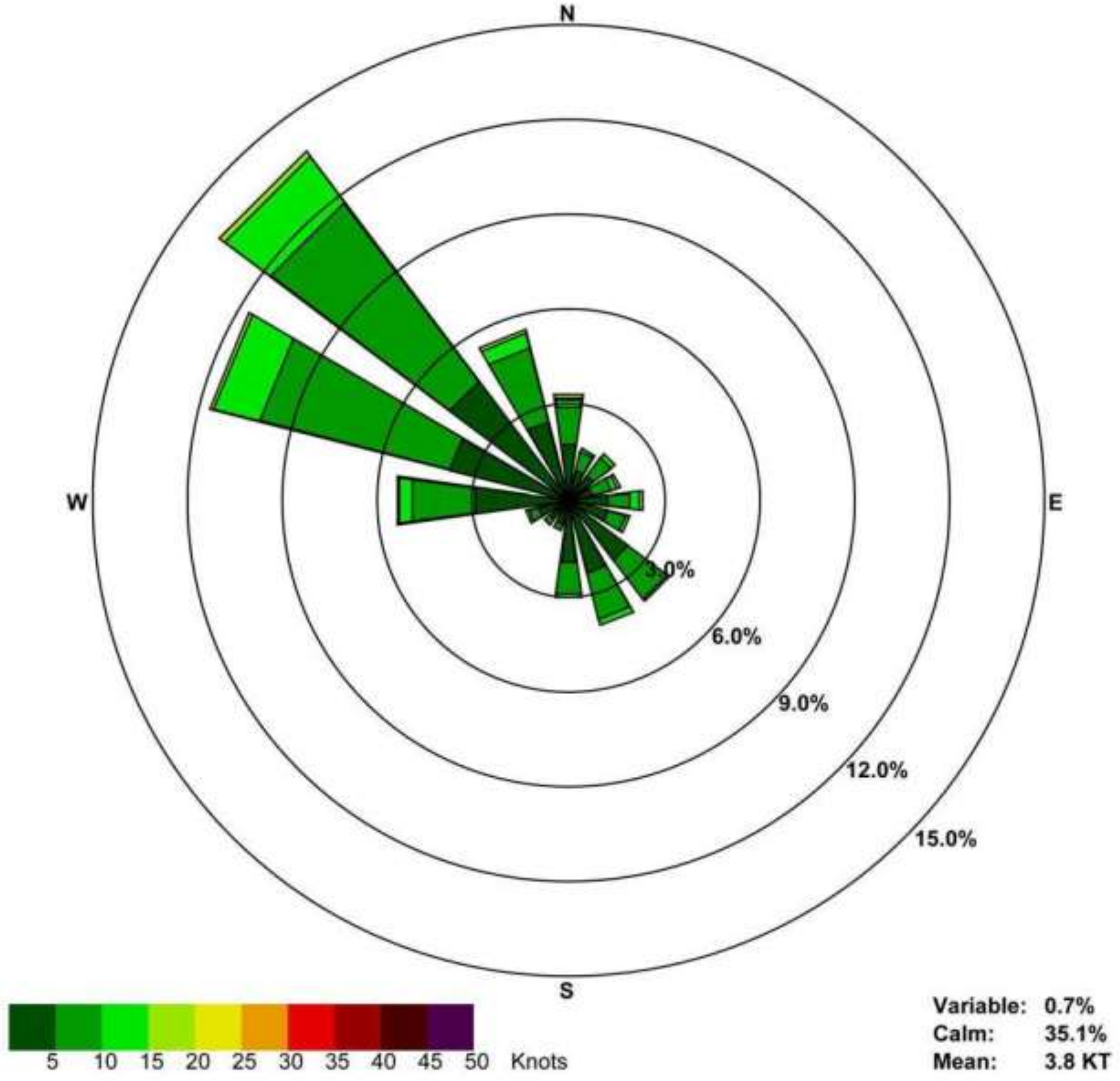
29-year summary: 1980 - 2008



Variable: 4.2%
Calm: 15.0%
Mean: 7.3 KT

# RIVERSIDE/MARCH AFB

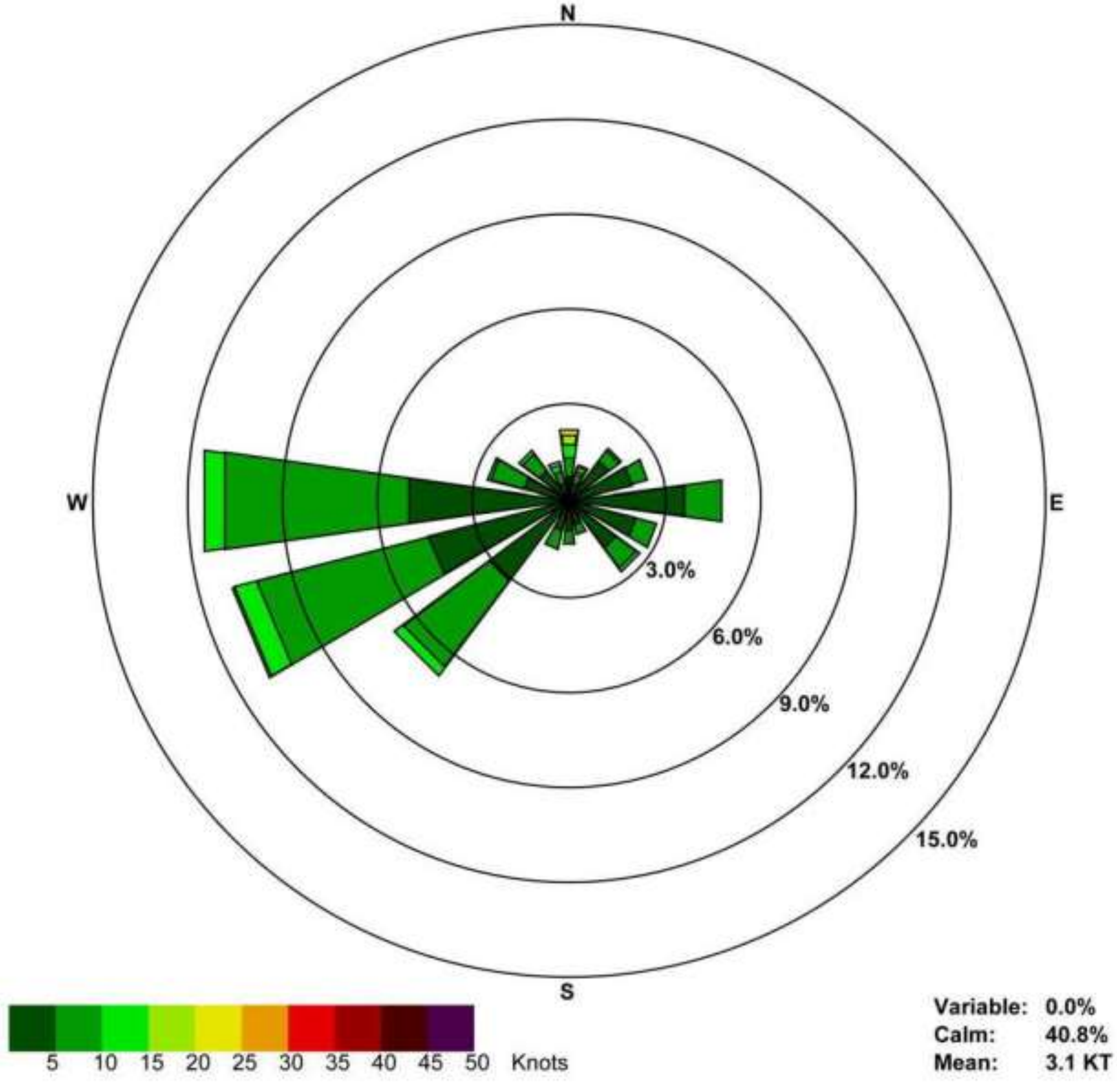
61-year summary: 1950 - 2010

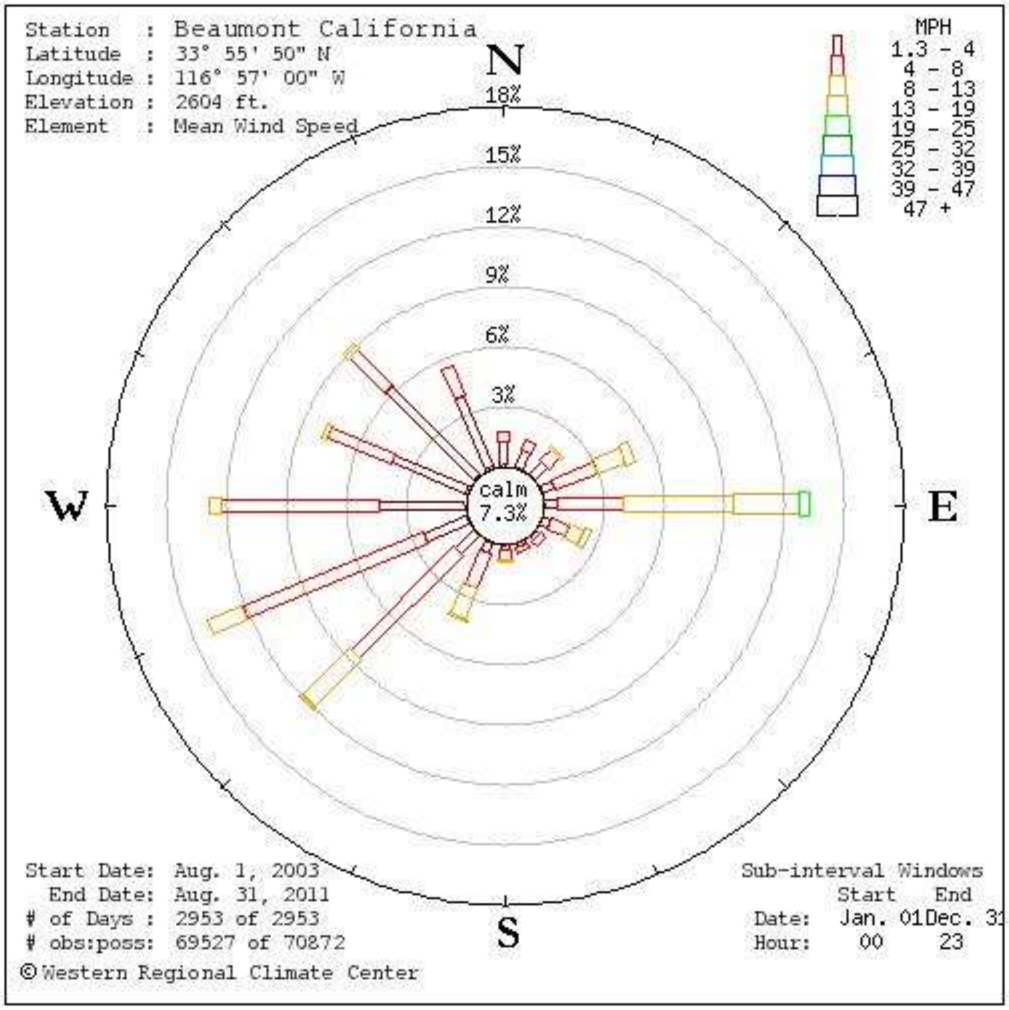


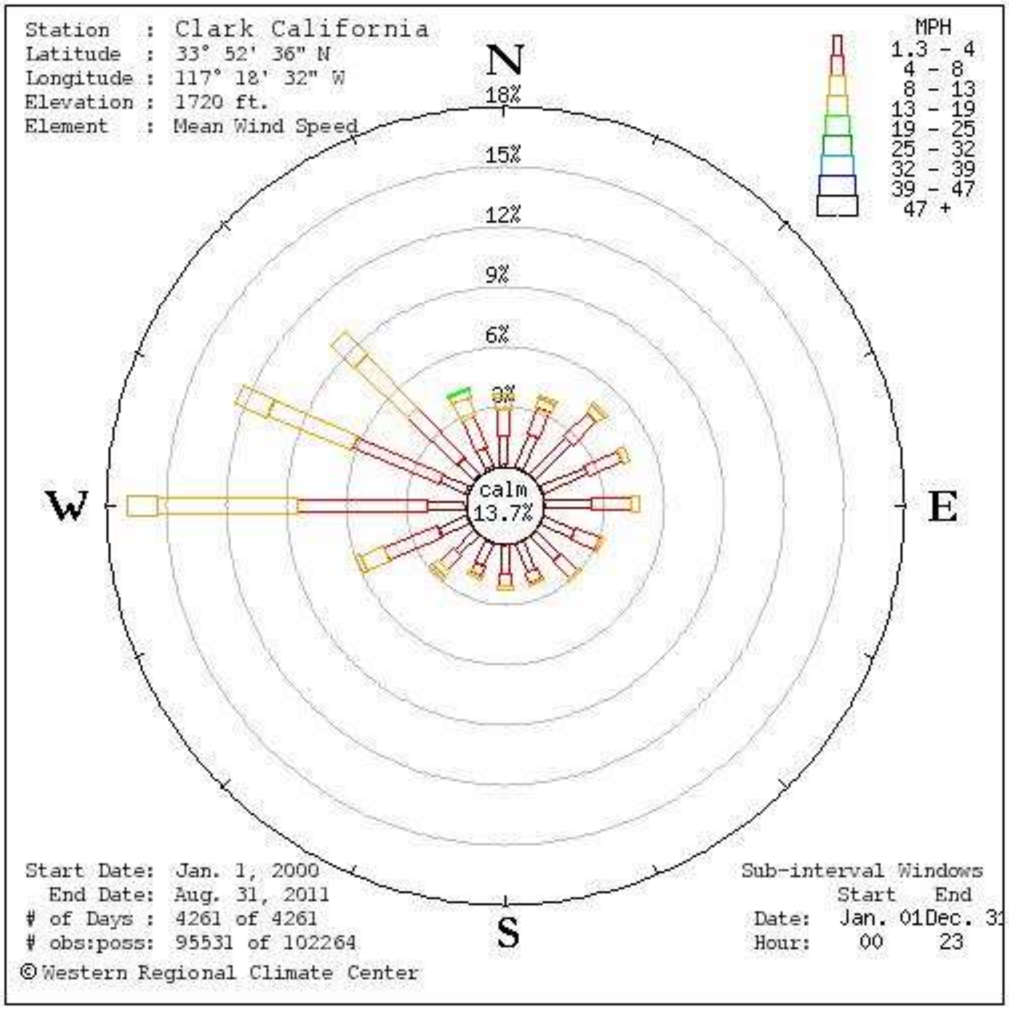
Variable: 0.7%
Calm: 35.1%
Mean: 3.8 KT

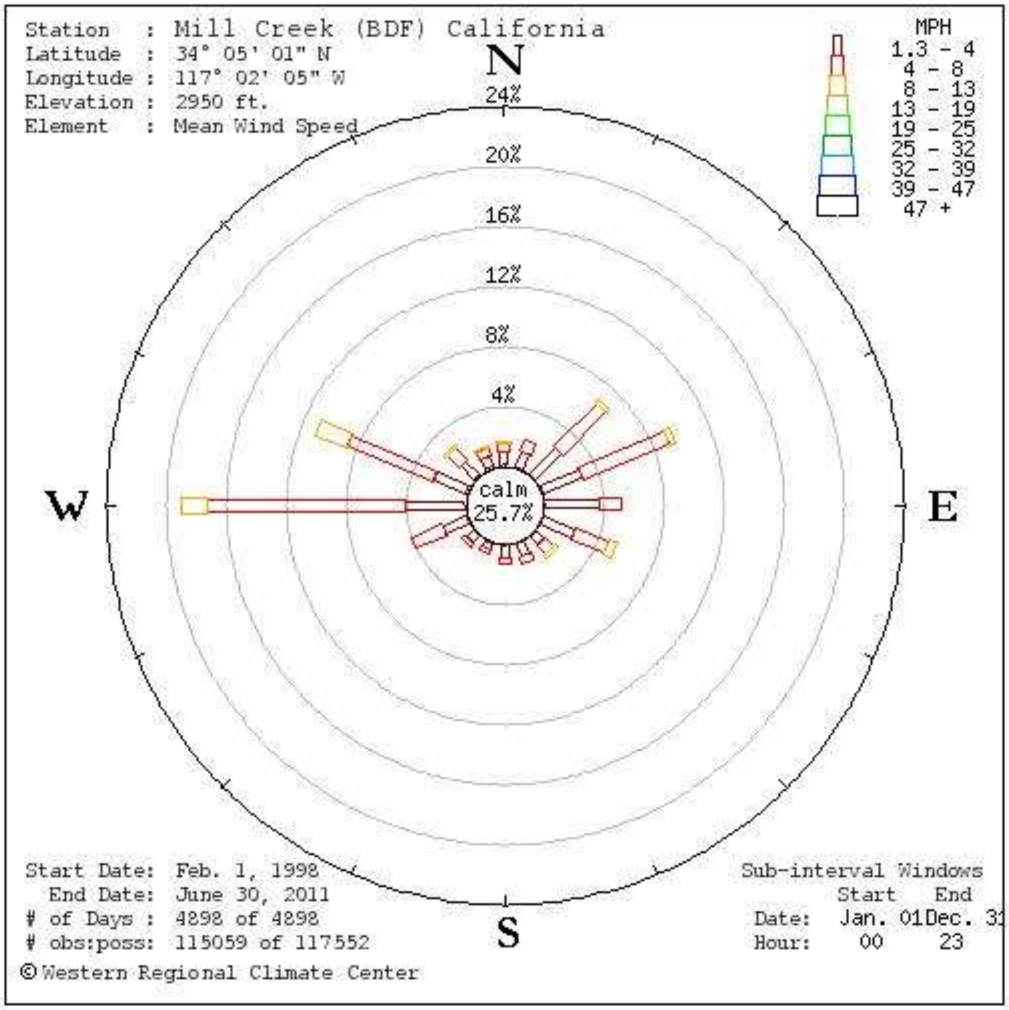
# SAN BERNARDINO INTL

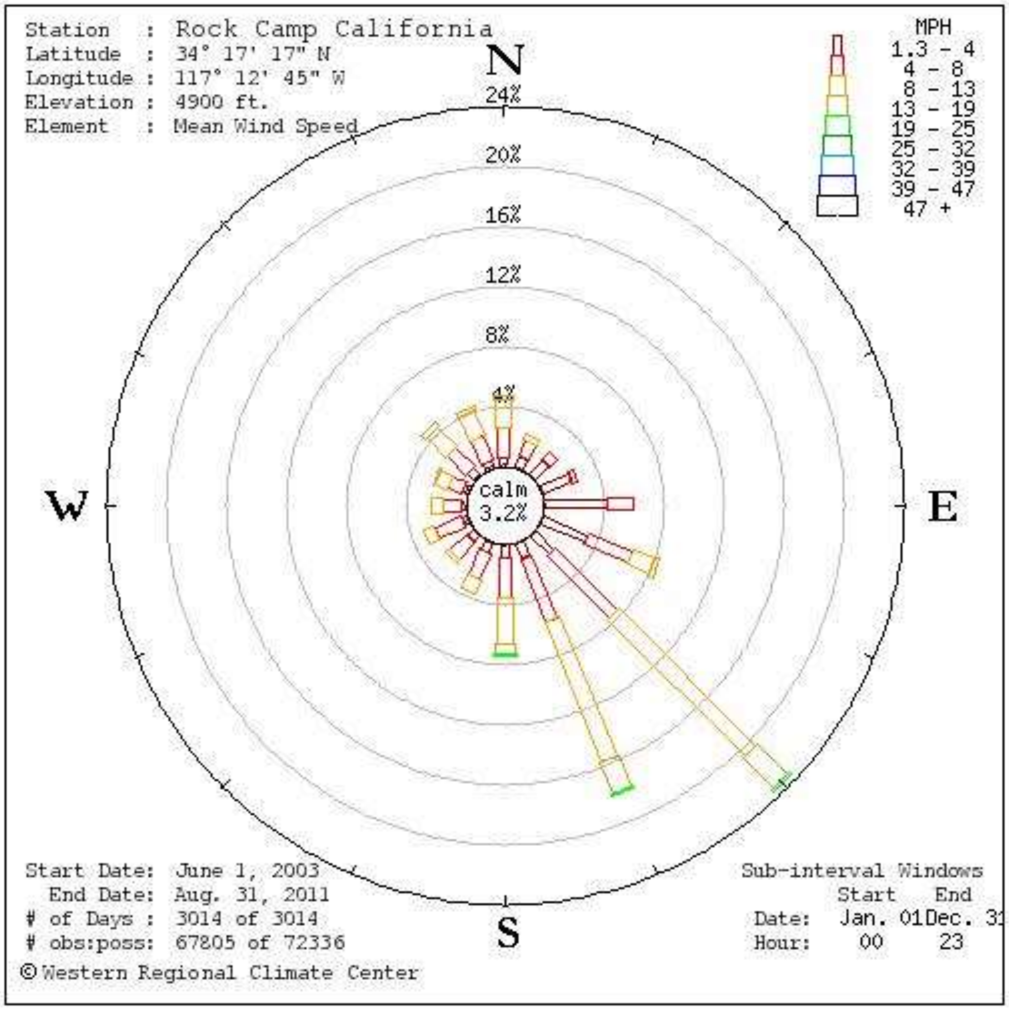
51-year summary: 1943 - 1993

