Oceano Dunes State Vehicular Recreation Area

Rule 1001 Draft Temporary Baseline Monitoring Program

First Draft

September 30, 2013

State of California
Department of Parks and Recreation
Off-Highway Motor Vehicle Recreation Division

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Oceano Dunes SVRA Temporary Baseline Monitoring Program
First Draft

Table of Contents

List of Tables

List of Figures

List of Appendices

TBMP Attachments (Separate Documents)

LIST OF ACRONYMS AND ABBREVIATIONS

AOI	Area of Influence
CDVAA	Coastal Dune Vehicle Activity Area
DRI	Desert Research Institute
FEM	Federal Equivalent Method
mph	Miles per hour
MSSP	Monitoring Site Selection Plan
OHMVR	Off-Highway Motor Vehicle Recreation
OHV	Off-Highway Motor Vehicle
PMRP	Particulate Matter Reduction Plan
SLO	San Luis Obispo County
SLOAPCD	San Luis Obispo County San Luis Obispo County
SVRA	State Vehicular Recreation Area
TBMP	Temporary Baseline Monitoring Program
WD	Wind Direction
WS	Wind Speed

1 INTRODUCTION

The California Department of Parks and Recreation, Off-Highway Motor Vehicle Recreation Division (OHMVR Division) has prepared this Temporary Baseline Monitoring Program (TBMP) for Oceano Dunes State Vehicular Recreation Area (Oceano Dunes SVRA) to comply with Sections C.1. and F.1.d. of San Luis Obispo County Air Pollution Control District (SLOACPD) Rule 1001, Coastal Dunes Dust Control Requirements, as modified by the May 2013 settlement agreement by and between the OHMVR Division and SLOAPCD. In accordance with Rule 1001 requirements, this first draft TBMP consists of:

- Information related to the siting of comparable temporary air quality monitors, including methodology and results of preliminary analyses related to the setting and wind conditions of Oceano Dunes SVRA and vicinity

This TBMP is one of the requirements of SLOAPCD Rule 1001, which applies to "any operator of a coastal dune vehicle activity area" greater than 100 acres in size. Though written generically, Rule 1001 was prepared specifically for Oceano Dunes SVRA, which lies within the Callender Dunes. The OHMVR Division of California State Parks manages Oceano Dunes SVRA.

1.1 BACKGROUND

In November 2011, the Board of the SLOAPCD passed Rule 1001, commonly known as the Dust Rule. The Dust Rule was developed by the staff of the SLOAPCD after they concluded that elevated levels of airborne particulate matter with an aerodynamic diameter less than or equal to 10 microns in diameter (PM10) detected in the Nipomo Mesa (the Mesa) area of SLO County were due to strong seasonal prevailing winds blowing over that portion of Oceano Dunes SVRA where off-highway vehicle (OHV) recreation occurs. The Oceano Dunes SVRA lies several miles upwind of the Mesa (Figure 1, Oceano Dunes and Vicinity). The process by which PM10 in the dunes is released is called "saltation," whereby the winds which build the dunes cause sand to bounce and creep along the dune surface. As sand grains bounce downwind, they carom off other grains, releasing them, and causing those grains to also creep and bounce downwind. A very small fraction of those grains are PM10 and can be released by the saltation process and become entrained in the prevailing wind. Consequently, that portion of PM10 detected on the Mesa that is of concern to the SLOAPCD and the Dust Rule is "crustal," meaning it is derived from rocks and soil.

1.2 TBMP REQUIREMENTS

Rule 1001, Section B.14, defines a TBMP as "a temporary monitoring program designed to determine baseline PM10 concentrations at the APCO-approved CDVAA and Control Site Monitor locations prior to implementation of the PMRP emission reduction strategies and monitoring program." Rule 1001 further states that this program shall include:

- A detailed description of the monitoring locations
- Sampling methods and equipment
- Operational and maintenance policies and procedures
- Data handling, storage, and retrieval methods
- Quality control and quality assurance procedures
- Related information needed to define how the temporary monitors will be sited, operated, and maintained to provide the required baseline data

Rule 1001 requires TBMP monitors to meet Federal Equivalent Method (FEM) specifications unless otherwise specified by the SLOAPCD Air Pollution Control Officer.

As defined in Rule 1001, the Oceano Dunes SVRA TBMP is required to contain information on sampling methods and equipment and operating and maintenance procedures, including data quality control and assurance procedures. The OHMVR Division has not completed development of this aspect of its TBMP because specific monitoring sites and equipment have not been selected or purchased yet. The OHMVR Division will submit this required information with a future version of this TBMP.

1.3 Setting

The Callender Dunes are part of the larger Guadalupe Nipomo Coastal Dune Complex, which extends along the coastline of southern SLO County and northern Santa Barbara County. The dune complex consists of more than 18,000 acres of coastal dunes. Oceano Dunes SVRA lies at the northern end of this complex and consists of about 3,600 acres, with about 1,500 of those acres devoted to OHV recreation (Figure 1, Oceano Dunes and Vicinity). From March through October, the 1,500 acre OHV riding area is reduced to about 1,250 acres to accommodate nesting shorebirds. The Pismo Dunes Natural Preserve, which borders the northern boundary of Oceano Dunes SVRA, consists of approximately 650 acres.

Every spring, strong prevailing winds blow from the northwest, over the ocean to the dunes and beyond. The elevated readings of PM10 levels in the Mesa that are of concern to the SLOAPCD coincide with these winds.

Off-Highway Vehicle Riding Area

Oceano Dunes SVRA State Park Boundary

Seasonal Exclosure for Plover

Dune Preserve

N

0 0.5 1

Miles

Map Scale: 1:60,000

Figure 1

Oceano Dunes and Vicinity

Imagery Source: NAIP, 2010

2 INFORMATION SOURCES AND METHODOLOGY

The TBMP mandated by the Dust Rule requires the placement of air monitoring stations downwind of the dunes where OHV recreation occurs and downwind of dunes where OHV recreation is prohibited. The Dust Rule requires the placement of the stations for PM10 comparison purposes. Per the Dust Rule, the OHV riding area of Oceano Dunes SVRA is called the "Coastal Dune Vehicle Activity Area," or CDVAA. A coastal dune area comparable to the CDVAA, but where vehicle activity has been prohibited, is considered a potential "Control Site." The OHMVR Division's PMRP describes the CDVAA and the four potential control sites that may be comparable to the CDVAA (OHMVR Division 2013).

The Dust Rule does not define the term comparable. In actuality, there are many variables that combine to ultimately create the distribution of dunes within and adjacent to the OHV riding area of the Oceano Dunes SVRA. These include strength and persistence of prevailing wind, shoreline slope, the onshore distribution of the sands, existence and type of vegetation in the dunes, and topography of the dunes. The OHMVR Division's Monitoring Site Selection Plan (MSSP) identifies five scientific factors to consider when comparing CDVAA and Control Monitor sites; Table 1 below presents these factors. In May 2012, the APCO approved four of these five factors for use in the CDVAA and Control Site selection process (the exception being dune source strength, or measurements of the amount and dust and PM10 generated during saltation).

A sizable amount of data was used to evaluate swaths of dune landscapes for potential comparability, including publically available aerial imagery, digitally-represented topographic data, and hourly air quality and meteorological measurements.

Air quality and meteorological data included data for the SLOAPCD's CDF and Mesa2 stations from the California Air Resources Board's online Air Quality and Meteorological Information System. Data from several locations within the dunes, collected during the OHMVR Division's 2013 Assessment Monitoring Program, were also used (Figure 2, Oceano Dunes SVRA and Temporary Array of Air and Wind Monitoring Equipment, and Figure 3, Oceano Dunes SVRA – Ten Meter High Anemometers Used for Wind Analysis). The OHMVR Division's 2013 Assessment Monitoring Program is described in the OHMVR Division's PMRP (OHMVR Division 2013).

These data made it possible to conduct a "desktop review"--an initial, systematic assessment of hypothetical CDVAA and Control Sites based on the scientific factors described in Table 1. The sections below describe the methodologies used to conduct this initial assessment.

Table 1 – Preliminary MSSP Characteristics to Consider When Comparing CDVAA and Control Monitor Sites	
Scientific Factor	**Preliminary Characteristic**
Upwind Dune Setting	
Management and land use	*Consistent management practices*
Open Sand/Vegetation, % Coverage	*Coverage upwind of CDVAA and Control monitor sites is representative of CDVAA and Control Source areas, respectively*
Fore-dune Presence, Absence, and Structure	*Representative of CDVAA and Control Source areas, respectively*
Vehicle Activity	*CDVAA monitor is downwind of "higher" vehicle activity area*
Topography	*PWD cross-section has similar dune ridge frequency and height*
Dune Wind Conditions (During High Wind Events)	
Prevailing wind direction (PWD) at the shoreline	*CDVAA/Control monitor sites are downwind of PWD at shoreline*
Hourly average wind speed (WS) at the shoreline	*CDVAA/Control monitor site WS $\pm$ 15% when from PWD*
Peak hourly average WS	*CDVAA/Control monitor peak WS occurs same general time of day*
Dune Source Dispersion	
Source Influence at Monitor Site	*CDVAA/Control Source Area overlap minimized*
Edge Effects	*CDVAA/Control monitor sites $\pm$ 100 m of plume source centerline*
Monitor Sites	
Distance Inland	*CDVAA/Control monitor sites $\pm$ 100 m of site distance from shore*
Elevation	*CDVAA/Control monitor sites $\pm$10 m of site elevation*
Dune Source Strength	
Emissivity Profile	*TBD as part of PMRP Process*
Aerosol Particulate Profile	*TBD as part of PMRP Process*
PM10, µg/m3	*TBD as part of PMRP Process*

