Oceano Dunes State Vehicular Recreation Area (ODSVRA) Dust Control Program
Provisional Final 2025 Annual Report and Work Plan (ARWP)

ATTACHMENTS

Attachment 01: 2011 to 2025 Dust Control Projects

Attachment 02: 2024/2025 ODSVRA Dust Control Program Vegetation Restoration Projects (State Parks' ARWP Work Product)

Attachment 03: Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024

- Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024 (DRI Document)
- SAG Review of Desert Research Institute (DRI) "Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024" (SAG Memo)

Attachment 04: ODSVRA Emissivity PI-SWERL Update Report (2013 – 2024):

- ODSVRA Emissivity PI-SWERL Update Report (2013 – 2024) (SAG Document)

Attachment 05: Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking of ODSVRA Beach Areas

- Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking of ODSVRA Beach Areas (DRI Document)
- SAG Review of DRI Document "Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking of ODSVRA Beach Areas" (SAG Memo)

Attachment 06: UCSB 2024-2025 ODSVRA Foredune Restoration UAS Survey Report

- UCSB 2024-2025 ODSVRA Foredune Restoration UAS Survey Report (UCSB Report)
- SAG Review of UCSB Report "2024-2025 ODSVRA Foredune Restoration UAS Monitoring Report" (SAG Memo)

Attachment 07: Summary of Vegetation Monitoring of Restoration Sites at ODSVRA (2024) (State Parks' ARWP Work Product)

Attachment 08: Increments of Progress Toward Air Quality Objectives, ODSVRA Dust Control 2024 Update

- Increments of Progress Toward Air Quality Objectives, ODSVRA Dust Control 2024 Update (DRI Document)
- SAG Review of Desert Research Institute (DRI) “Increments of Progress Toward Air Quality Objectives, ODSVRA Dust Control 2024 Update” (SAG Memo)

Attachment 09: Recent (2020-2024) Changes in Vegetation Cover within the Oceano Dunes SVRA

- Recent (2020-2024) Changes in Vegetation Cover within the Oceano Dunes SVRA (UCSB Document)
- SAG Review of UCSB “Recent 2020-2024 Changes in Vegetation Cover within the Oceano Dunes SVRA” (SAG Memo)

Attachment 10: Ground Cover Information for Dust Control Projects 2022-VG-01 and 2022-VG-02 (State Parks ARWP Work Product)

Attachment 11: Modeling to Determine the Condition of Excess Emissions for 2024 ODSVRA (DRI Documents)

Attachment 12: 2025 PMRP Evaluation Metrics

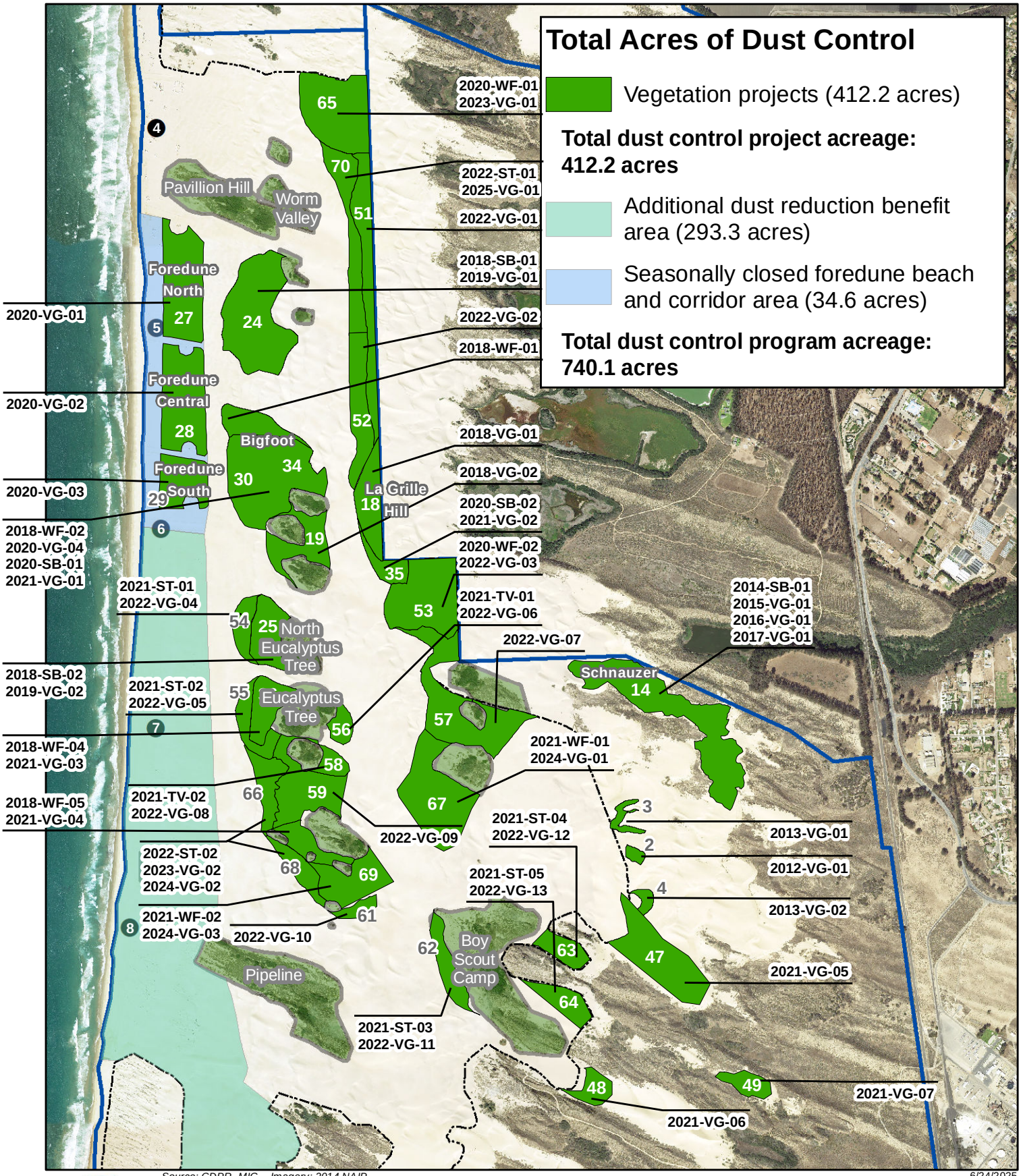
Attachment 13: 2025/2026 ODSVRA Dust Control Program Vegetation Restoration Projects

ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 01

2011 to 2025 Dust Control Projects

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Source: CDPR, MIG Imagery: 2014 NAIP

6/24/2025

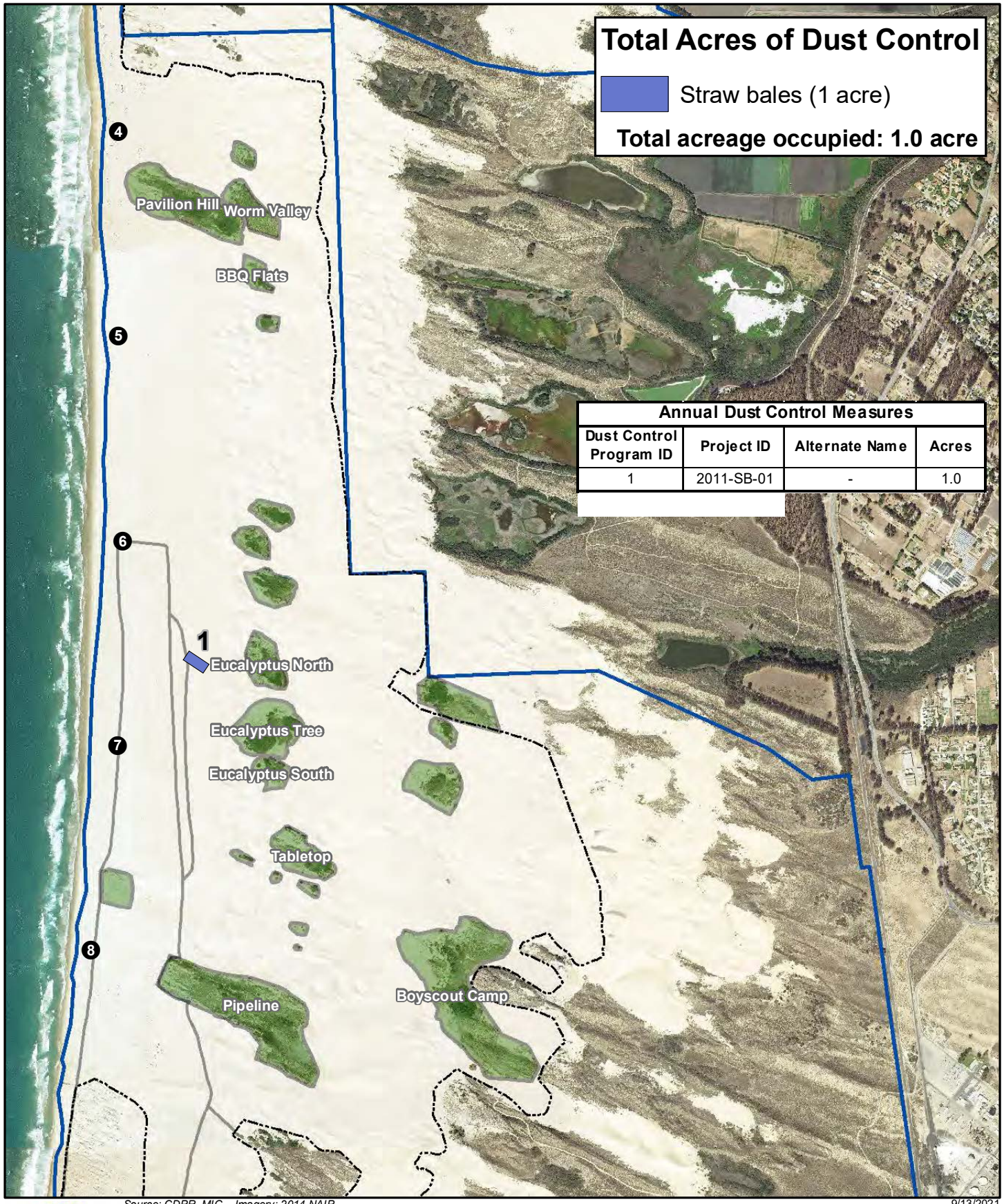
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N