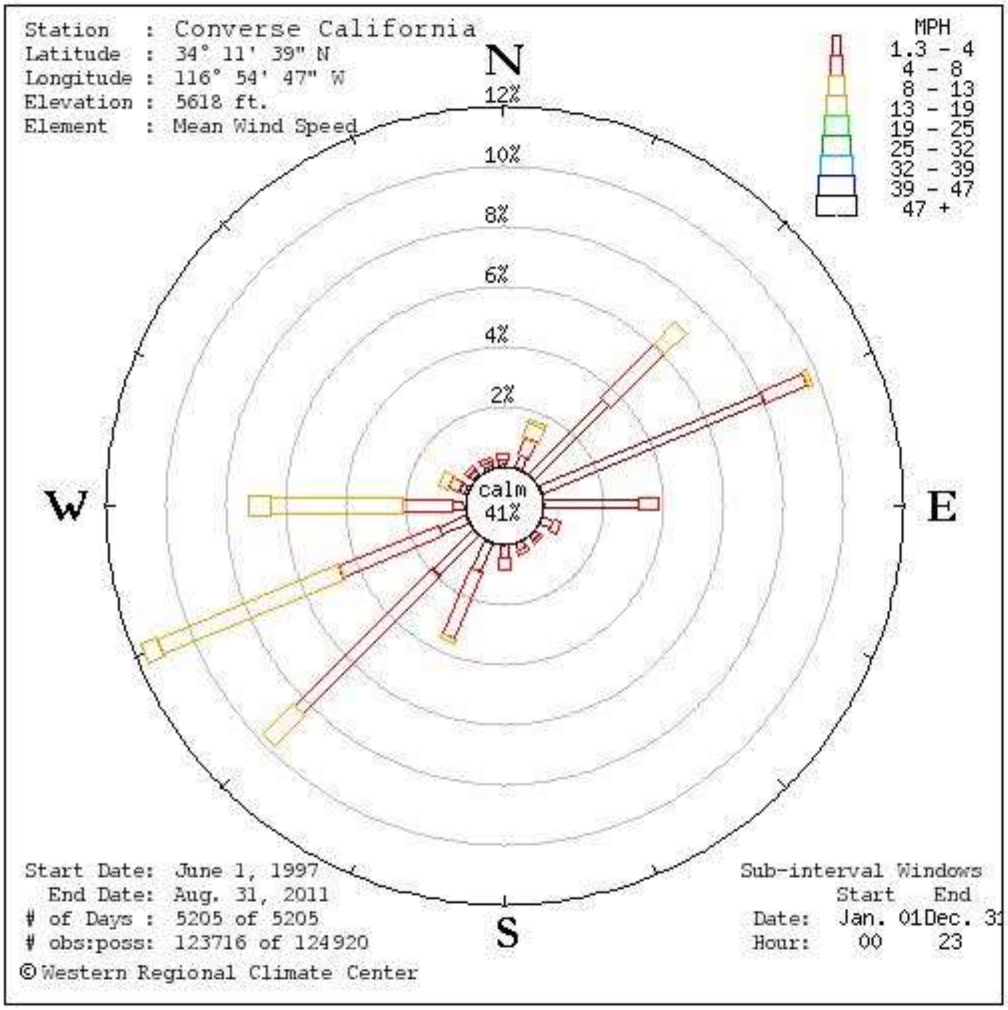



Station : Beaumont California
Latitude : 33° 55' 50" N
Longitude : 116° 57' 00" W
Elevation : 2604 ft.
Element : Mean Wind Speed
MPH
1.3 - 4
4 - 8
8 - 13
13 - 19
19 - 25
25 - 32
32 - 39
39 - 47
47 +
N
E
S
W
18%
15%
12%
9%
6%
3%
calm
7.3%
Start Date: Aug. 1, 2003
End Date: Aug. 31, 2011
# of Days : 2953 of 2953
# obs:poss: 69527 of 70872
© Western Regional Climate Center
Sub-interval Windows
Start
End
Date: Jan. 01
Dec. 3