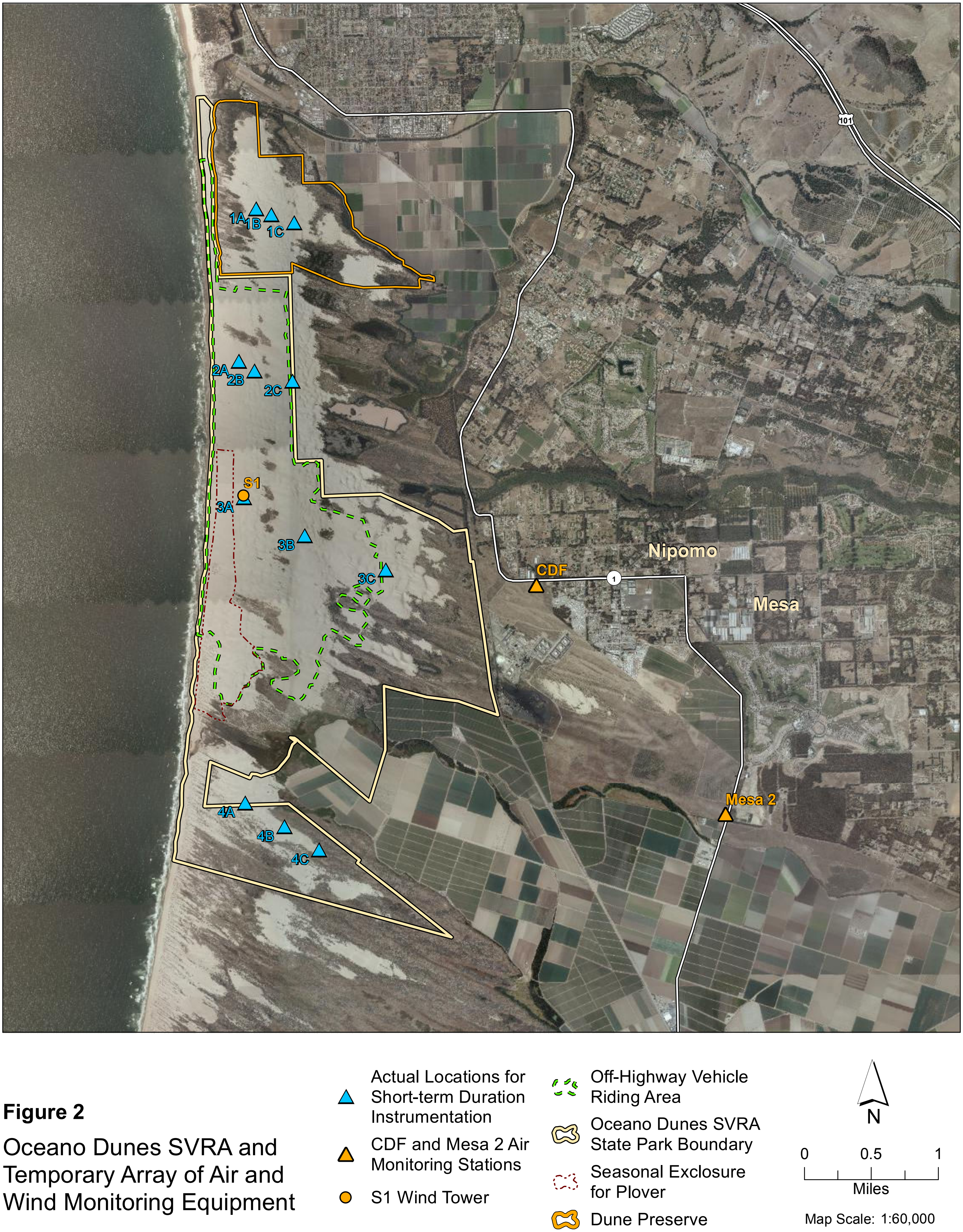

Figure 2

Oceano Dunes SVRA and Temporary Array of Air and Wind Monitoring Equipment

Imagery Source: NAIP, 2010

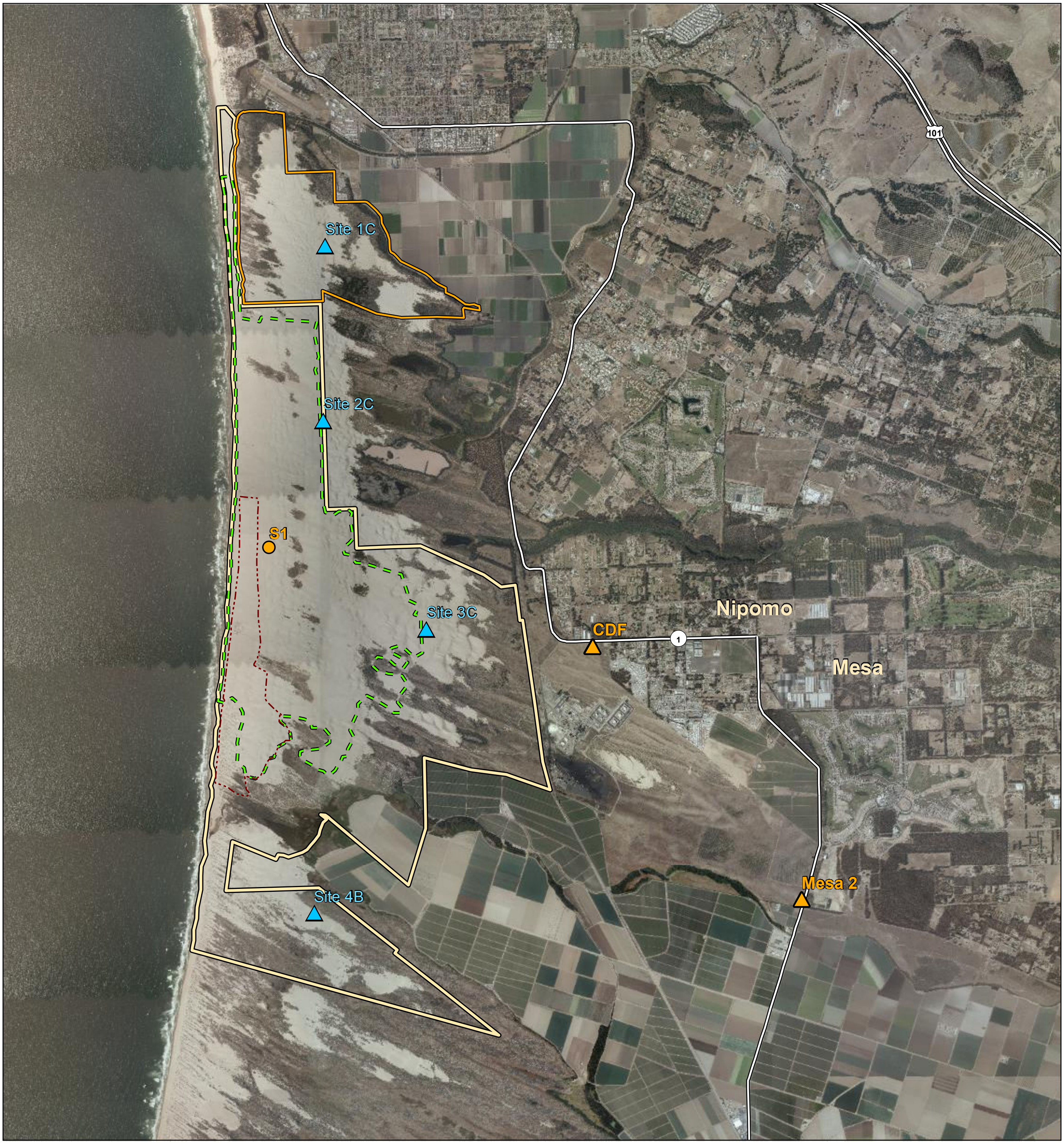

Figure 3

Oceano Dunes SVRA -
Ten Meter High Anemometers
Used For Wind Analysis

Ten Meter Anemometer Stations

- Temporary Monitoring Station (Spring 2013)
- CDF and Mesa 2 Air Monitoring Stations
- S1 Wind Tower
- Off-Highway Vehicle Riding Area
- Oceano Dunes SVRA State Park Boundary
- Seasonal Exclosure for Plover
- Dune Preserve

N

0 0.5 1
Miles

Map Scale: 1:60,000

Imagery Source: NAIP, 2010

2.1 Methodology for Developing Desktop Grid

Consistent with the OHMVR Division's MSSP, the OHMVR Division plotted a digital grid of hypothetical desktop monitoring sites over aerial imagery of Oceano Dunes SVRA and vicinity (Figure 4, Oceano Dunes SVRA – Grid Analysis for Potential CDVAA and Control Site Monitoring Location). The western boundary of the grid is parallel to the shoreline, approximately 1,000 meters (3,280 feet) from it. This western boundary was chosen because it coincides with narrowest portion of the open riding and camping area at Oceano Dunes SVRA . Grid spacing is approximately 500 meters (1,640 feet) in the east-west direction and 650 meters (2,140 feet) in the north-south direction.

A total of 168 sites were plotted; however, visual screening and comparison of geographic and land use features allowed most points (158) to be eliminated from consideration. For example, desktop sites located in residential areas and agricultural fields and in or near the Phillips refinery were eliminated because these land uses are likely to influence monitor measurements. Sites in areas with different topographic elements, such as the dune lakes region, were also eliminated from consideration in this initial assessment because wind profiles are presumed to be different in these areas.

After visual screening, six potential CDVAA sites and four potential Control sites were selected for further evaluation, as presented in Table 2 below and depicted on Figure 5.

Table 2 - Desktop Review Sites Selected for Further Evaluation and Comparison

Potential CDVAA Site	Potential Comparable Control Site
A2, A13	A4, A5, A6
C3, C14	C8
E8, E9	None

It is important to note that a portion of the Guadalupe Dunes, south of the Santa Maria River, in Santa Barbara County, could not be considered for potential Control Site monitoring in this initial assessment due to permitting and access constraints. The OHMVR Division may evaluate this area for Control Site suitability further in the future.

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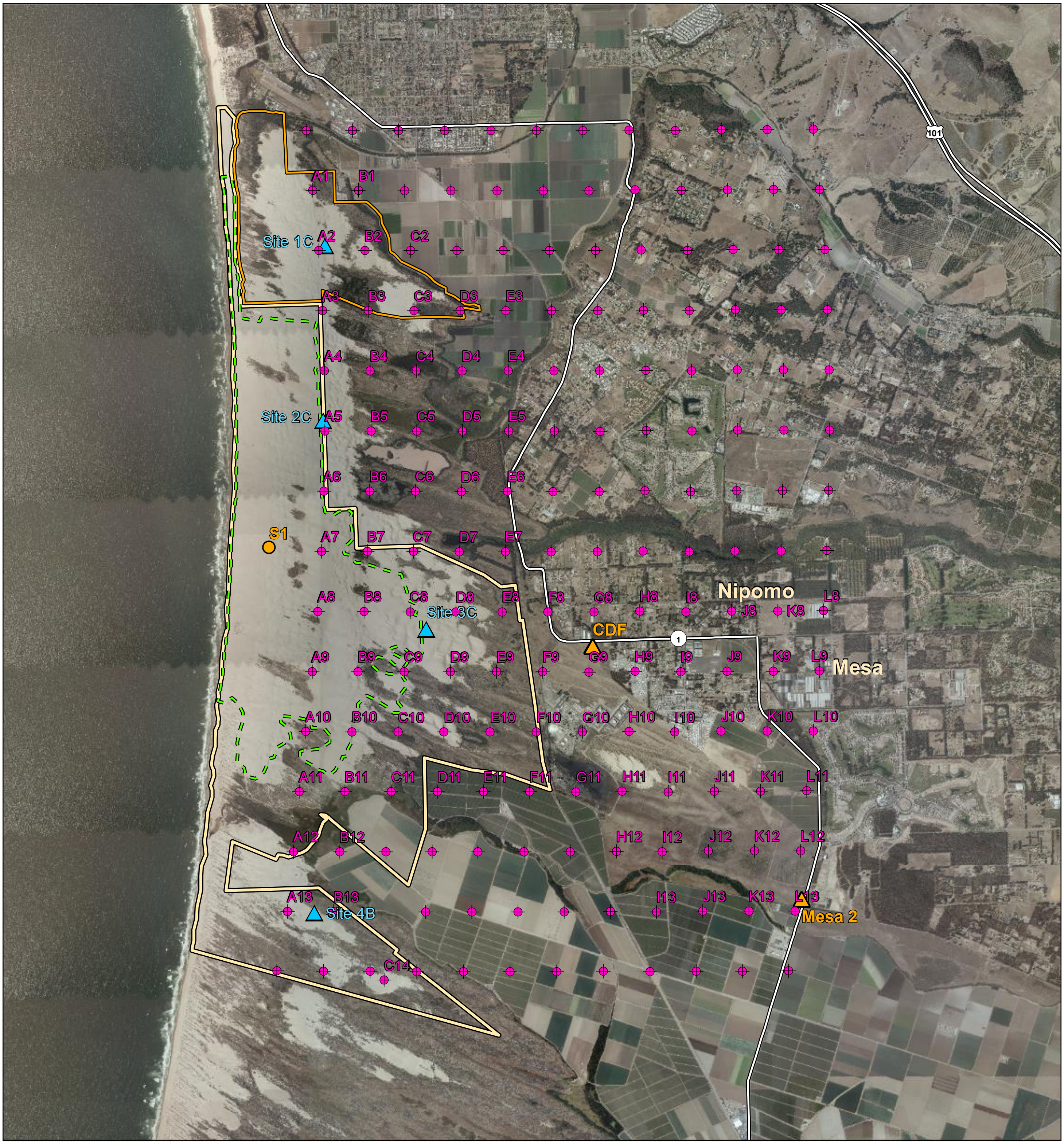

Figure 4

Oceano Dunes SVRA - Grid Analysis for Potential CDVAA and Control Site Monitoring Location

Ten Meter Anemometer Stations

- Temporary Monitoring Station (Spring 2013)
- CDF and Mesa 2 Air Monitoring Stations
- S1 Wind Tower

- Grid Analysis for Potential CDVAA and Control Site Monitoring Location
- Off-Highway Vehicle Riding Area
- Oceano Dunes SVRA State Park Boundary
- Dune Preserve

N

0 0.5 1

Miles

Map Scale: 1:60,000

Imagery Source: NAIP, 2010

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Figure 5

Oceano Dunes SVRA - Potential CDVAA and Control Site Locations to be Evaluated

Potential CDVAA and Control Site Selected for Evaluation

Off-Highway Vehicle Riding Area

Oceano Dunes SVRA State Park Boundary

Seasonal Exclosure for Plover

Dune Preserve

Ten Meter Anemometer Stations

Temporary Monitoring Station (Spring 2013)

CDF and Mesa 2 Air Monitoring Stations

S1 Wind Tower

N

0 0.5 1

Miles

Map Scale: 1:60,000

Imagery Source: NAIP, 2010

2.2 Methodology for Selection and Analysis of Wind Data

Consistent with its MSSP, the OHMVR Division evaluated dune wind conditions; however, this analysis was based on high PM10 events (as measured at CDF and Mesa2) and dune wind speeds greater than approximately 9 miles per hour (mph), rather than solely high wind events (> 15 mph) as indicated in the MSSP.

- **Time frame:** The OHMVR Division used wind data collected from May through July, 2013. This is because:
  - The windiest season and resultant dust events on the Mesa occur at this time of year
  - Instruments for measuring winds and resultant dune processes (e.g., saltation) were placed in the dunes in May, when the California Coastal Commission gave permission to conduct temporary monitoring within the dunes
  - May through July 2013 data have been processed for quality assurance by Parks' meteorological contractor Sonoma Technologies, Inc.
- **Data Restrictions:** The OHMVR Division used wind data from a height of 10 meters above ground surface. This is because:
  - Wind data collected from lower heights, e.g. 3 meters, are more likely to be influenced by local upwind topography.
  - There are seven stations with wind data at 10 meters. Five are within the dunes (S1, 1C, 2C, 3C, and 4B), and two are operated by the APCD (CDF and Mesa2).
- **Data Filters:** The OHMVR Division applied three filters to the resulting data set. First, hourly-averaged wind data were extracted for further analysis from all seven stations for those hours when PM10 at either CDF or Mesa 2 exceeded 50 micrograms/cubic meter. Second, these high PM10 records were then filtered to exclude wind data not emanating from the west-northwest (everything outside the azimuthal arc of 250° to 360°). Finally, 10-meter wind data from assessment monitoring sites within the dunes (Sites S1, 1C, 2C, 3C, and 4B) were filtered to exclude any times when winds were less than 4 meters/second (approximately 9 miles per hour). This last filter is based on analysis of 2013 sand movement data collected at each wind station in the dunes. The analysis was performed by the Desert Research Institute of Reno, Nevada, and is included herein as Attachment 1 to this TBMP. DRI calculated the minimum wind necessary to begin the saltation process, also known as the threshold wind speed. DRI found that there was no significant difference in the threshold wind speed, whether data came from inside the OHV riding area of the dunes or in the non-ride areas. On average, the area-wide calculated threshold speed is about five meters per second (11.2 miles per hour). Because lesser winds do not generate PM10, those winds which were clearly below the average threshold wind speed (winds less than 4 meters/ second) were not considered in this analysis. These filters resulted in a data set consisting of 10-meter high winds from the northwest quadrant for all seven sites, with

emphasis on winds above threshold wind speed within the dunes. The resulting data set is included in Appendix A to this TBMP.

- **Data Analysis:** The OHMVR Division averaged the filtered wind speed and wind direction records for each of the seven monitoring stations and calculated the standard deviation for these averages. The results of this analysis are presented on Figure 6, Average Wind and Speed, Spring 2013, and in Table 3 in Section 3.1.

2.3 Methodology for Topographic and Aerial Analysis

Consistent with the MSSP, the OHMVR Division evaluated the upwind dune setting, including land cover, topography, and vehicle activity.

- **Topography and Land Cover:** The OHMVR Division used available GIS topographic data to calculate the land cover upwind of the site and draw topographic profiles for each set of comparable stations listed in Table 2. For each site, only the upwind area of influence defined by average wind direction ± one standard deviation was considered (see Figure 6 and Table 3).

The OHMVR Division did not prioritize the presence, absence, or structure of foredunes upwind of desktop CDVAA and Control Sites in this initial TBMP assessment because other variables, specifically wind speed and open sand acreage, are more directly linked to the potential for saltation and dust generation. Observations of real-time PM10 data collected during Spring 2013 that indicated hourly PM10 concentrations were highest in Transect 4, south of Oso Flaco Lake, support further analysis and inclusion of PM10 data for site selection purposes.

2.4 Methodology for Dune Source Dispersion and Monitor Sites

Specific dune source dispersion exercises were not conducted for the desktop sites evaluated in this TBMP because visual screening indicated nearly all of the sites would be influenced by either the CDVAA or a Control Site. The exception to this is sites E8 and E9, which are influenced by both the CDVAA and a Control Site.