A01-01: Cumulative Dust Control as of 7/31/25

2025 ARWP

Marker post
Existing fenced vegetated islands
Park boundary
Open riding and camping area boundary fence



Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
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N

A01-02: 2011 Dust Control Treatment Areas

2025 ARWP

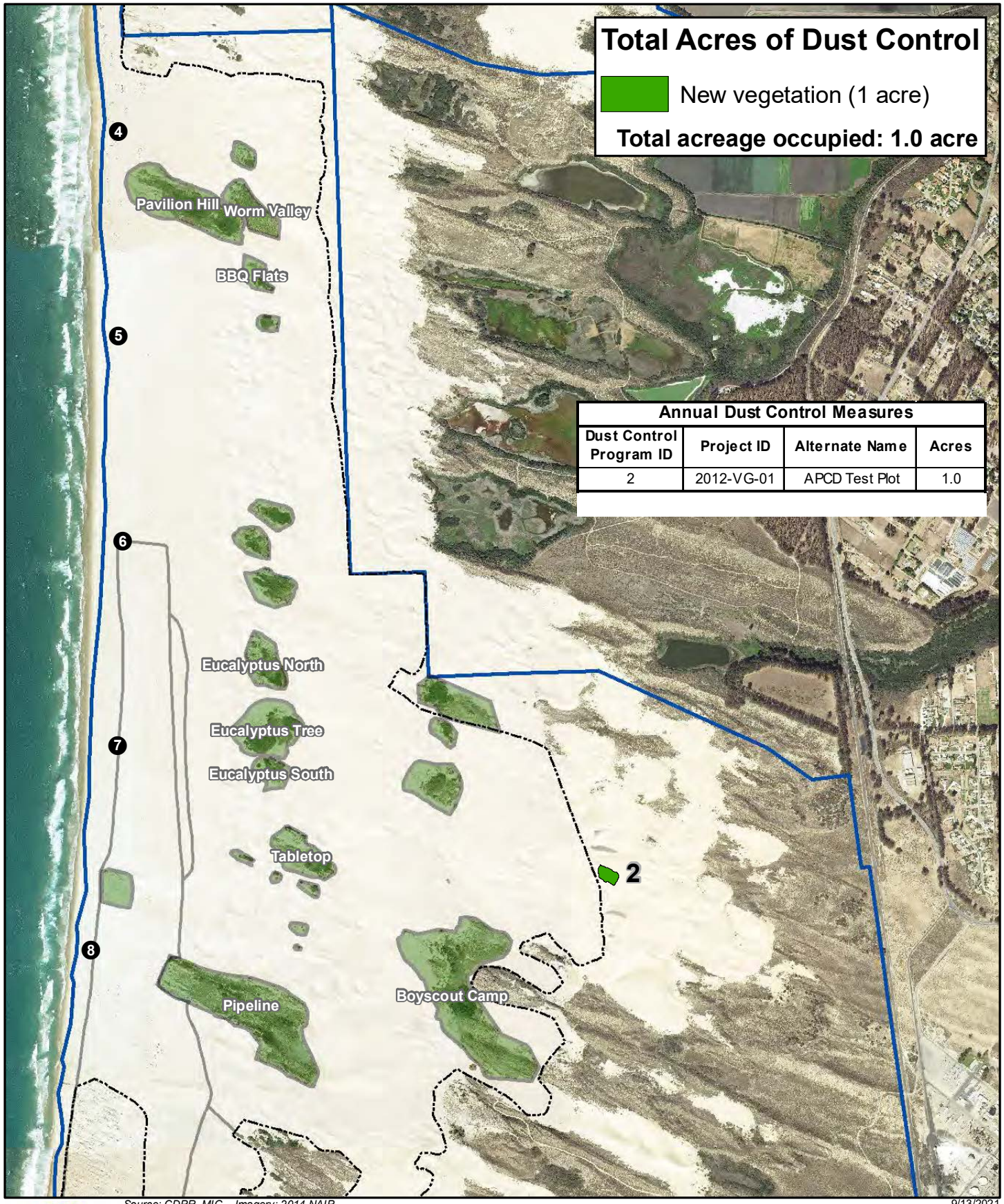
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
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N