Hour: 00
23


Station : Clark California
Latitude : 33° 52' 36" N
Longitude : 117° 18' 32" W
Elevation : 1720 ft.
Element : Mean Wind Speed
MPH
1.3 - 4
4 - 8
8 - 13
13 - 19
19 - 25
25 - 32
32 - 39
39 - 47
47 +
N
E
S
W
18%
15%
12%
9%
6%
3%
calm
13.7%
Start Date: Jan. 1, 2000
End Date: Aug. 31, 2011
# of Days : 4261 of 4261
# obs:poss: 95531 of 102264
© Western Regional Climate Center
Sub-interval Windows
Start End
Date: Jan. 01 Dec. 31
Hour: 00 23

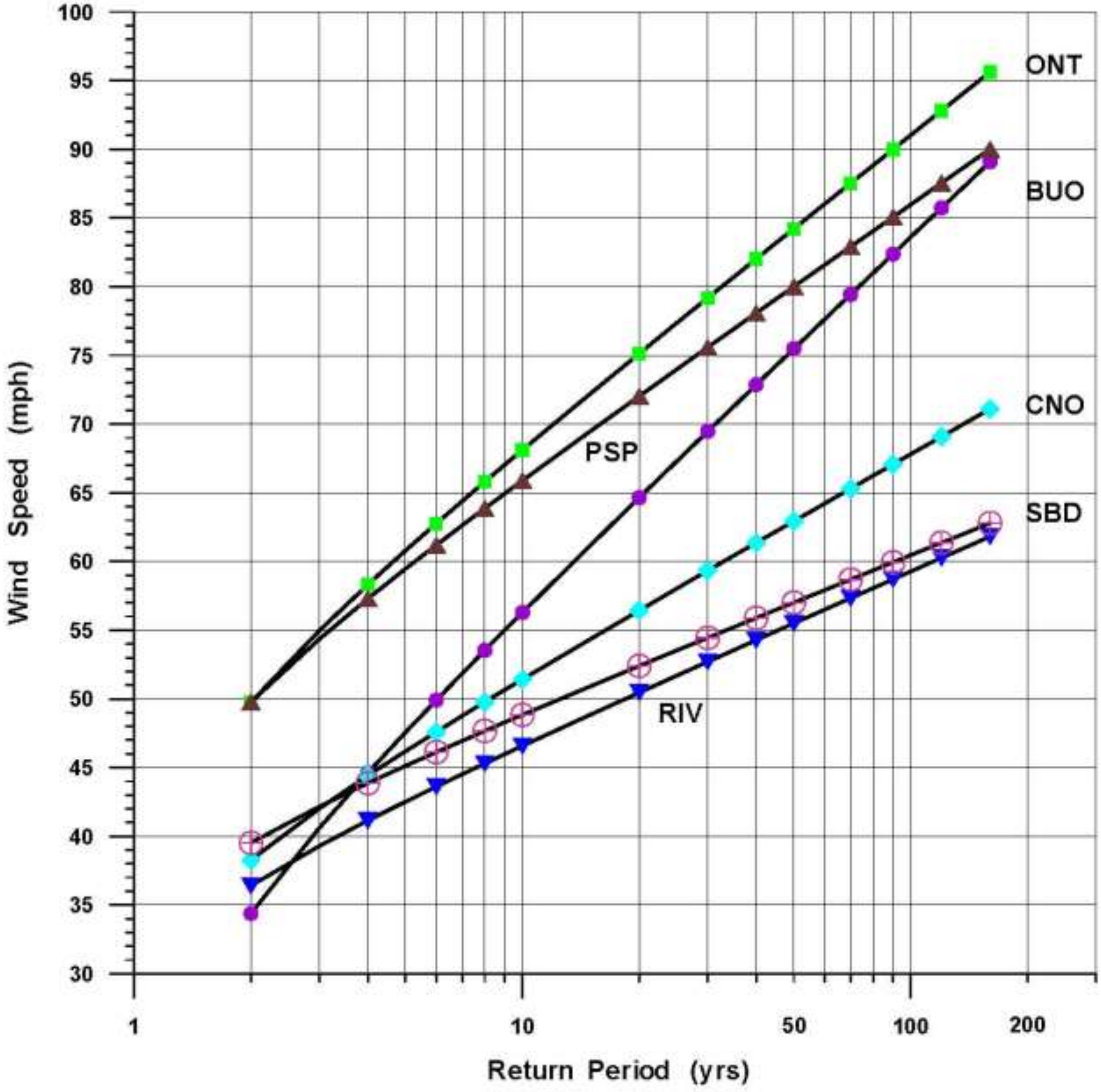

Station : Mill Creek (BDF) California
Latitude : 34° 05' 01" N
Longitude : 117° 02' 05" W
Elevation : 2950 ft.
Element : Mean Wind Speed
N
E
S
W
24%
20%
16%
12%
8%
4%
calm
25.7%
MPH
1.3 - 4
4 - 8
8 - 13
13 - 19
19 - 25
25 - 32
32 - 39
39 - 47
47 +
Start Date: Feb. 1, 1998
End Date: June 30, 2011
# of Days : 4898 of 4898
# obs:poss: 115059 of 117552
© Western Regional Climate Center
Sub-interval Windows
Start End
Date: Jan. 01 Dec. 3
Hour: 00 23