2.5 Methodology for Comparing Desktop Monitor Sites

The OHMVR Division compared desktop sites by evaluating the similarities and differences in the scientific factors present at each desktop site. For each desktop site, wind conditions were defined using wind data collected from the nearest 10 meter high station in the dunes. For example, desktop Control Site A2 is closest to the actual site 1C (See Table 3 and Figure 5), so the wind speed and direction data collected and analyzed from station 1C were presumed to be representative for desktop Control Site A2. Similarly, the average wind direction from actual site 1C was used to define upwind landscape area of influence (AOI) for desktop site A2. This AOI was then evaluated for land coverage and topography factors. Figure 7, Oceano Dunes SVRA – Evaluation of CDVAA and Control Site Locations, displays the upwind AOI projected from each potential Control Site and CDVAA Site listed in Table 2 above, as well as those projected from SLOAPCD station Mesa 2 and CDF.

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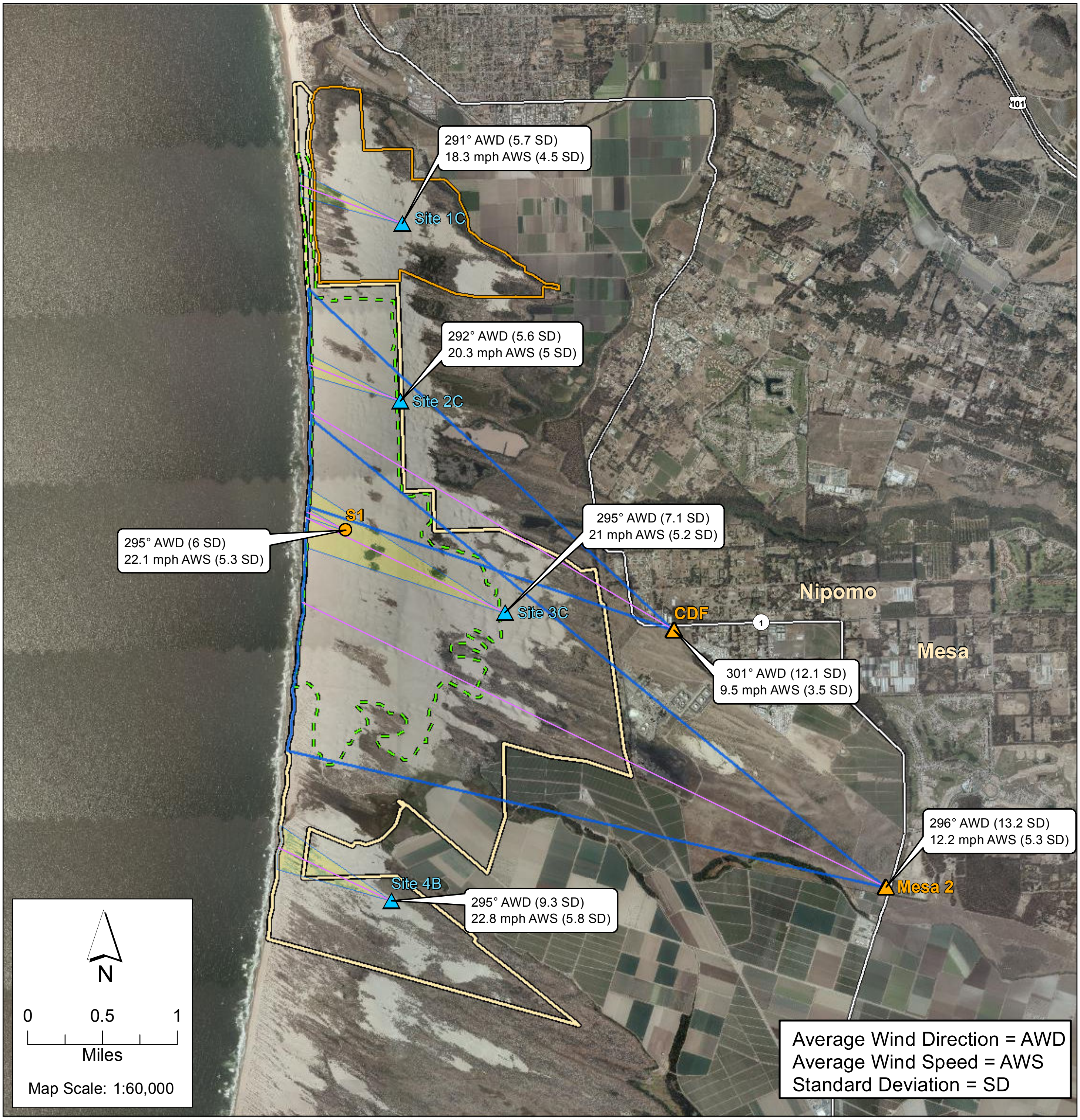

Ten Meter Anemometer Stations

- Temporary Monitoring Station (Spring 2013)
- CDF and Mesa 2 Air Monitoring Stations
- S1 Wind Tower

- Average Wind Direction
- One Standard Deviation of Average Wind Direction

Coverage Analysis of the Standard Deviation of Wind Direction for Temporary Monitoring Stations

- Sand
- Vegetation

- Off-Highway Vehicle Riding Area
- Oceano Dunes SVRA State Park Boundary
- Dune Preserve

Figure 6

Oceano Dunes SVRA - Average Wind Direction and Speed, Spring 2013

Imagery Source: NAIP, 2010

Figure 7

Oceano Dunes SVRA - Evaluation of CDVAA and Control Site Locations

Potential CDVAA and Control Site Selected for Evaluation

Average Wind Direction used for Evaluation Sites

One Standard Deviation of Average Wind Direction

Coverage Analysis of the Standard Deviation of Wind Direction for Potential Monitoring Stations

Sand

Vegetation

Ten Meter Anemometer Stations

Temporary Monitoring Station (Spring 2013)

CDF and Mesa 2 Air Monitoring Stations

S1 Wind Tower

Off-Highway Vehicle Riding Area

Oceano Dunes SVRA State Park Boundary

Dune Preserve

N

0 0.5 1

Miles

Map Scale: 1:60,000

Imagery Source: NAIP, 2010

3 RESULTS AND DISCUSSION

3.1 Wind Conditions and Land Cover

Table 3 summarizes the 10-meter wind data from the five dune Assessment Monitoring sites as well as the SLOAPCD's CDF and Mesa 2 sites used in this TBMP, filtered as described in Section 2.1.1. Table 3 also identifies the desktop site for which existing wind data were assumed to be representative.

Table 3 – Spring 2013 10-meter Average Wind Direction (WD) and Wind Speed (WS)[(A)]

Site	Filtered Records[(B)]	Average WD (degrees)	Average WS (mph)	Corresponding Desktop Site
Site 1C	199	290.7 $\pm$ 5.7	18.3 $\pm$ 4.5	Control Site A2, C3
Site 2C	225	291.7 $\pm$ 5.6	20.3 $\pm$ 5.0	CDVAA Sites A4, A5, A6
Site 3C	251	295.5 $\pm$ 7.1	21.0 $\pm$ 5.2	CDVAA Sites C8, E8, E9
Site 4B	261	295.1 $\pm$ 9.3	22.8 $\pm$ 5.8	Control Sites A13, C14
S1	288	294.7 $\pm$ 6.0	22.1 $\pm$ 5.3	Not Applicable
CDF	309	300.9 $\pm$ 12.1	9.5 $\pm$ 3.5	Not Applicable
Mesa 2	316	296.0 $\pm$ 13.2	12.2 $\pm$ 5.3	Not Applicable

(A) Average WD and WS data are presented as average $\pm$ one standard deviation
(B) Filtered records refers to the number of hours wind speeds were high enough toexceed the estimated threshold for sand movement (see discussion at end of section)

Table 3 indicates that the winds at Oceano Dunes and vicinity are generally from the west-northwest, the regional prevailing wind direction. This is not surprising since the dune landforms in this wind-influenced environmental exhibit a west-northwest alignment (See Figure 1, Oceano Dunes and Vicinity). The S1 tower, which measures incoming, on-shore winds, recorded an average WD of 294.7 $\pm$ 6.0 degrees during times of dune saltation and elevated PM10 at SLOAPCD monitoring locations. Inland stations recorded an average WD similar to this shoreline value, although wind direction is generally more variable inland, as evident by the more northerly component to the winds measured at CDF and the larger standard deviation in wind direction observed at CDF and Mesa2.

Table 3 also indicates that wind speed within the dunes increases in strength from north to south. Wind speed is weakest north of the OHV riding area and strongest in the dunes south of the riding area, ranging from 18.3 to 22.8 mph, respectively. Winds recorded in the OHV riding area fall in between, with winds at the S1 tower, which is closest to the shore, and Site 3C, which is at the easternmost edge of the riding area (see Figure 4), being most similar to winds recorded at Site 4B. Wind speed data from Mesa 2 suggest this site has generally lower wind speed than measured in the dunes, but the station is 4.1 miles from the shoreline and a decline in wind speed is expected as an air mass moves from open ocean to over vegetation and developed land, due to momentum absorption by the complex roughness. The CDF station records the lowest wind speeds approximately 10 mph less than in the dunes – though it is more than one and a half miles closer to the shoreline than Mesa 2.

Table 4 groups potential CDVAA Sites with the Control Sites most suited for comparison based on site proximity and geography, as was done for Table 2. Additionally, Table 4 shows wind data with upwind land acreage data for these hypothetical sites (see Figure 6).

Table 4 - Desktop CDVAA and Control Site Comparability – Wind and Open Sand Acreage

Desktop Site / Type	Average WD (degrees)(A)	Average WS (mph)(A)	Upwind AOI (acres)	Upwind Open Sand	
				Acres	% AOI
A4 (CDVAA) *A2 (Control)* *A13(Control)*	291.7 ± 5.6 290.7 ± 5.7 295.1 ± 9.3	20.3 ± 5.0 18.3 ± 4.5 22.8 ± 5.8	27.0 *28.4* *42.5*	26.5 *15.5* *21.2*	98.1% 54.6% 49.9%
A5 (CDVAA) *A2 (Control)* *A13(Control)*	291.7 ± 5.6 290.7 ± 5.7 295.1 ± 9.3	20.3 ± 5.0 18.3 ± 4.5 22.8 ± 5.8	27.3 *28.4* *42.5*	27.1 *15.5* *21.2*	99.3% 54.6% 49.9%
A6 (CDVAA) *A2 (Control)* *A13(Control)*	291.7 ± 5.6 290.7 ± 5.7 295.1 ± 9.3	20.3 ± 5.0 18.3 ± 4.5 22.8 ± 5.8	25.9 *28.4* *42.5*	25.9 *15.5* *21.2*	100% 54.6% 49.9%
C8 (CDVAA) *C3 (Control)* *C14(Control)*	295.5 ± 7.1 290.7 ± 5.7 295.1 ± 9.3	21.0 ± 5.2 18.3 ± 4.5 22.8 ± 5.8	138.8 *114.8* *199.0*	126.4 *62* *80.4*	91.1% 54.0% 40.4%
E8 (CDVAA) *No Control Site*	295.5 ± 7.1 --	21.0 ± 5.2 --	317.2 --	282.6 --	89.1% --
E9 (CDVAA) *No Control Site*	295.5 ± 7.1 --	21.0 ± 5.2 --	311.1 -	295.2 --	94.9% --

(A) Average WD and WS data are presented as average ± one standard deviation

Table 4 indicates that average wind speeds for desktop CDVAA Sites A4, A5, and A6 are within 2 to 3 mph of the average wind speeds for both desktop Control Sites A2 and A13. Average wind direction, wind speed, and total upwind AOI for CDVAA Sites A4, A5, and A6 are more similar to Control Site A2 than Control Site A13; however, Control Site A13 has more upwind open sand acreage than Control Site A2.

Similarly, Table 4 indicates that the average wind speed for CDVAA Site C8 is within 2 to 3 mph of Control Sites C3 and C14. In comparing upwind AOI, CDVAA Site A8 is closer to Control Site C3 than Control Site C14; however, Control Site C14 has more upwind open sand acreage.

The last two CDVAA sites listed on Table 4, sites E8 and E9, take in the most open sand acreage, but that acreage is a mix of OHV riding and non-riding areas, negating comparisons with potential Control Sites.

As filtered for this initial TBMP assessment, dune wind speeds are relatively consistent, measuring within a 5 mph spread; however, a closer examination shows a greater disparity in wind speeds in the dunes. The average wind data collected and presented in Table 3 was simply calculated by adding up all of the wind speed entries that meet or exceed approximately 9 mph for that station and dividing that sum by the number of entries. Therein lies the greater difference for wind speed in the dunes: The frequency in which local wind speeds meet or exceed 9 mph varies from station to station (see "Filtered Records column in Table 3. For Station 1C, in the northernmost dune area, there were 200 hours during May 1 to July 31 when winds were greater than or equal to 9 mph. For station 4B, in the southernmost dune area, there were 262 hours when winds were greater than or equal to 9 mph. In other words, winds that are high enough to exceed the estimated threshold for sand movement occur less often in the north of the dunes and more often in the southern dune area. The greatest number of exceedances (289) was within the OHV riding area, at the S1 Tower.

3.2 Topography

Figure 8 pairs the profiles of CDVAA Sites A4, A5, and A6 with those of Control Sites A2 and A13. Profiles for CDVAA Sites A4, A5, and A6 are roughly similar, exhibiting approximately the same slope for the first 1,400 feet. In comparison, the profile for Control Site A2 is highly variable due in part to the greater density of vegetation. Non-native, invasive grasses are pervasive in this portion of the dunes (See Figure 7) and have caused the dunes closest to the ocean to build to unnatural heights. The profile for Control Site A13, south of the OHV riding area, is also variable, but more subdued and with less dramatic peaks and valleys than A3 to the north. The southern area of the dunes is much less affected by non-native vegetation. Neither Control Site topographic profile depicted on Figure 8 matches well with the CDVAA Site profiles, but the slope of the A13 profile more closely matches the CDVAA Sites, particularly the middle portions of the profiles.

Figure 9 shows the profile for CDVAA Site C8 along with the profiles for Control Sites C3 and C14. The western portion of the CDVAA Site C8 profile is similar to the other CDVAA profiles shown on Figure 8, which reflect the geomorphology of the large, open dune sheet seen on aerial imagery. The western portions of the profiles for Control Sites C3 and C14 are roughly similar to A3 and A13, respectively, because they trace over similar geomorphology. Following along the eastern portion of the CDVAA Site C8 profile, the topography climbs and drops, climbs and drops, reflecting the transverse dune set found in the eastern half of the Oceano Dunes SVRA. For the Control Sites, the slope of C14 is subdued compared to C3, and roughly matches the first and second rises of dunes seen in the profile of CDVAA Site C8, but as with Figure 8, it is far from a perfect match.