Station : Rock Camp California
Latitude : 34° 17' 17" N
Longitude : 117° 12' 45" W
Elevation : 4900 ft.
Element : Mean Wind Speed
MPH
1.3 - 4
4 - 8
8 - 13
13 - 19
19 - 25
25 - 32
32 - 39
39 - 47
47 +
N
E
S
W
24%
20%
16%
12%
8%
4%
calm
3.2%
Start Date: June 1, 2003
End Date: Aug. 31, 2011
# of Days : 3014 of 3014
# obs:poss: 67805 of 72336
© Western Regional Climate Center
Sub-interval Windows
Start End
Date: Jan. 01 Dec. 3
Hour: 00 23

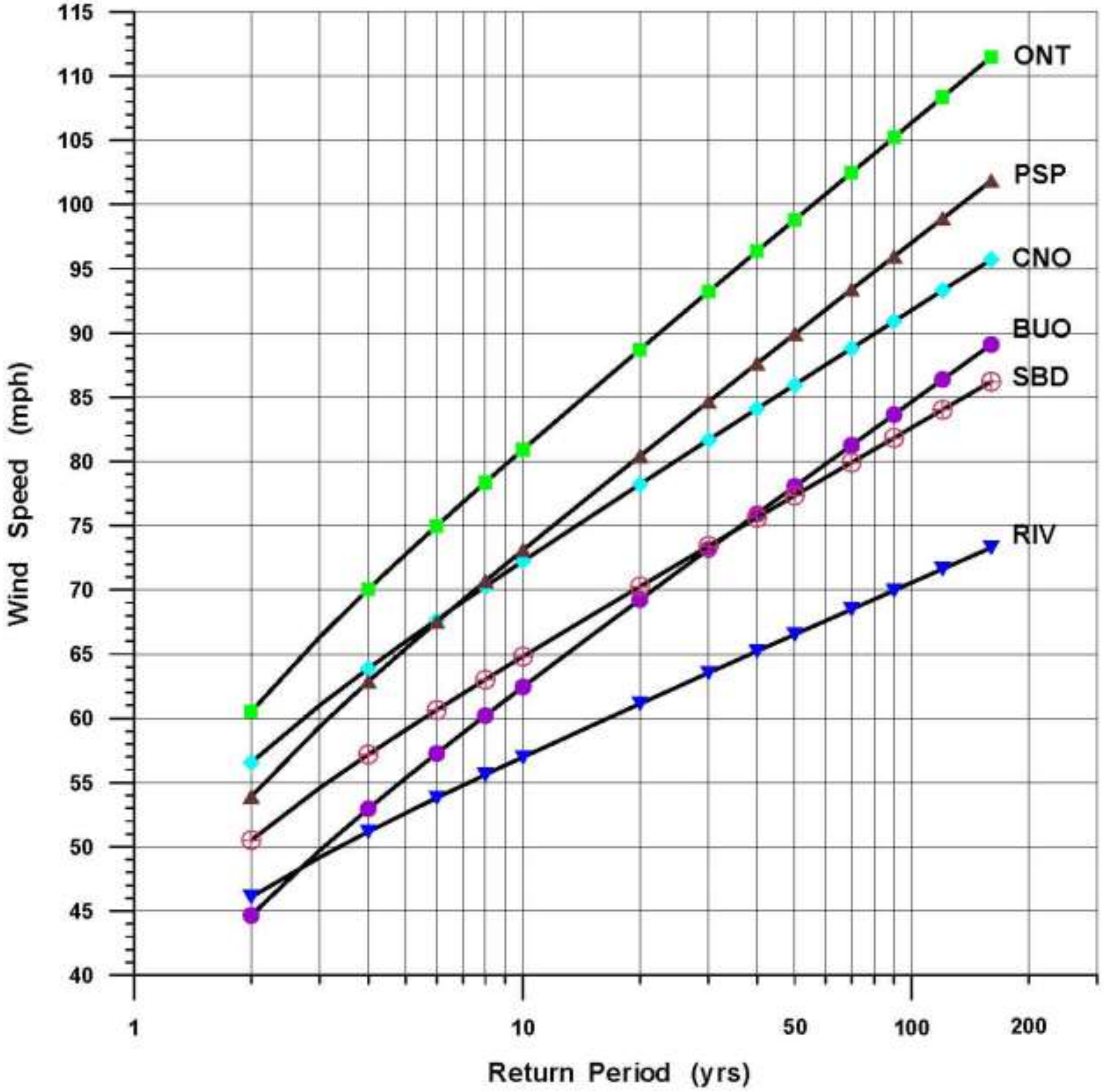

Station : Converse California
Latitude : 34° 11' 39" N
Longitude : 116° 54' 47" W
Elevation : 5618 ft.
Element : Mean Wind Speed
N
E
S
W
12%
10%
8%
6%
4%
2%
calm
41%
MPH
1.3 - 4
4 - 8
8 - 13
13 - 19
19 - 25
25 - 32
32 - 39
39 - 47
47 +
Start Date: June 1, 1997
End Date: Aug. 31, 2011
# of Days : 5205 of 5205
# obs:poss: 123716 of 124920
© Western Regional Climate Center
Sub-interval Windows
Start End
Date: Jan. 01 Dec. 3
Hour: 00 23

# Appendix B -- Return Period Graphs for Sustained and Gust Speeds at 80 Feet

# Sustained-wind Return Periods for Weather Stations in the Area (Adjusted to Conductor Height of 80 feet)

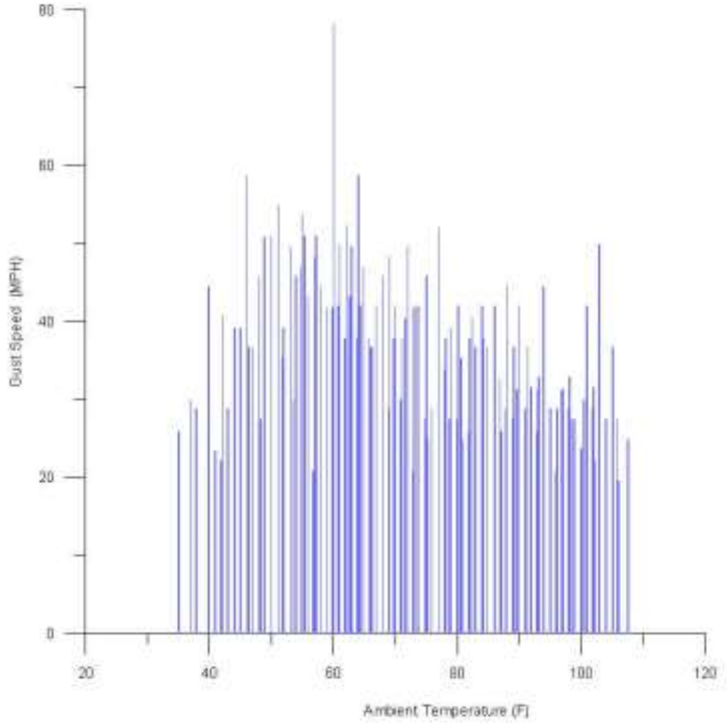


## Wind-gust Return Periods for Weather Stations in the Area (Adjusted to Conductor Height of 80 feet)

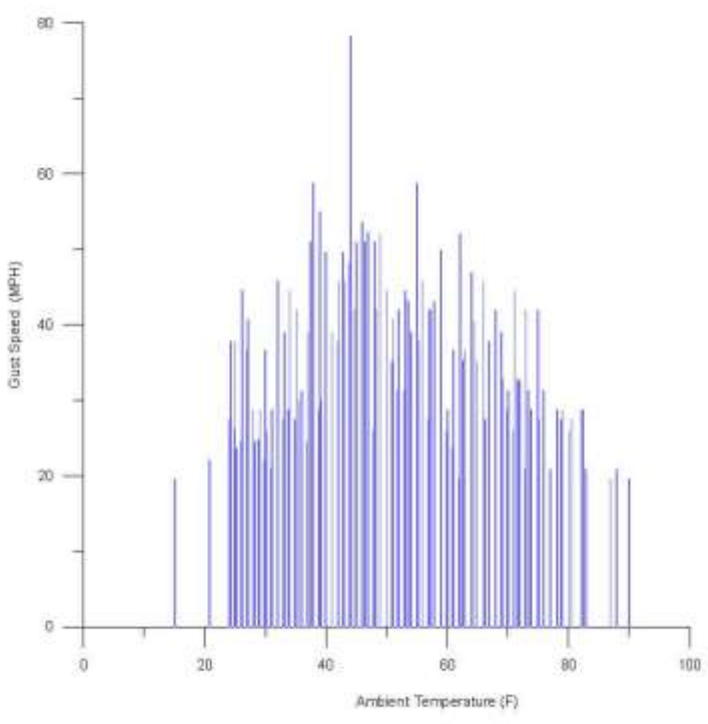


# Appendix C -- Wind and Temperature Bar Charts for Five Stations in the Region

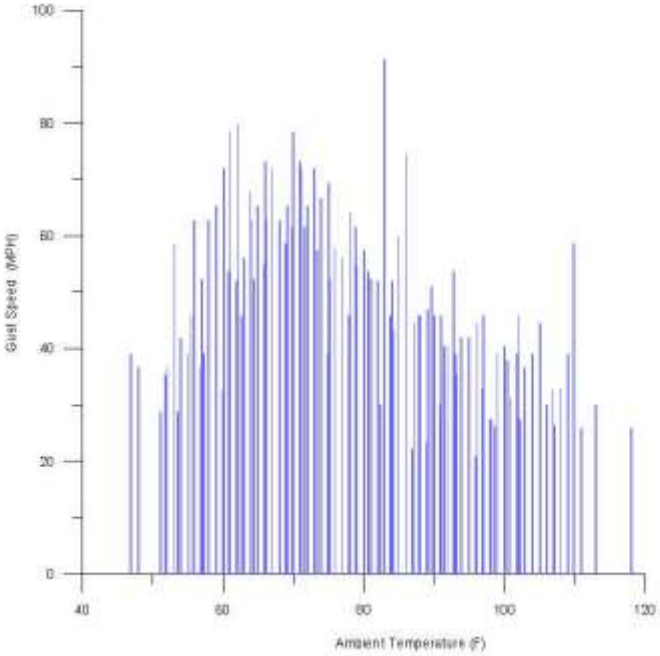
Surface Maximum Temperature and Peak Gusts at Line level
Station: Beaumont, CA Period: 1973-1999



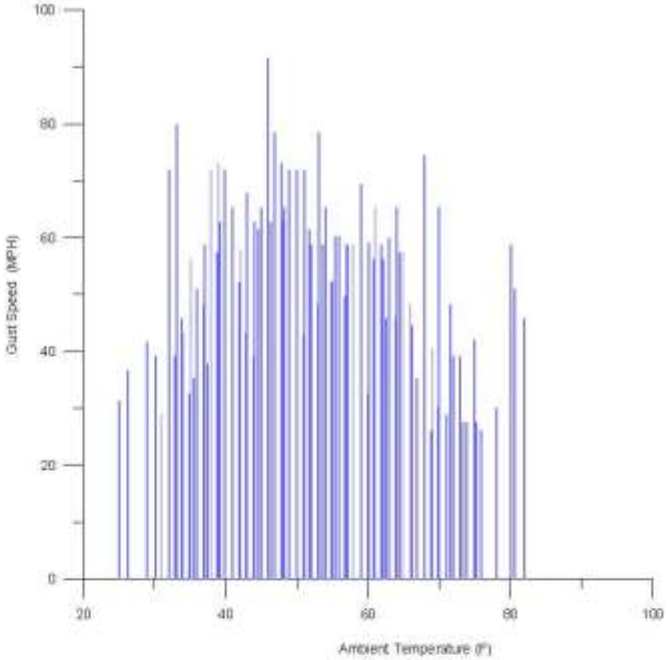
Surface Minimum Temperature and Peak Gusts at Line level
Station: Beaumont, CA Period: 1973-1999

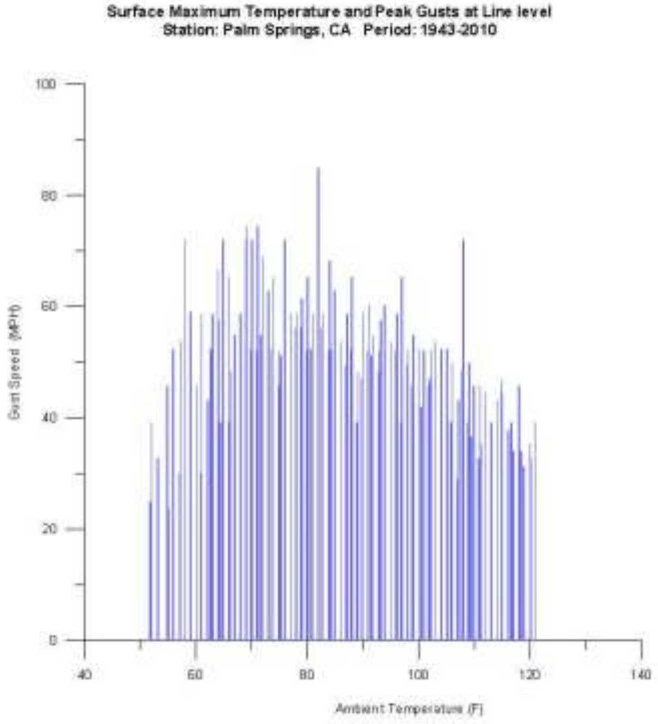


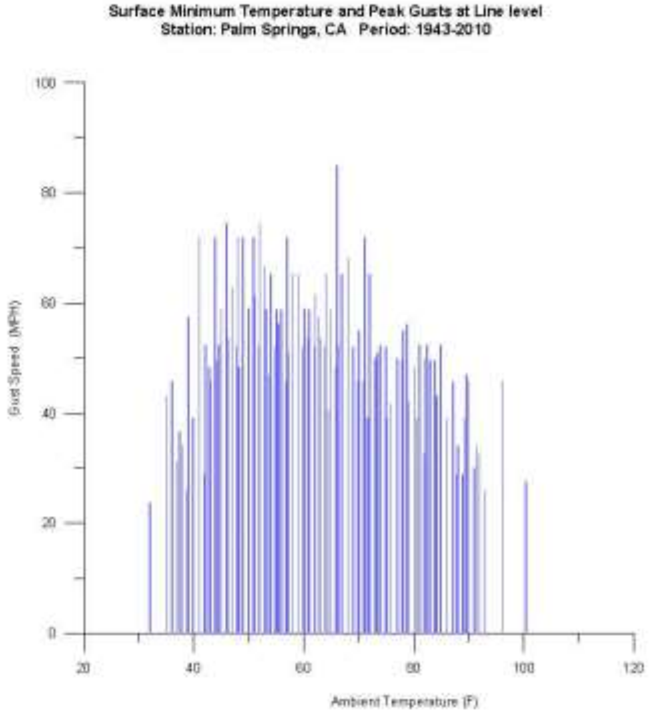
Surface Maximum Temperature and Peak Gusts at Line level
Station: Ontario, CA Period: 1943-2009
(missing years 2000, 2001)