3.3 Vehicle Activity

At the request of the SLOAPCD, a survey of activity of OHV's within Oceano Dunes SVRA was conducted to discern if one area of the OHV riding area had more OHV activity than another. The survey and results were presented in the third draft of the MSSP submitted to the SLOAPCD in May 2012 (OHMVR Division 2012). In general, the area with the most OHV activity includes the shoreline area. This is the access route to camping in the SVRA, and OHV activity spreads from the camping areas. However, much of the activity in this shoreline area occurs along the stretch of damp, hard pack sand, near the mean high tide line. Operators of OHV's use this part of the SVRA to access through-areas leading to the back of the dunes. In relation to the CDVAA sites, it is difficult to use the vehicle survey data to determine influence on one CDVAA site or another. It is most probable that vehicle activity is high within the upwind AOI for each CDVAA site, given that visitors travel from camping areas to back-dune areas such as the Maidenform area. The OHMVR Division notes, however, that the upwind AOI for site CDVAA Site C8 in which vehicle activity is permitted is approximately five times greater than the upwind AOI for CDVAA sites A4, A5, and A6 (139 acres to approximately 27 acres) and would appear to be a better representation for overall vehicle activity within a 1,500 acre OHV recreation area.

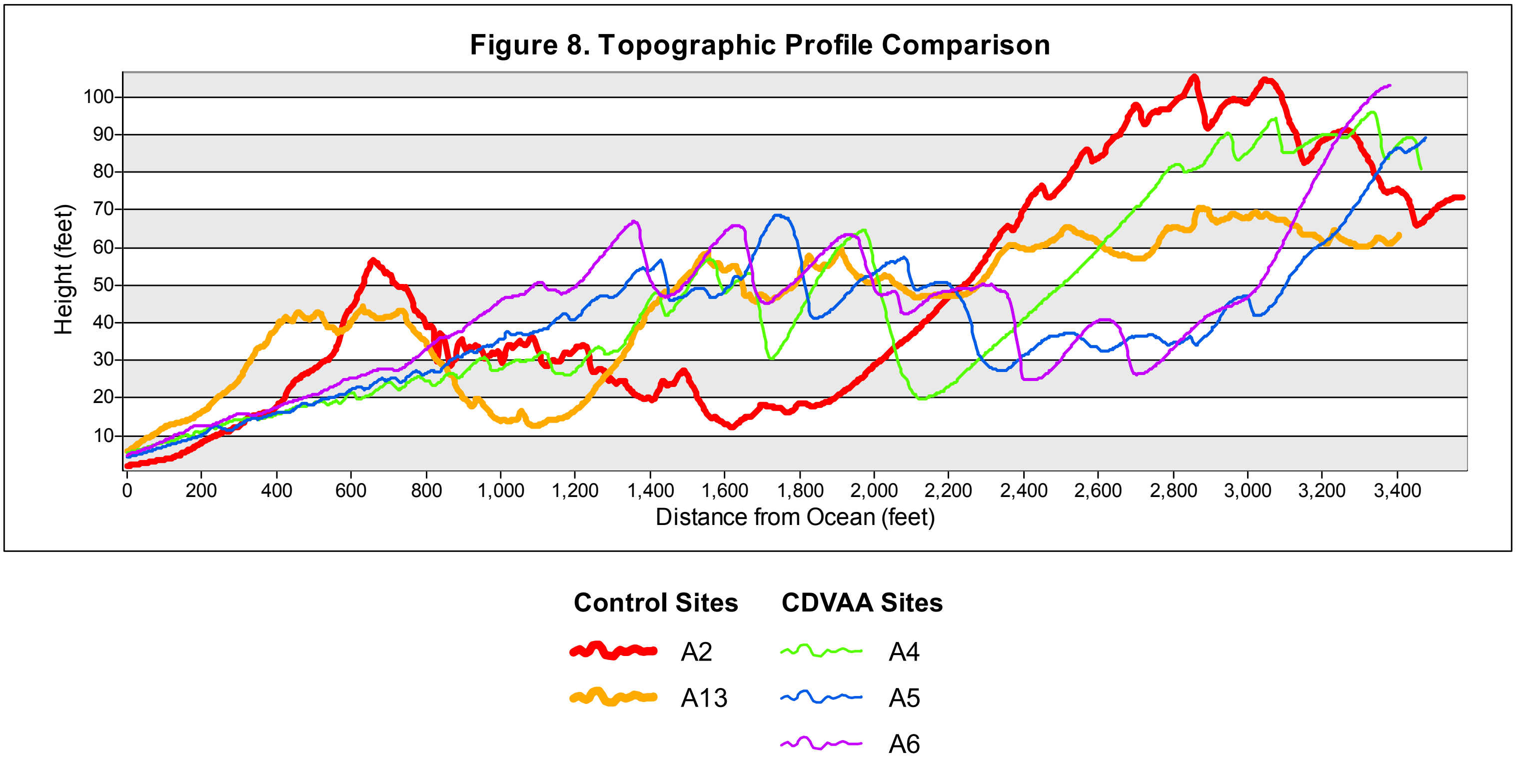
Figure 8. Topographic Profile Comparison
Height (feet)
Distance from Ocean (feet)
Control Sites
A2
A13
CDVAA Sites
A4
A5
A6

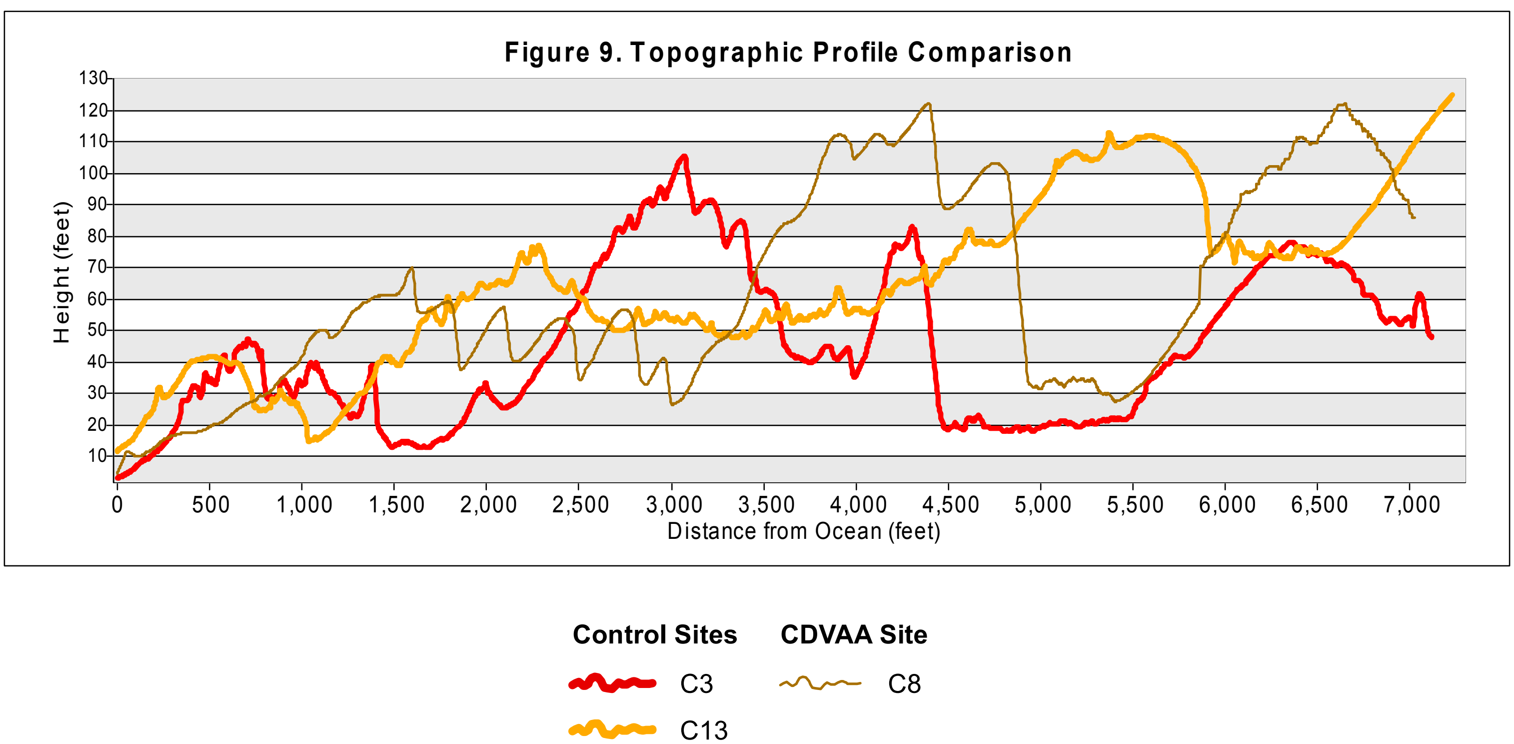
Figure 9. Topographic Profile Comparison
Height (feet)
Distance from Ocean (feet)
Control Sites
C3
C13
CDVAA Site
C8

4 PRELIMINARY CONCLUSIONS AND NEXT STEPS

The Dust Rule requires the OHMVR Division to select locations to monitor PM10 generated from the dune-building process of saltation. The locations are to be downwind of the OHV riding area of the dunes and downwind of dunes where OHV recreation is prohibited. Once the monitors are in place, PM10 readings will be recorded and the readings from each monitor will be compared with the other. If higher readings are recorded downwind of the OHV riding area, the OHMVR Division would be out of compliance with the Dust Rule because the Dust Rule presumes the higher readings are solely attributable to OHV recreation. This is a limitation of the Dust Rule. The saltation process occurs where there are dunes, not where there are dunes *and* OHV recreation. In actuality, higher readings may be the result of one or more factors related to wind speed, topography, etc.

Table 5 at the end of this section summarizes the comparison of desktop CDVAA and Control Sites. Finding temporary monitoring stations with comparable wind conditions, land cover, and topography that are solely influenced by a single source of potential emissions is an imperfect exercise. The OHV riding area of Oceano Dunes SVRA is within the largest and widest section of open sand within the Callender Dunes. The open sand sheet is a natural component of the dune setting that pre-dates OHV recreation (CGS 2011). The dune areas north and south of the OHV riding area have much less open sand, and the topography is far more variable, in part due to the introduction of nonnative, invasive dune grasses. The lack of comparability is borne out in the numbers presented in Table 3, which compares possible CDVAA and Control sites, and in the topographic profiles displayed on Figure 8 and Figure 9.

Nonetheless, the Dust Rule requires finding comparable dune locations for monitoring of PM10 generated from wind blowing over sand. It follows then that, along with comparable wind speeds, the areas upwind of a CDVAA Site and a Control Site should have similar amounts of open sand acreage.

In terms of wind speed, Sites 3C and 4B recorded the closest average wind speeds; the frequency with which these sites experiences winds above threshold wind speed (approximately 9 mph), was also similar (251 for Site 3C versus 261 for site 4B – see Table 3). Given that CDVAA Site C8 is best represented by Site 3C, and Control Site C14 is informed by Site 4B, it appears the best Control and CDVAA site comparison for wind speed considerations is CDVAA Site C8 paired with Control Site C14.

The amount of open sand acreage is not consistent and varies upwind of each desktop CDVAA and Control Site considered in this initial assessment (see Table 4). All of the Control Sites have less open sand than their potential CDVAA counterparts, with the dunes in the north having the fewest acres. Considering this variability, as well as the dynamic and varied nature of the dunes generally, it would be prudent to pair two monitoring locations with the largest open sand areas upwind. That makes CDVAA Site C8, at the back of the dunes, with 126 open sand acres, and Control Site C14, south of the OHV riding area, with 80 open sand acres, the most comparable -- though not ideal--candidates for open sand comparability. With regard to topographic profiles, the qualitative analysis performed is limited in its ability to discern similarity, and therefore comparability, between CDVAA and Control sites; however, it would seems the profiles generated from the southern dunes are better suited for comparison because they have not been altered dramatically by invasive, nonnative grasses, as is the case with the dunes north of the OHV riding area.

Finally, factoring in upwind OHV activity, it again appears that the best CDVAA site is C8. The upwind area from this site contains the most acres of open sand open to OHV recreation, so it follows that this site provides the best monitoring of OHV activity for a 1,500 acre park.

Overall, comparability between dune locations per the Dust Rule is best achieved by examining wind speeds and open sand acreage because saltation-derived PM10 is generated by strong winds blowing over open sand. Thus, the OHMVR Division preliminarily concludes that CDVAA Site C8 paired with Control Site C14 (see Figure 7) are the sites with best potential to meet the purposes of the Dust Rule's TBMP.

4.1 Next Steps

The TBMP relies upon in-situ dune wind measurements from approximately mid-May to mid-July 2013. Due to time constraints, wind data for the period after July 15, 2013 could not be validated in time for inclusion. The SLOAPCD air quality stations on the Nipomo Mesa measured high levels of PM10 in early September 2013.

In addition, the TBMP is intended to determine baseline concentrations of PM10 prior to implementation of the OHMVR Division's PMRP monitoring program. The OHMVR Division has collected important information on dune surface emissivity, sand transport, and airborne PM10 within Oceano Dunes. Though excluded from consideration during the MSSP process, these data are vital to the evaluation of scientific factors that influence saltation and the site selection process. TBMP and PMRP monitoring programs are directly linked and the use of these data are vital to the OHMVR Division's PMRP.

The OHMVR Division intends to use this additional data to undertake the following additional analyses:

- **Wind data:** The OHMVR Division intends to analyze wind data for the time period after July 15th to make the data set more robust.
- **Particulate matter data:** The OHMVR Division intends to analyze dune surface emissivity, sand transport, and airborne PM10 data collected within Oceano Dunes to inform the site selection process.