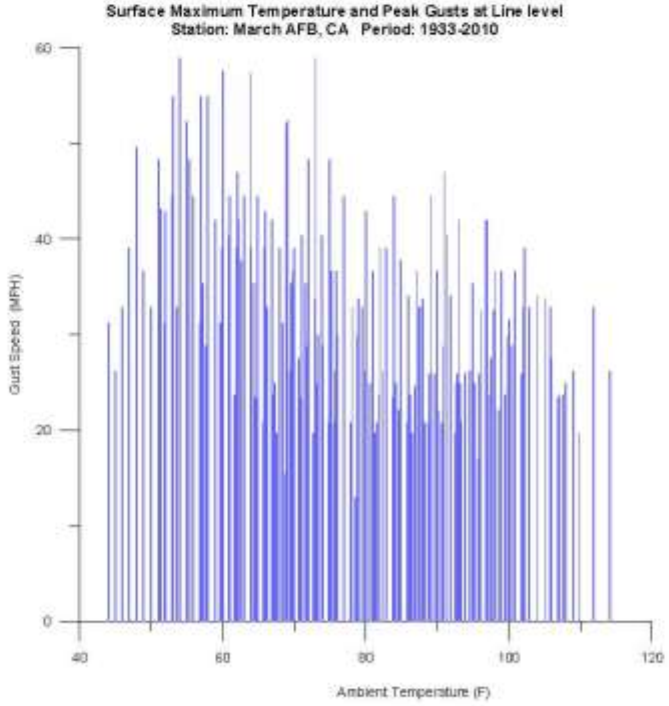


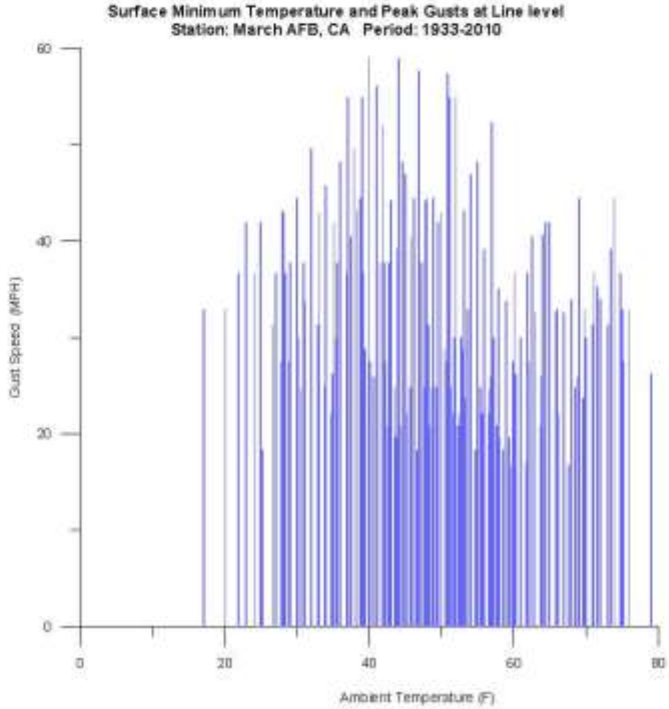
Surface Minimum Temperature and Peak Gusts at Line level
Station: Ontario, CA Period: 1943-2009
(missing years 2000, 2001)



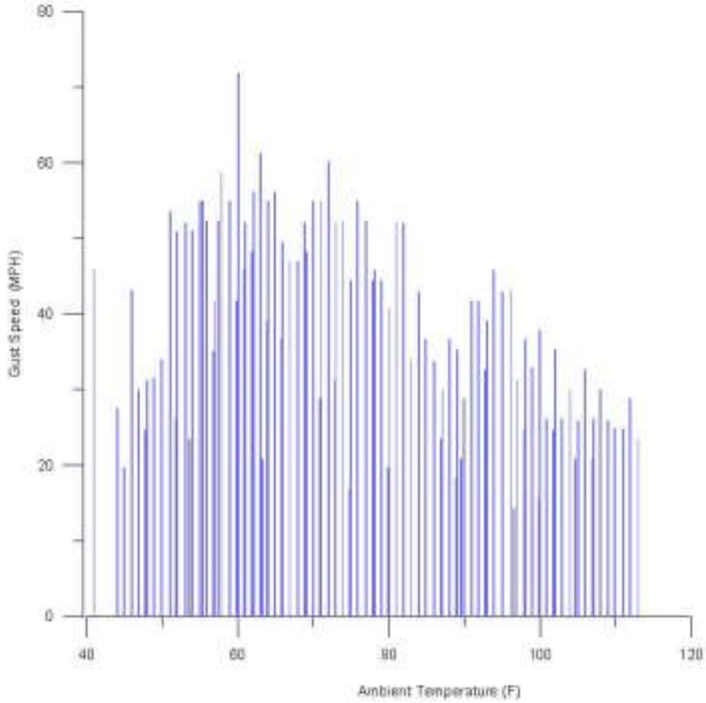

Surface Maximum Temperature and Peak Gusts at Line level
Station: Palm Springs, CA Period: 1943-2010
Gust Speed (MPH)
0
20
40
60
80
100
40
60
80
100
120
140
Ambient Temperature (F)


Surface Minimum Temperature and Peak Gusts at Line level
Station: Palm Springs, CA Period: 1943-2010
Gust Speed (MPH)
0
20
40
60
80
100
20
40
60
80
100
120
Ambient Temperature (F)

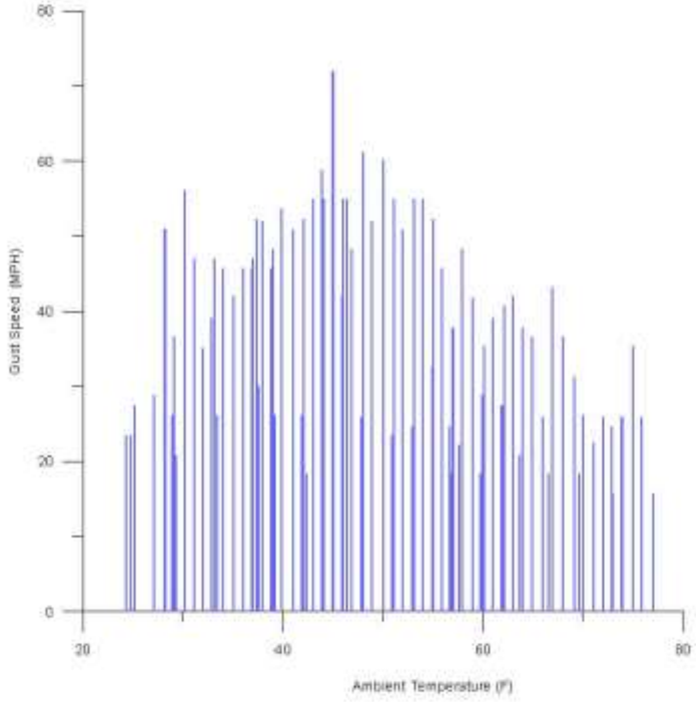

Surface Maximum Temperature and Peak Gusts at Line level
Station: March AFB, CA Period: 1933-2010


Surface Minimum Temperature and Peak Gusts at Line level
Station: March AFB, CA Period: 1933-2010

Surface Maximum Temperature and Peak Gusts at Line level
Station: Norton AFB, CA Period: 1943-1993



Surface Minimum Temperature and Peak Gusts at Line level
Station: Norton AFB, CA Period: 1943-1993



## West of Devers Existing route

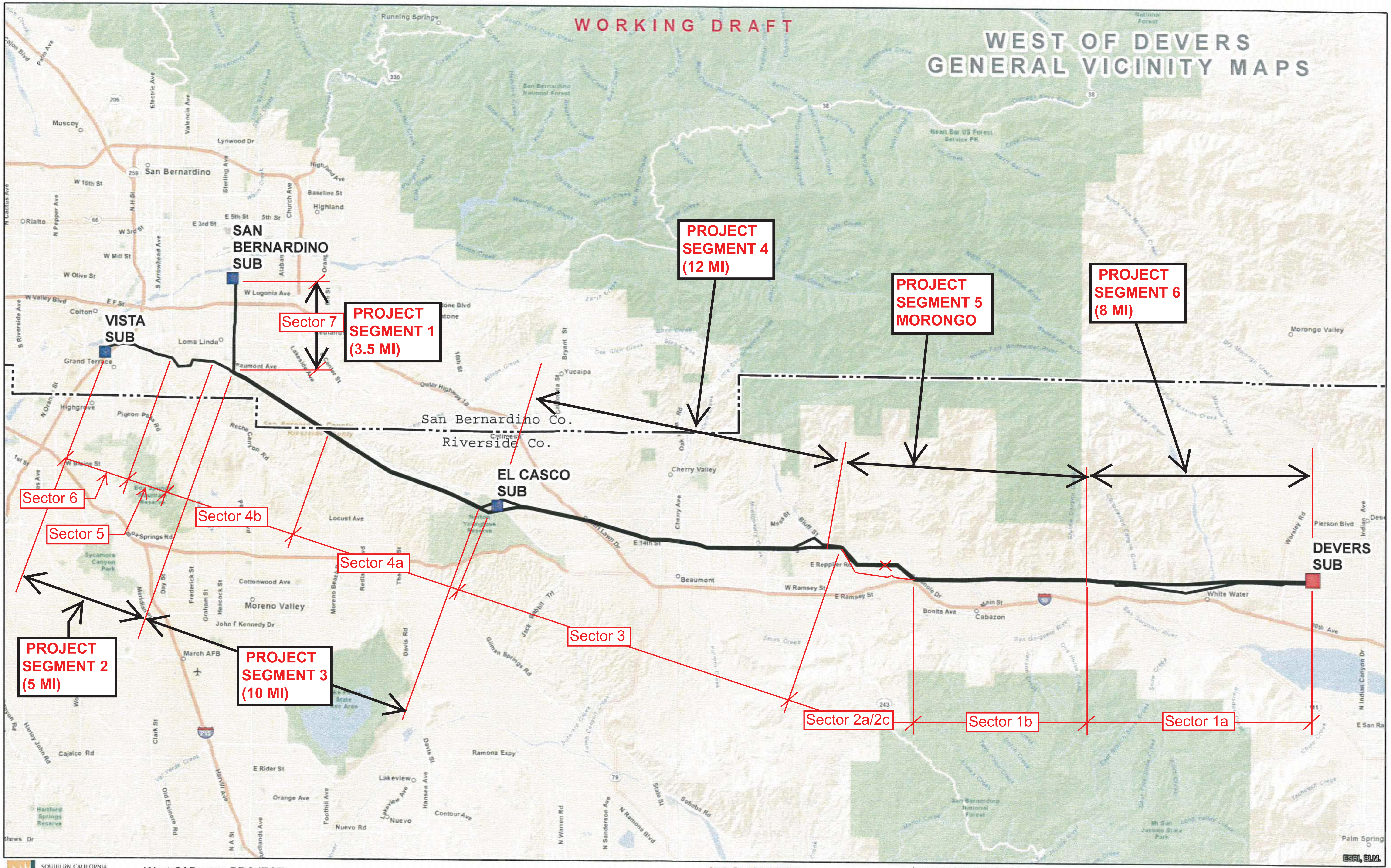
| | | Devers-Vista 2 M-T for reference | | | | | | | | | For reference | | | | **Extreme Wind Design[2]** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sector** | **Subsector** | **From D-Vista2 Tower No.** | | | **To Tower No.** | | | **Wind Span** | **GO95 Load District** | **Line Dir** | **ASCE 74 1991** | **ASCE 74 2006** | **50 yr Wind per Met. Study** | **50 yr Gust per Met. Study** | **Extreme Wind Load lb/ft$^2$** | **Temp for Wire Tension** | **Temp for Blowout Check** | **Exposure** | **Wind Angle from Normal to Line** |
| | | **M** | **T** | **Elev** | **M** | **T** | **Elev** | | | | | | mph | mph | | | | | |
| 1 | 1a | Devers Rack | | 1070 | 8 | 1 | 1660 | 1300 | Light | E-W | 11.5 | 10.2 | 80 | 90 | 12 | 55 | 80 | C | 30 |
| 1 | 1b | 8 | 1 | 1660 | 13 | 3 | 2074 | 1400 | Light | E-W | 1.0 | 1.0 | 80 | 94 | <8 | 55 | 70 | C | 75 |
| 2 | 2a | 13 | 3 | 2074 | 14 | 3 | 2186 | 1350 | Light | SE-NW | 8.9 | 8.0 | 80 | 90 | 10 | 55 | 70 | C | 40 |
| 2 | 2b | 14 | 3 | 2186 | 16 | 1 | 2376 | 1250 | Light | E-W | 1.0 | 0.9 | 92 | 96 | <8 | 55 | 70 | C | 75 |
| 2 | 2c | 16 | 1 | 2376 | 16 | 4 | 2541 | 1300 | Light | SE-NW | 9.0 | 8.0 | 92 | 96 | 10 | 55 | 70 | C | 40 |
| 3 | 3 | 16 | 4 | 2541 | 29 | 3 | 2241 | 1250 | Light[1] | E-W | 7.5 | 7.4 | 56 | 66 | <8 | 55 | 70 | C | 0 |
| | | From Tower Number | | | To Tower No. | | | | | | | | | | | | | | |
| 4 | 4a | 108 | | 2241 | 66 | | 1482 | 650 | Light | WNW | 16.1 | 15.4 | 80 | 92 | 16 | 40 | 70 | C | 0 |
| 4 | 4b | 66 | | 1482 | 37 | | 1482 | 725 | Light | WNW | 16.3 | 15.2 | 80 | 92 | 16 | 40 | 70 | C | 0 |
| 5 | 5 | 37 | | 1482 | 3 | | 1263 | 625 | Light | E-W | 17.4 | 16.1 | 82 | 94 | 18 | 40 | 70 | C | 0 |
| 6 | 6 | 3 | | 1263 | 7 | | 3642 | 650 | Light | E-W | 17.8 | 16.7 | 84 | 96 | 18 | 40 | 70 | C | 0 |
| | | | | | | | | | | | | | | | | | | | |
| | | From SB-Vista M-T | | | **To Tower No.** | | | | | | | | | | | | | | |
| 7 | 7 | 0 | 1 | 1115 | 3 | 1 | 1531 | 1200 | Light | N-S | 9.6 | 12.6 | 63 | 86 | 12 | 40 | 70 | C | 0 |

Notes:

1 One section of line goes above 3000 ft, and heavy loading should be used from Devers Vista #2 M18-T1 to M19-T2 (the existing line is designed heavy from M18-T1 to M18-T3 only.

2 Where extreme winds are evaluated at less than 12 psf, a minimum value of 12 psf shall be used for structure loading only, with the evaluated loads used for all other checks.

# WEST OF DEVERS GENERAL VICINITY MAPS



SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

West Of Devers PROJECT
Devers Sub to SanBern/Vista Sub

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N
1 " = 3 MI

WOD_VM20110524V1,Date: 5/24/2011