Table 5 – Comparison of Desktop CDVAA and Control Sites, excluding topography								
Desktop Site / Type	**Wind Conditions**		**Dune Setting**				**Dispersion and Site Elevation**	
	Downwind of Shoreline Average WD	**Average WS ± 15 % when from Average WD**	**Upwind AOI (acres)**	**Open Sand**		**Vehicle Activity**	**Source Influence**	**Site Elevation (meters)**
				Acres	**% AOI**			
A4 (CDVAA) *A2 (Control)* *A13(Control)*	Yes *Yes* *Yes*	 *Yes (9.9%)* *Yes (-12.3%)*	27.0 *28.4* *42.5*	26.5 *15.5* *21.2*	98.1% *54.6%* *49.9%*	High -- --	100% CDVAA *100% Control* *100% Control*	80 m *73 m* *64 m*
A5 (CDVAA) *A2 (Control)* *A13(Control)*	Yes *Yes* *Yes*	 *Yes (9.9%)* *Yes (-12.3%)*	27.3 *28.4* *42.5*	27.1 *15.5* *21.2*	99.3% *54.6%* *49.9%*	High -- --	100% CDVAA *100% Control* *100% Control*	90m *73 m* *64 m*
A6 (CDVAA) *A2 (Control)* *A13(Control)*	Yes *Yes* *Yes*	 *Yes (9.9%)* *Yes (-12.3%)*	25.9 *28.4* *42.5*	25.9 *15.5* *21.2*	100% *54.6%* *49.9%*	High -- --	100% CDVAA *100% Control* *100% Control*	105 m *73 m* *64 m*
C8 (CDVAA) *C3 (Control)* *C14(Control)*	Yes *Yes* *Yes*	 *Yes (12.9%)* *Yes (-8.6%)*	138.8 *114.8* *199.0*	126.4 *62* *80.4*	91.1% *54.0%* *40.4%*	High -- --	100% CDVAA *100% Control* *100% Control*	86 m *48 m* *125 m*
E8 (CDVAA) *No Control Site*	Yes --	-- --	317.2 --	282.6 --	89.1% --	High --	Mix --	28 m --
E9 (CDVAA) *No Control Site*	Yes --	-- --	311.1 --	295.2 --	94.9% --	High --	Mix --	22 m --

REFERENCES

California Geological Survey (CGS) 2011. An Analysis of Wind, Soils, and Open Sand Sheet and Vegetation Acreage in the Active Dunes of the Callender Dune Sheet, San Luis Obispo County, California, prepared for the Off-Highway Motor Vehicle Recreation Division of California State Parks. November 1, 2011.

Off-Highway Motor Vehicle Recreation (OHMVR) Division 2012. Oceano Dunes State Vehicular Recreation Area Rule 1001 Monitoring Site Selection Plan. Sacramento, CA. May 4, 2012 (revised).

______2013. Oceano Dunes State Vehicular Recreation Area Rule 1001 Draft Particulate Matter Reduction Plan. Sacramento, CA. March 29, 2013 (third draft).

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Appendix A
Spring 2013 Wind Data Set

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Attachment 1
Wind Characteristics at Oceano Dunes SVRA from the Spring 2013 Assessment Monitoring Network (Draft)

Wind Characteristics at Oceano Dunes SVRA from the Spring 2013 Assessment Monitoring Network (Draft)

Wind Speed and Direction Characteristics for Transects

Mean Hourly Wind Speed and Direction at 10m

At each measurement position along the East-West transects data on wind speed and direction (at 3 m. and in four locations at 10 m above ground level) were obtained to characterize the local conditions and regional air flow patterns. When these characteristics are compared across space they provide information on the regional wind flow characteristics across the ODSVRA and the Dune preserves. This information will be used, in part, to aid in the selection of monitoring locations that will be used to evaluate compliance with the Dust Rule.

The locations (latitude and longitude), distances between transect monitoring positions and their elevation above sea level are listed in Table 1. The data used in this (draft) report encompass the time period from May 10, 2013 through July 15, 2013. These data were quality assured and quality controlled using criteria set forth in the MSSP Document and as administered by STI, Inc.

Transect 1 lies within the northern section of Dune Preserve, to the east of the fore-dune complex dominated by non-native plant species. The three measurement positions span a distance of approximately 1185 m and align on 292°. Position B, it must be noted, does not fall on the straight line distance between A and C, it is shifted slightly off-line to the south. This was required to avoid topography that was unsuitable for siting the tower and platform that held the meteorological instrumentation, but this minor deviation of B off the line between positions A and C does not affect the observed general patterns of wind speed and direction.

Table 1. The positional data for the measurement locations.

Transect ID	Latitude	Longitude	Distance from Shoreline (m)	Elevation (m)
T1A	35.088257	-120.6235	700	17.95
T1B	35.087615	-120.6216	893	29.05
T1C	35.086687	-120.6186	1185	21.15
T2A	35.071805	-120.6263	409	13.09
T2B	35.070713	-120.6243	628	19.04
T2C	35.069508	-120.6193	1101	32.35
T3A	35.056977	-120.6261	500	19.64
T3B	35.052712	-120.6181	1365	34.31
T3C	35.048821	-120.6076	2420	24.31
T4A	35.023906	-120.6269	859	18.6
T4B	35.021225	-120.6218	1411	37.28
T4C	35.018632	-120.6173	1913	37.08

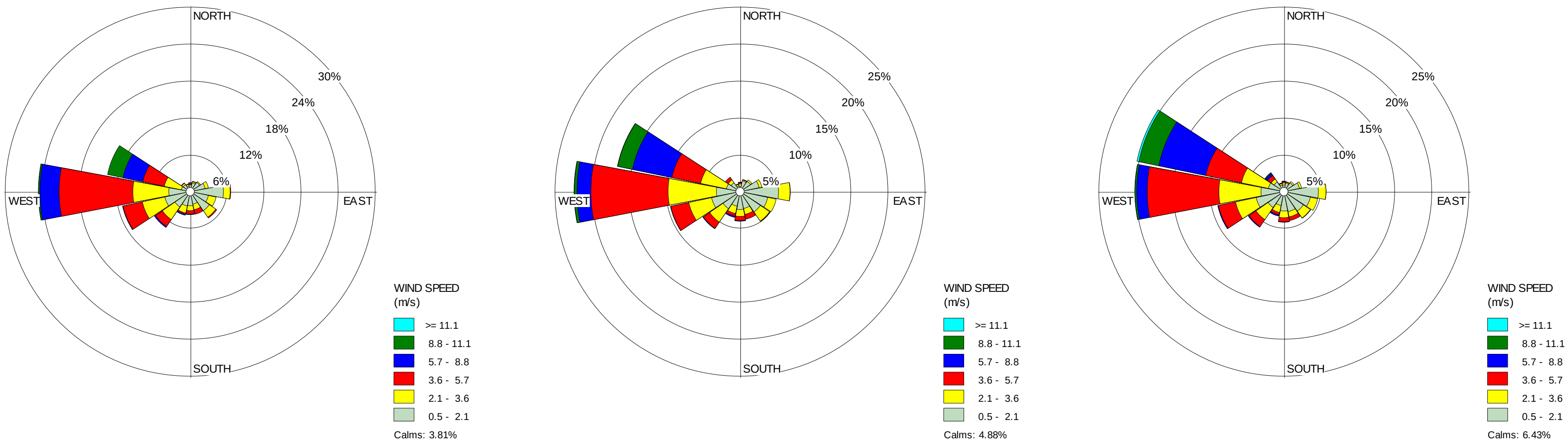
Transect 1, Position A is approximately 700 m from the shoreline and the distances between A, B and C positions are provided in Table 1. Wind roses, based on wind speed and direction measurements made at 3 m above ground level (a.g.l.) for the three positions are shown in Fig. 1. As these wind roses show the winds reach position A with a dominant westerly component (270°). With increasing distance from the shoreline there is change in the dominant wind direction to the west-north-west (292.5°). This series of wind roses also indicates that 10 m mean hourly wind speeds are increasing moving from west to east. This is a likely result of compression of the streamlines as the airflow encounters the dunes (Wiggs et al., 1996). Plotting the frequency of wind speed occurrence (in 1 m/s bins) (Fig. 2) shows that the frequency of winds greater than 6.5 m/s measured at 3 m a.g.l. is highest for Position C on this transect. For comparison purposes the wind rose for T1C for the wind speed and direction measured at 10 m is shown in Fig. 3, and shows essentially the same directional pattern, but higher wind speeds occur with greater frequency (Fig. 4).

Transect 2 Position A is approximately 893 m from the shoreline and the distances between positions A, B and C are provided in Table 1. Transect 2 lies approximately 1885 m to the south of Transect 1 and has the same azimuth, i.e., 292°. Wind roses for the three positions based on measurement of wind speed and direction made at 3 m a.g.l. are shown in Fig. 5.

Transect 2 shows a similar pattern to Transect 1 in the wind roses moving west to east, but position 2A shows that west-north-west (292°) winds are of equivalent frequency to west winds, unlike at position 1A, and these winds are also of greater magnitude (Fig. 5). In the progression from west to east on Transect 2, the frequency of the 292° winds is maintained and the magnitude of the winds along this direction increases. This is illustrated in Fig. 6, which shows the histogram of wind speed at each of the three positions along this transect. The wind rose for position T2C for wind speed and direction measured at 10 m a.g.l. is shown in Fig. 7 and the directional pattern is similar except for the increased frequency of higher winds at 10 m a.g.l. (Fig. 8).

Transect 3, approximately 1760 m south of Transect 2, maintains the same pattern in the wind roses moving west to east as Transect 2, but position 3A shows that west-north-west (292°) winds are more frequent than west winds and these winds are of greater magnitude (Fig. 9). In the progression from west to east on transect 3, the frequency of the 292° winds is maintained. Along transect 3 there is more frequent and stronger winds from the north-west direction (315°). The histogram of wind speed frequency (Fig. 10) shows that the winds are increasing in their magnitude moving eastward. The wind rose for position T3C for wind speed and direction measured at 10 m a.g.l. is shown in Fig. 11 and the directional pattern is similar except for the increased frequency of higher winds at 10 m a.g.l. (Fig. 12).

Transect 4 is approximately 3600 m south of Transect 3, and lies within the southern Dune Preserve area. At all three positions the dominant wind direction is west-north-west (292°), and the highest magnitude mean hourly 3 m a.g.l. wind speeds are associated with this direction (Fig. 13). Winds at 3 m a.g.l. from the west (270°) are the second most frequent direction but do not exceed 11 m/s. Unlike the three transects to the north of Transect 4, winds from the north-west are more frequent and can reach hourly mean 3 m wind speeds in excess of 11 m/s. The wind speed frequency distribution (Fig. 14) also shows that Transect 4 experiences increased frequency of higher mean 3 m wind speeds with a few values exceeding 15 m/s. The wind rose for position T4B for wind speed and direction measured at 10 m a.g.l. is shown in Fig. 15 and the directional pattern is similar except for the increased frequency of higher winds at 10 m a.g.l. (Fig. 16).



T1A T1B T1C

Figure 1. Wind roses for the three positions along Transect 1 for wind speed and direction measured at 3 m a.g.l.

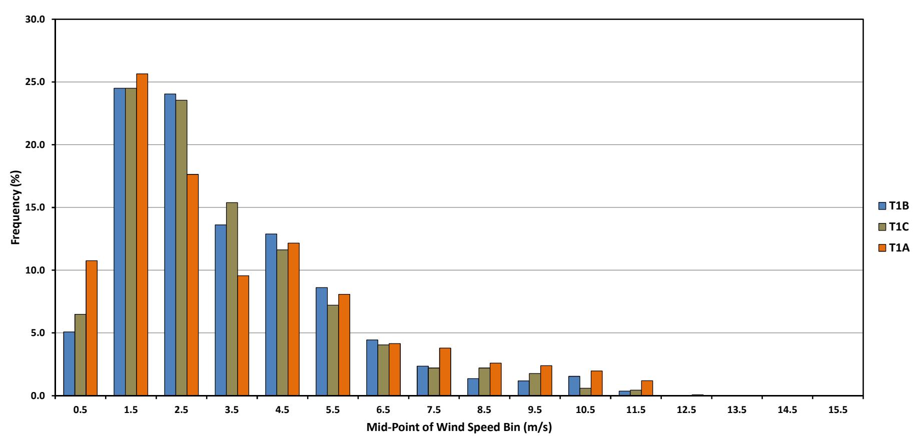


Figure 2. Wind speed frequency distribution for the three positions along Transect 1 for wind speed measured at 3 m a.g.l.

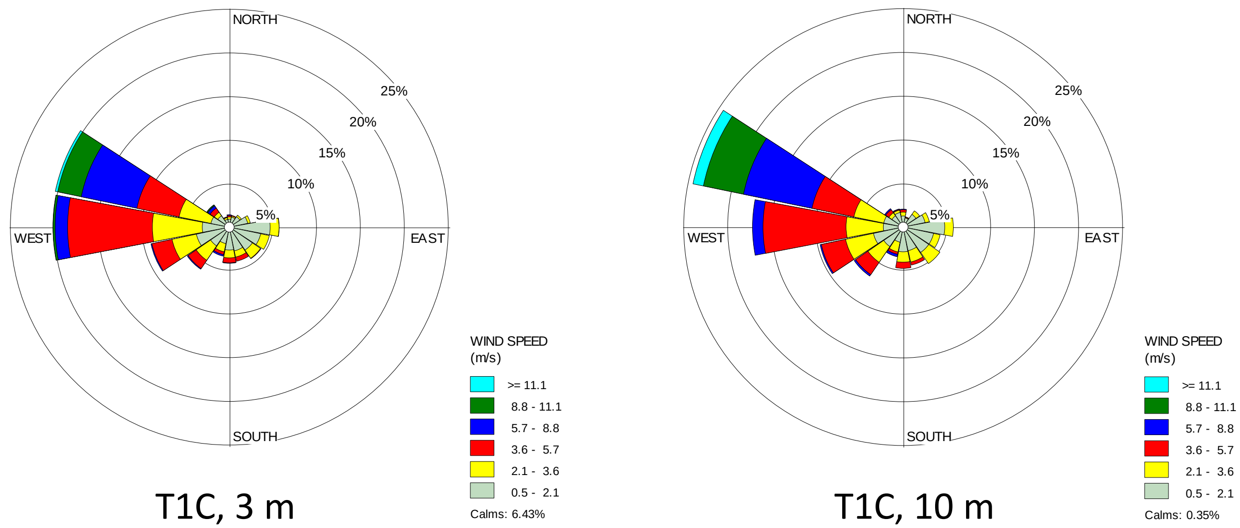


Figure 3. Wind roses for position T1C for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

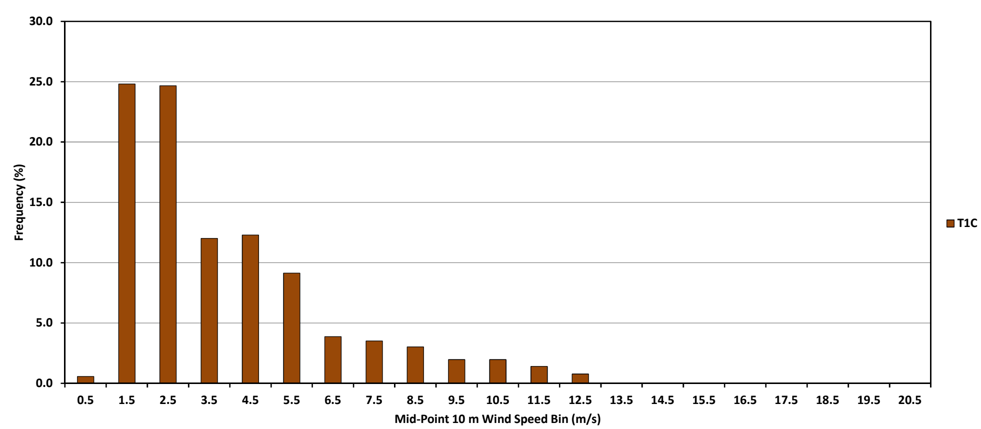


Figure 4. Wind speed frequency distribution for T1C for wind speed measured at 10 m a.g.l.

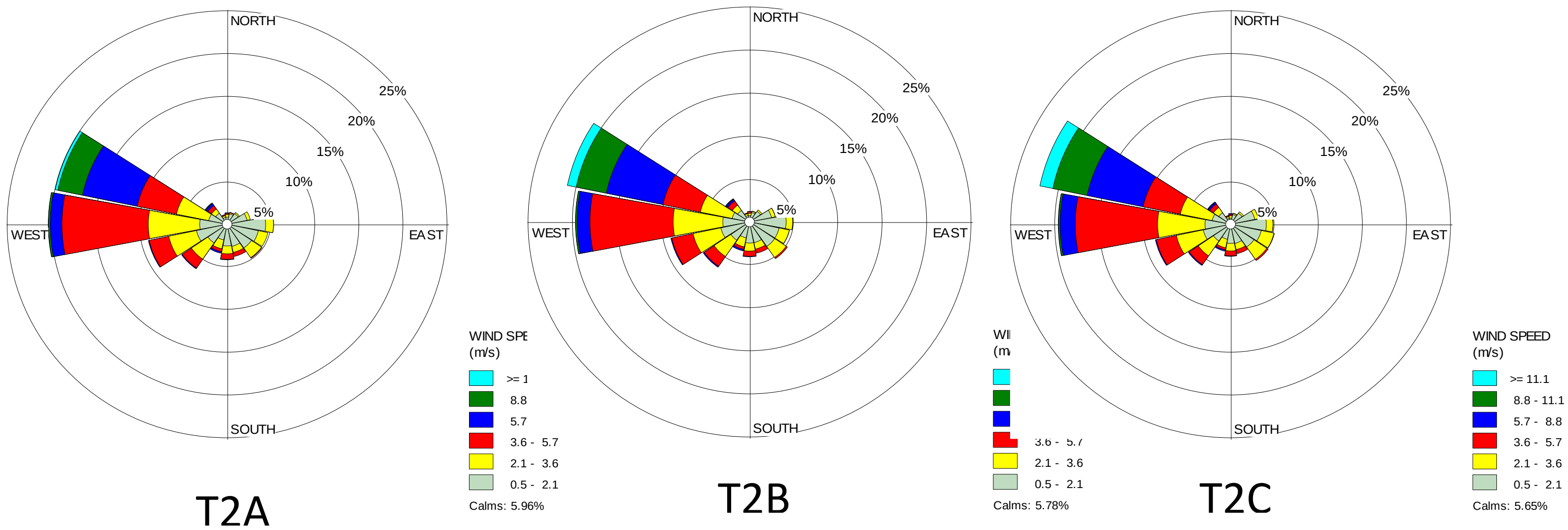


Figure 5. Wind roses for the three positions along Transect 2 for wind speed and direction measured at 3 m a.g.l.

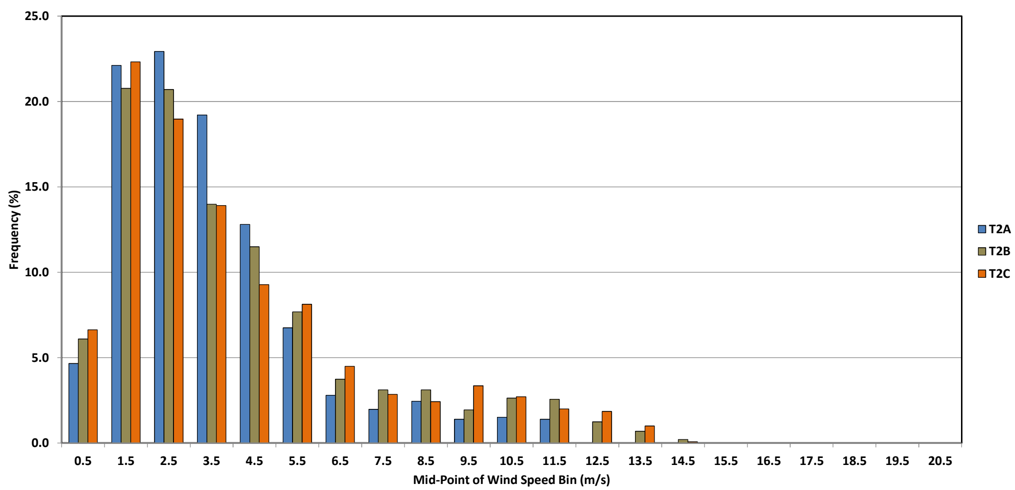


Figure 6. Wind speed frequency distribution for the three positions along Transect 2 for wind speed measured at 3 m a.g.l.

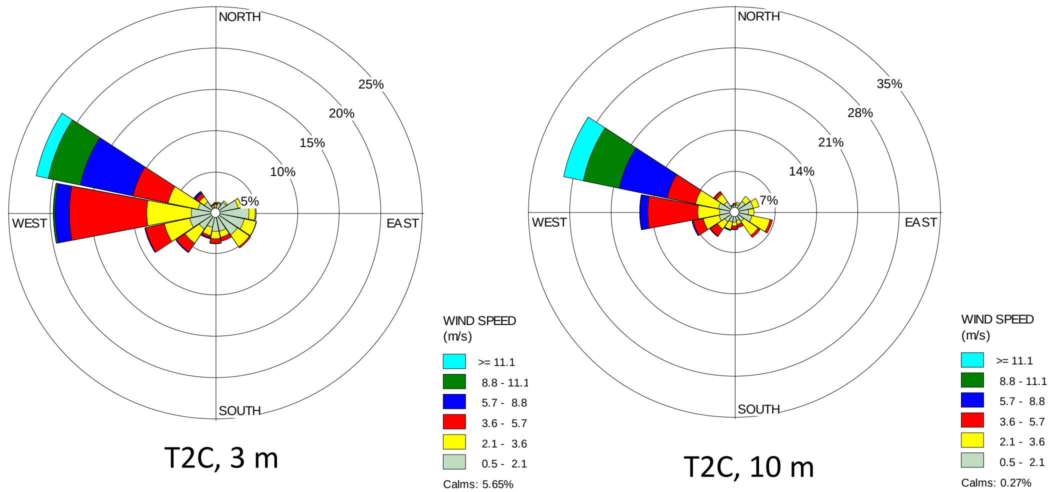


Figure 7. Wind roses for position T2C for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

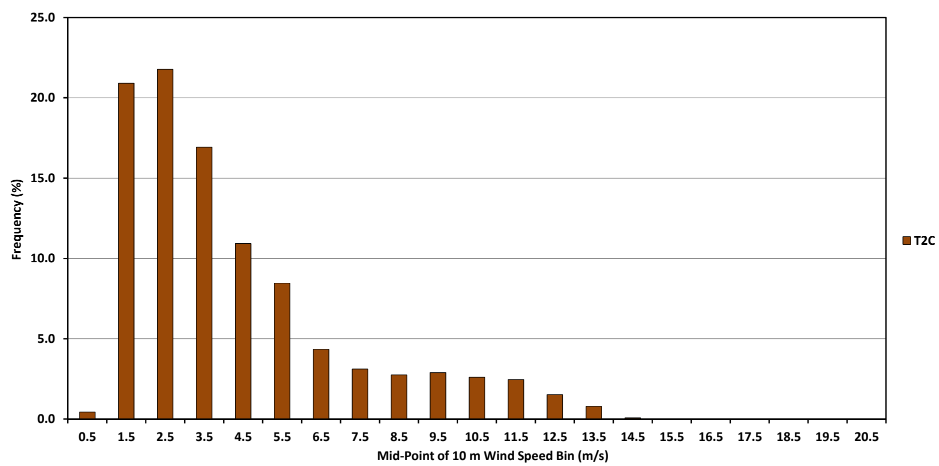


Figure 8. Wind speed frequency distribution for T2C for wind speed measured at 10 m a.g.l.

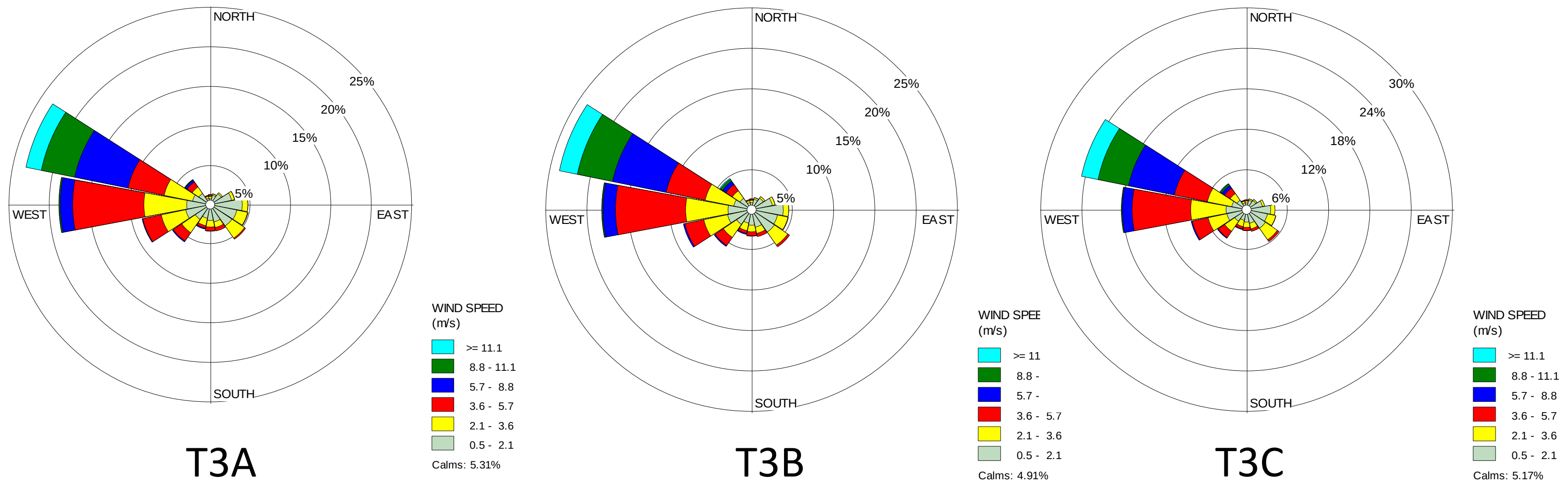


Figure 9. Wind roses for the three positions along Transect 3. for wind speed and direction measured at 3 m a.g.l.

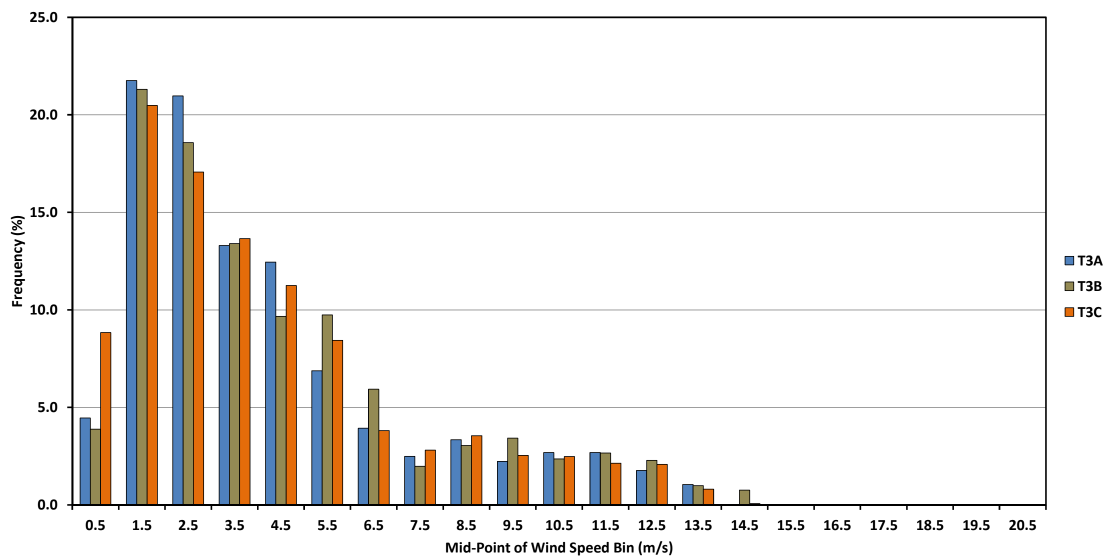


Figure 10. Wind speed frequency distribution for the three positions along Transect 3 for wind speed measured at 3 m a.g.l.

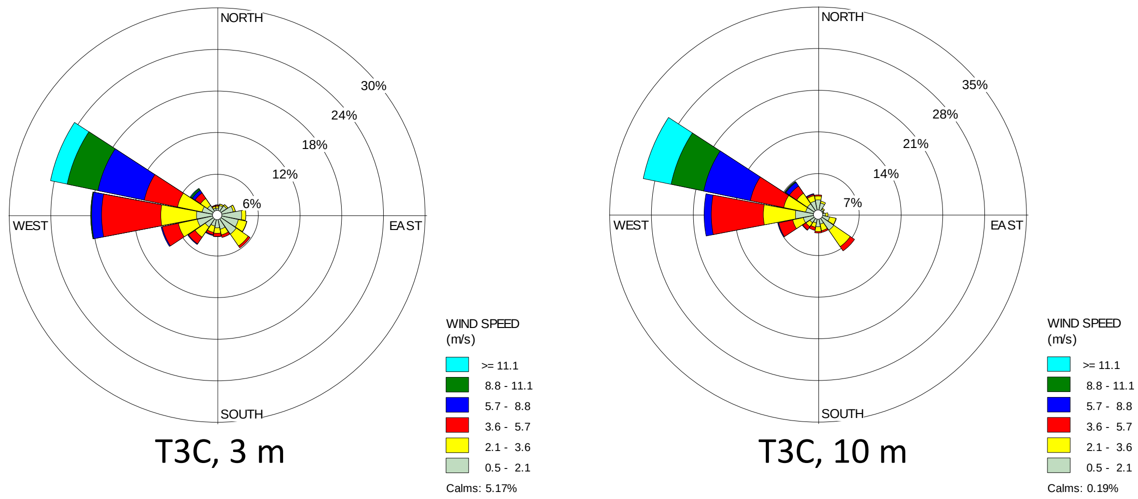


Figure 11. Wind roses for position T3C for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

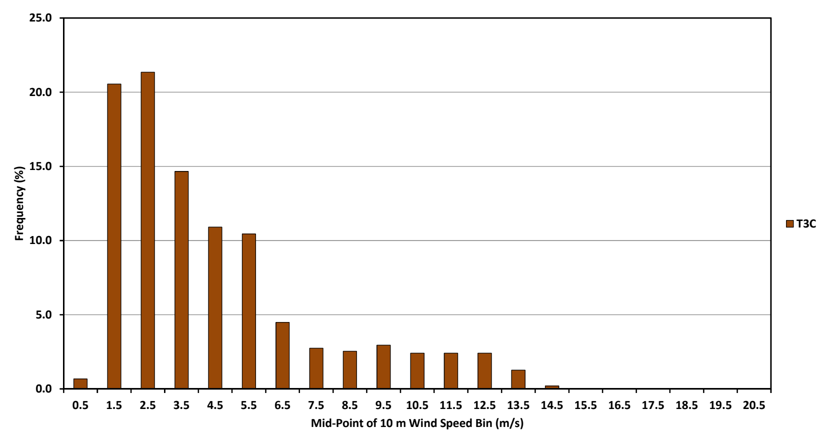


Figure 12. Wind speed frequency distribution for T3C for wind speed measured at 10 m a.g.l.

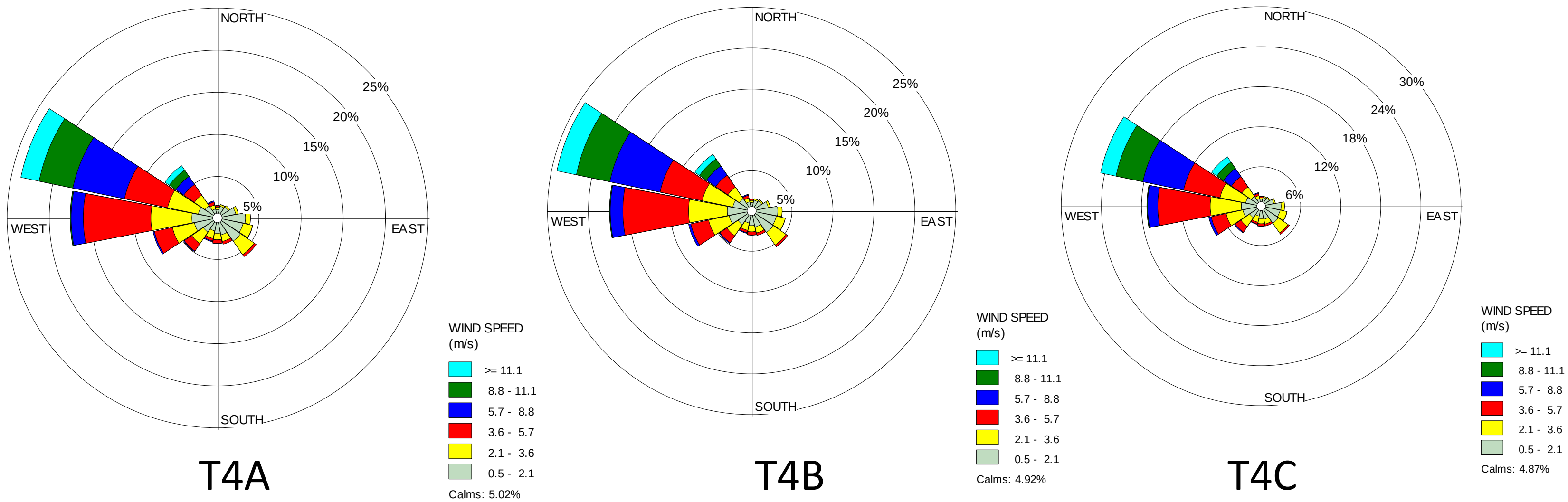


Figure 13. Wind roses for the three positions along Transect 4 for wind speed and direction measured at 3 m a.g.l.

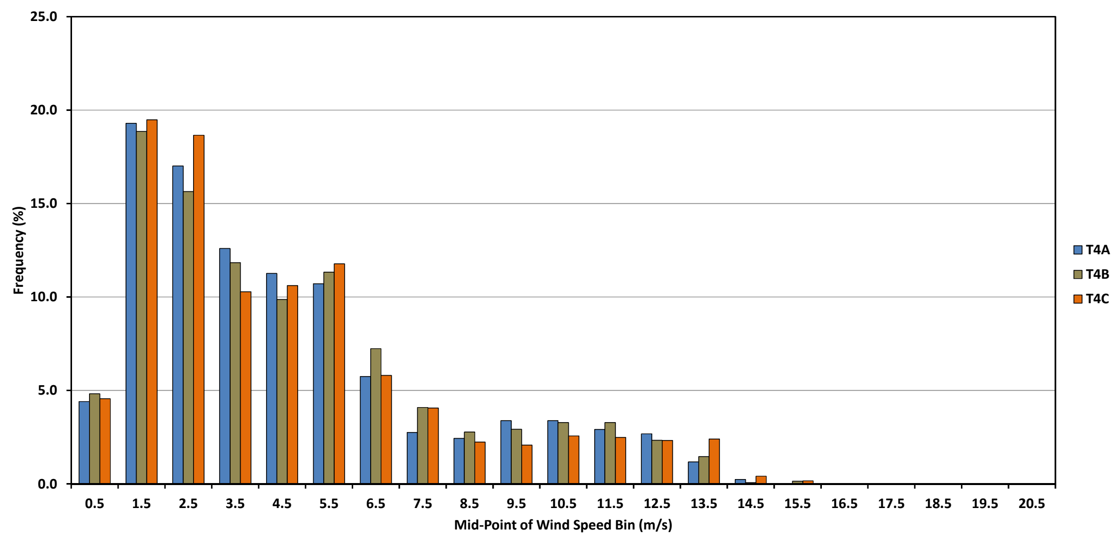


Figure 14. Wind speed frequency distribution for the three positions along Transect 4 for wind speed at 3 m a.g.l.

Based on the comparisons of wind roses using wind speed and wind direction data from 3 m and 10 m a.g.l., it is clear that there is very little difference between the patterns, and information on the characteristics of wind speed and direction at the ODSVRA can be obtained with a high degree of confidence using measurements from either height.

One Hour Maximum Wind Gust at 3 m and 10 m a.g.l.

The emission of dust is a fast process operating at time scales much less than one hour. The emission system (entrainment and transport of sand and dust) responds quickly to changes in wind shear at the scale of seconds (Baas, 2006), and the relationship between wind shear and the flux of sand and dust is non-linear (Gillies, 2013). This suggests that mean hourly wind speed data do not provide the best means to evaluate how local winds may be controlling the emission system. Further understanding how the local winds may affect the sand transport and dust emissions along the four transects can be gained from examining the range and frequency distribution of the one hour maximum wind gust data.

Histograms of the percent frequency of occurrence of one hour maximum wind gusts at each of the measurement positions along the four transect are shown in Fig. 17 for the 3 m measurement height a.g.l. These histograms show that the magnitude of wind gusts in all cases increase in frequency and magnitude from west to east. This suggests that sand transport and dust emissions would increase moving west to east, assuming that the emission potential of the dune sands is constant. These histograms also show that Transects 3 and 4 experience higher magnitude wind gusts than Transects 1 and 2, with values in excess of 20 m/s. These higher magnitude wind gusts will produce large transient increases in the instantaneous sand and dust flux. Once entrained by these high speed gust events the dust is available for longer transport distances unlike the sand in motion that will quickly respond to rapidly decreasing wind speeds.

The three stations with measurements at 10 m also show that there is a shift to higher magnitude gusts of greater frequency moving from north to south along the positions T1C, T2C, T3C, and T4B.

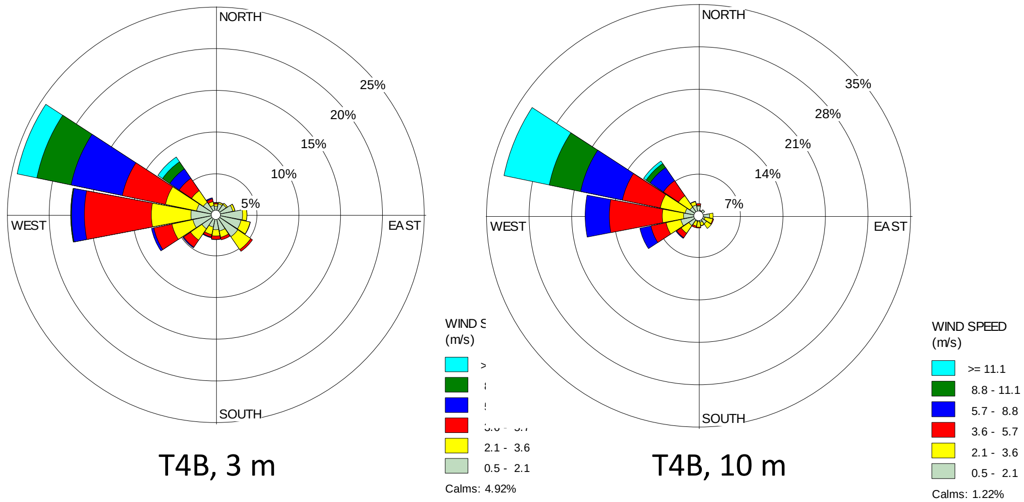


Figure 15. Wind roses for position T4B for wind speed and direction measured at 3 m and 10 m a.g.l. The wind direction pattern is essentially identical, but the frequency of higher wind speeds measured at 10 m is greater than at 3 m.

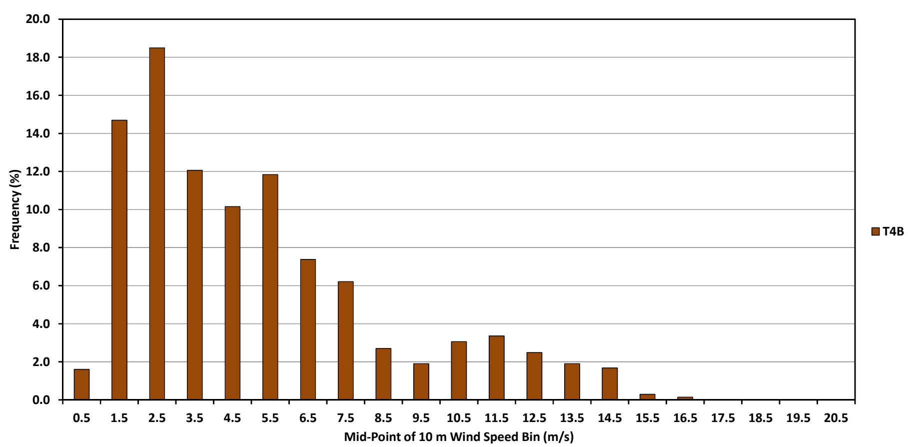


Figure 16. Wind speed frequency distribution for T4B for wind speed measured at 10 m a.g.l.

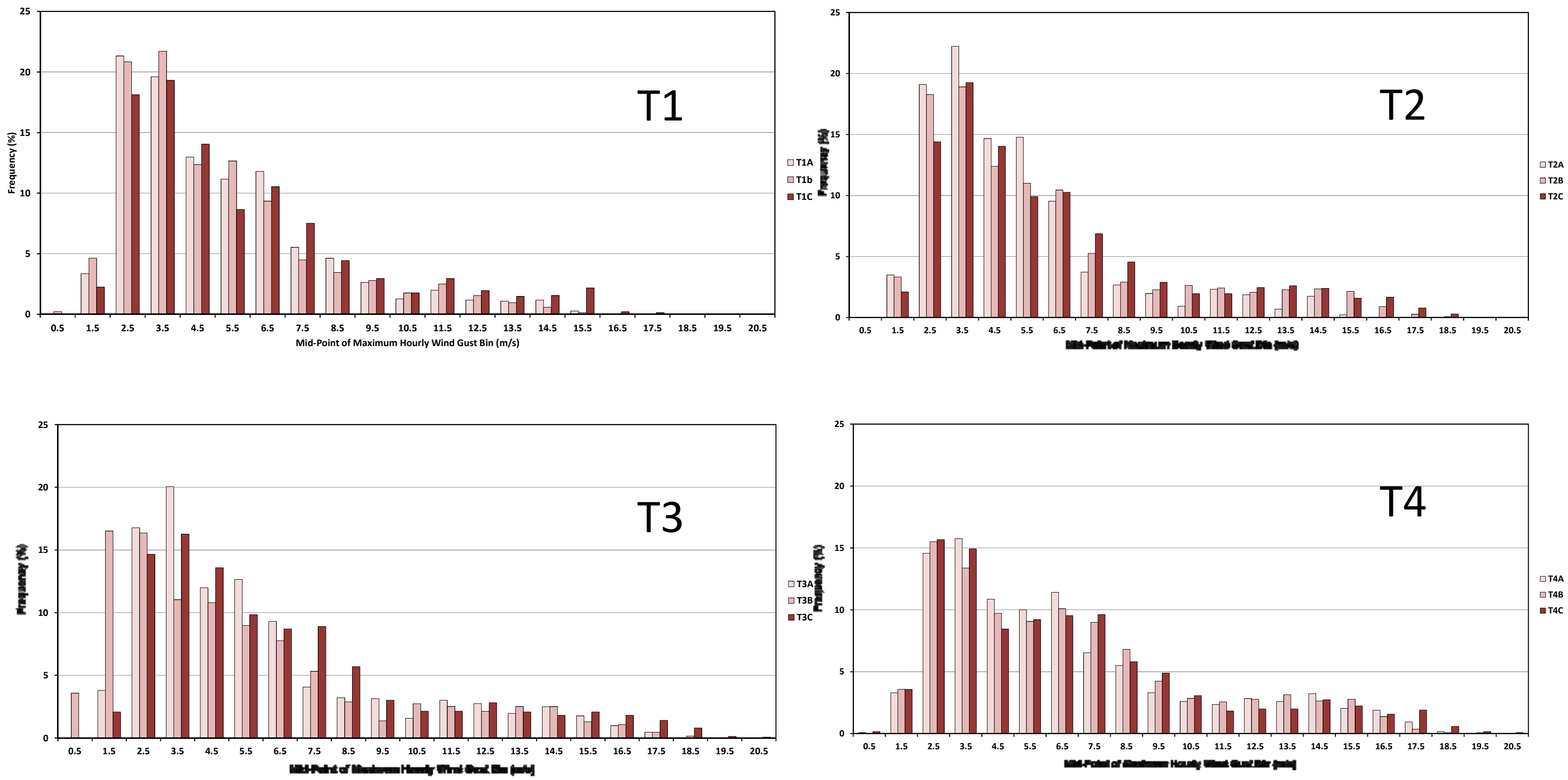


Figure 17. Wind gust frequency distributions for the three positions along each transect for wind speed and direction measured at 3 m a.g.l.

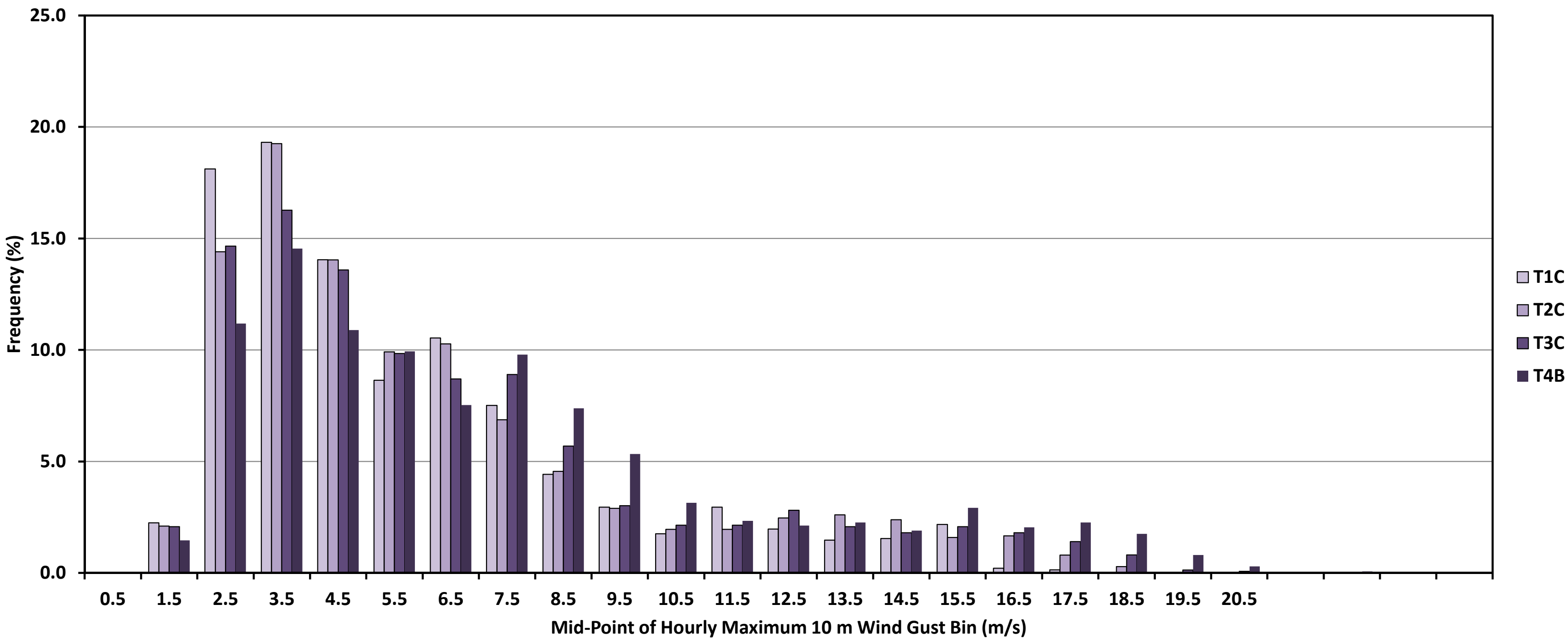


Figure 18. Wind gust frequency distributions for the 4 measurement positions with wind speed measurements at 10 m a.g.l.

Average Threshold Wind Speeds for Saltation

Estimating the threshold wind speed for particle entrainment from ambient measurements with a low degree of uncertainty requires measurement of the wind speed (or wind shear) and the presence or absence of saltating sand or elevated levels of dust (i.e., PM_{10}) at a frequency of at least 1 Hz (Stout, 2004). This frequency of measurement was not possible for logistical reasons for this project phase, so an alternative method was used that utilizes the acquired Sensit count and the mean 3 m and 10 m wind speed data. As threshold of motion is achieved on the scale of seconds, in an hour where Sensits indicate that saltation has occurred it is not possible to define the exact time and wind speed that initiated the motion. Threshold is defined here by the mean of all wind speed values that indicate saltation has been registered by the Sensit in the hour immediately following an hour for which no Sensit counts were registered, and all wind speeds that show zero counts immediately following an hour with counts. This takes into account the critical hour long intervals where saltation begins and then ceases. Sensit counts of one were treated as zero in this analysis. The mean threshold 3 m wind speed for each transect and each position along the four transects and the standard deviation of the mean threshold wind speed value are shown in Table 2. The range of estimated threshold 3 m wind speed is 4.01 m/s (±0.86 m/s) to 6.28 (±2.38 m/s). The mean threshold for the study area is 4.97 m/s (±0.70 m/s). Given the standard deviations of the mean values, a mean minimum wind speed threshold should be around 3.6 m/s, measured at 3 m a.g.l.

At the three positions where wind speed is measured at 10 m a.g.l. (i.e., T1C, T2C, T3C, and T4B) the same analysis can be performed to define the threshold wind speed for this standard wind measurement height. At these positions the 10 m a.g.l. threshold wind speed ranges from 5.81 m/s (±1.34 m/s) at T1C to 6.21 m/s (±1.50 m/s) at T4B. The 10 m threshold wind speed can be estimated for the other locations on the same transect by using the 3 m to 10 m threshold wind speed ratio. These 10 m threshold wind speed estimates for T1A, T1B, T2A, T2B, T2C, T3A, T3B, T4A, and T4C are provided in Table 2.

Based on the threshold wind speed data, saltation and dust emissions should begin to commence within the ODSVRA and the Dune Preserve areas at any time that 3 m mean hourly wind speed exceeds 3.7 m/s, or the 10 m wind speed exceeds 3.8 m/s. These estimates represent the lowest values based on the standard deviations of the mean threshold value for the position with the lowest estimated threshold wind speed. This does not mean that saltation will begin everywhere at these wind speeds, but only at the most susceptible areas.

The threshold wind speed data presented in Table 2, show several patterns based on location and position of measurement along the transects. In general, there seems to be no relationships between elevation and 3 m mean threshold wind speed. Transect 1 shows a linear increase in threshold mean wind speed for saltation with increasing distance from the shoreline. Transects 2 and 3 show a decrease in threshold wind speed with increasing distance from the shoreline and Transect 4 does not show any appreciable change in threshold wind speed as a function of distance from the shoreline. In all these cases however, the small sample size and the overlap of the associated standard deviations of the mean values makes the certainty of these relationships ambiguous.

Table 2. Mean Hourly 3 m and 10 m Wind Speed Threshold for Saltation.

Transect ID	Distance from Shoreline	Elevation (m)	Mean Threshold 3 m Wind Speed (m/s)	Std. Dev. Threshold 3 m Wind Speed (m/s)	Mean Threshold 10 m Wind Speed (m/s)	Std. Dev. Threshold 10 m Wind Speed (m/s)
T1A	700	17.95	4.01	0.86	4.13	
T1B	893	29.05	4.20	0.84	4.33	
T1C	1185	21.15	5.63	1.33	5.81	1.34
T2A	409	13.09	5.02	1.34	4.95	
T2B	628	19.04	5.09	1.66	5.02	
T2C	1101	32.35	4.40	1.21	4.34	1.20
T3A	500	19.64	6.28	2.38	6.65	
T3B	1365	34.31	5.06	1.30	5.35	
T3C	2420	24.31	4.27	0.98	4.52	0.970
T4A	859	18.6	5.07	1.43	5.38	
T4B	1411	37.28	5.85	1.51	6.21	1.50
T4C	1913	37.08	4.77	1.16	5.06	

Shaded grey cells represent estimated wind speed based on the ratio of 3 m wind speed threshold to10 m wind speed threshold for positions with wind speed measurements at both heights along the same transect (i.e., T1C, T2C, T3C, T4B).

Mean threshold wind speed at 3 m and 10 m can also be examined for patterns of change in the north-south direction. The mean transect threshold wind speed increases linearly with increasing distance south from Transect 1 to 4 (Fig. 19. At Transect 4 the mean 3 m threshold wind speed for all positions combined is 5.2 m/s (±0.2 m/s), which is the same as Transect 3 (5.2 m/s, ±1.0 m/s). The 10 m wind speed threshold at positions T3C and T4B are 5.5 (±1.1 m/s) and 5.6 (±0.6 m/s), which also suggests that the difference between them is too uncertain to unambiguously declare they are different. The overall trend of increasing threshold wind speed from north to south is, however, supported by these data. The reasons for this could be two-fold. The most likely is that there is an increase in size of the sand particles (e.g., mean grain size) from north to south. Larger particles require higher wind shear to entrain them. A second effect could be due to increased shear stress partitioning caused by the presence of increasing roughness of the surface from north to south. More roughness will require that higher wind speeds be attained to create the necessary shear stress to mobilize the sand among those elements. Both of these affects may be, in part, responsible for this trend. The most likely explanation is a particle size increase and this can be examined when the particle size analyses is completed.

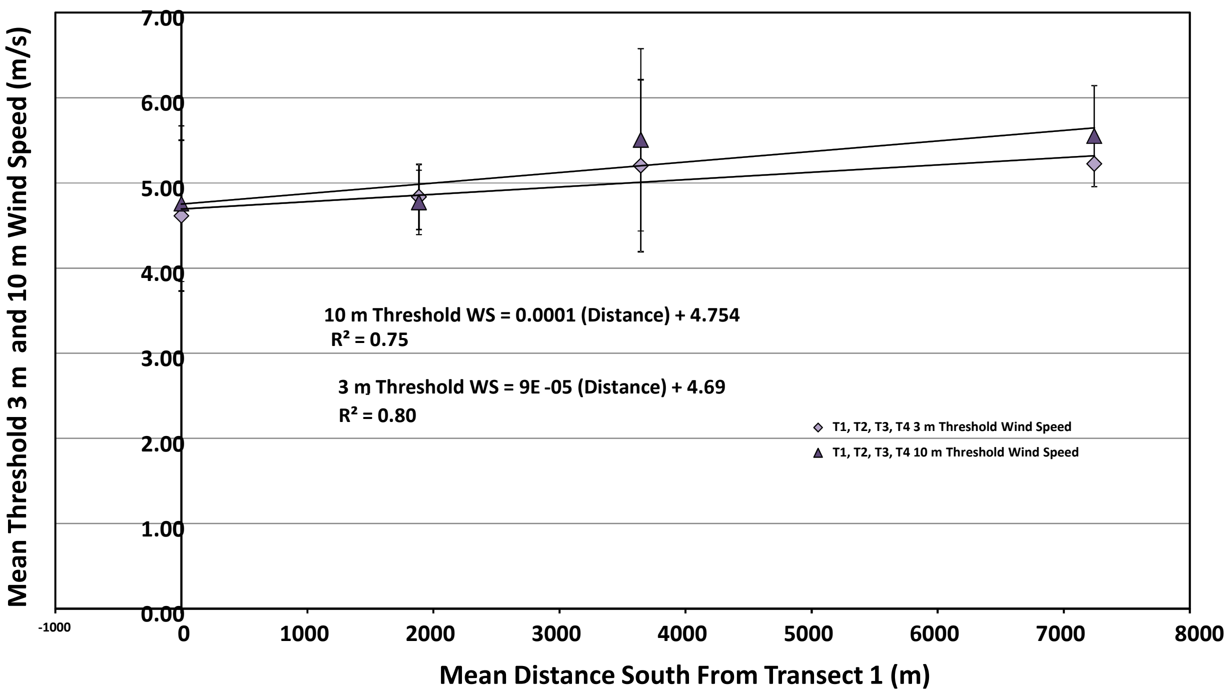


Figure 19. Mean saltation threshold 3 m wind speed for each transect as a function of mean distance south of Transect 1.

Summary

Based on the analysis provided above there are several important characteristics of the wind field pattern over the ODSVRA that can be described. In all positions the strongest most frequent winds are associated with winds from the west through west-north-west. The winds show a tendency to accelerate as they move from west to east, most likely due to compression of the streamlines over the dunes that force the wind to accelerate. In addition to this acceleration there appears to be an increase in gust strength along the west to east direction, indicating an increase in turbulent intensity. Both of these will contribute to potentially greater magnitude sand and dust emission fluxes along this gradient. There is also a wind speed gradient from north to south. The data presented here indicate that mean wind speeds increase from north to south and mean hourly maximum wind speeds as well. This also increases the potential for sand transport and dust emissions along the north to south gradient. Because of the presence of these gradients it will be challenging to locate PM_{10} sampling monitors that experience the same wind conditions during a 24 hour period. As saltation of sand and the associated dust emissions scale as a power function of wind speed, small changes in wind speed produce significant changes in dust emission.

Further analyses is forthcoming on relationships between wind speed, direction, and PM_{10} emissions obtained with the e-BAMs, and the Met One Particle Profilers, located in the ODSVRA and Dune Preserves along the measurement transect. This analysis will provide further insight into the sand transport and dust emission system at the ODSVRA and the Dune Preserves.