A01-03: 2012 Dust Control Treatment Areas

2025 ARWP

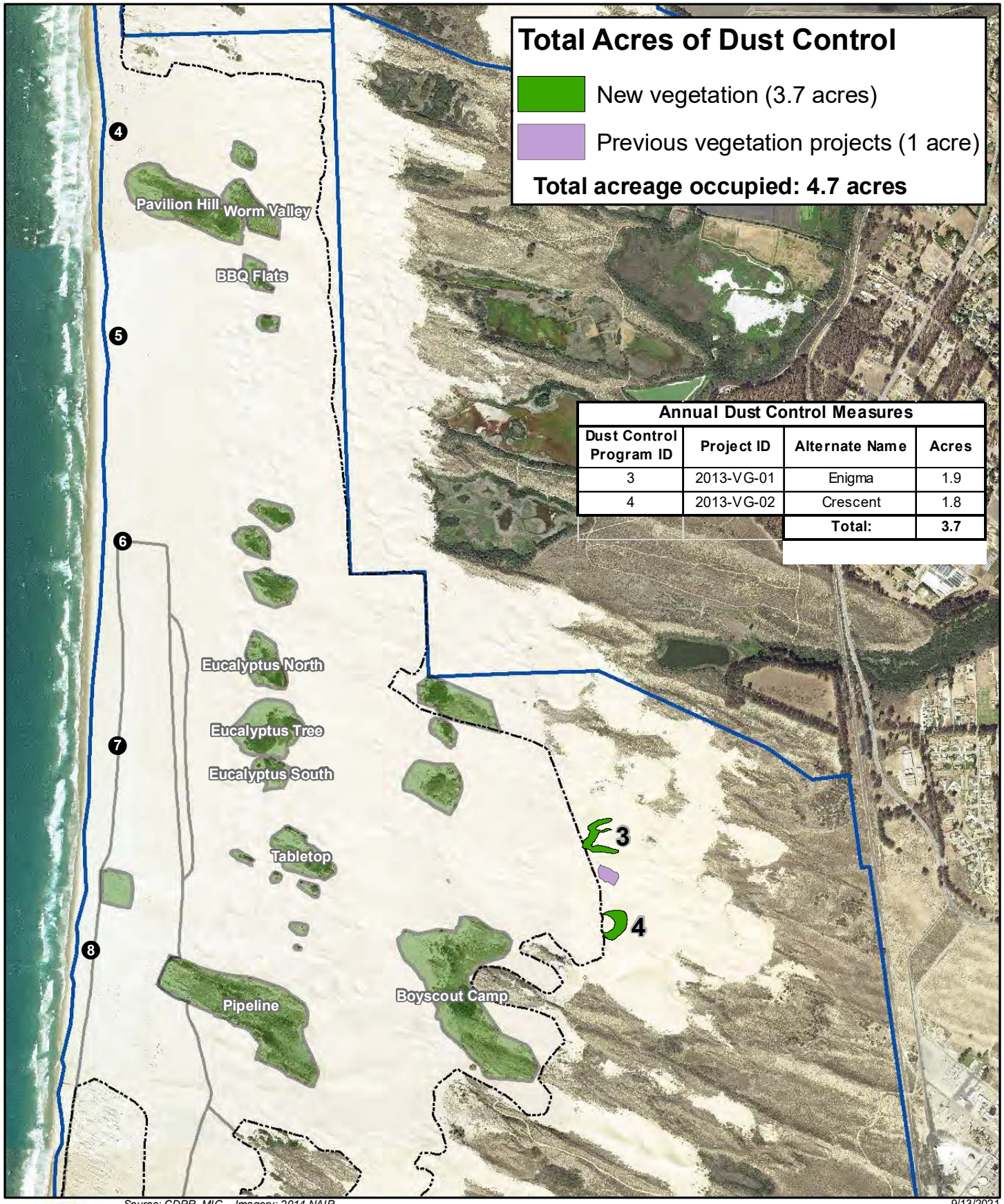
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
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N

A01-04: 2013 Dust Control Treatment Areas

2025 ARWP

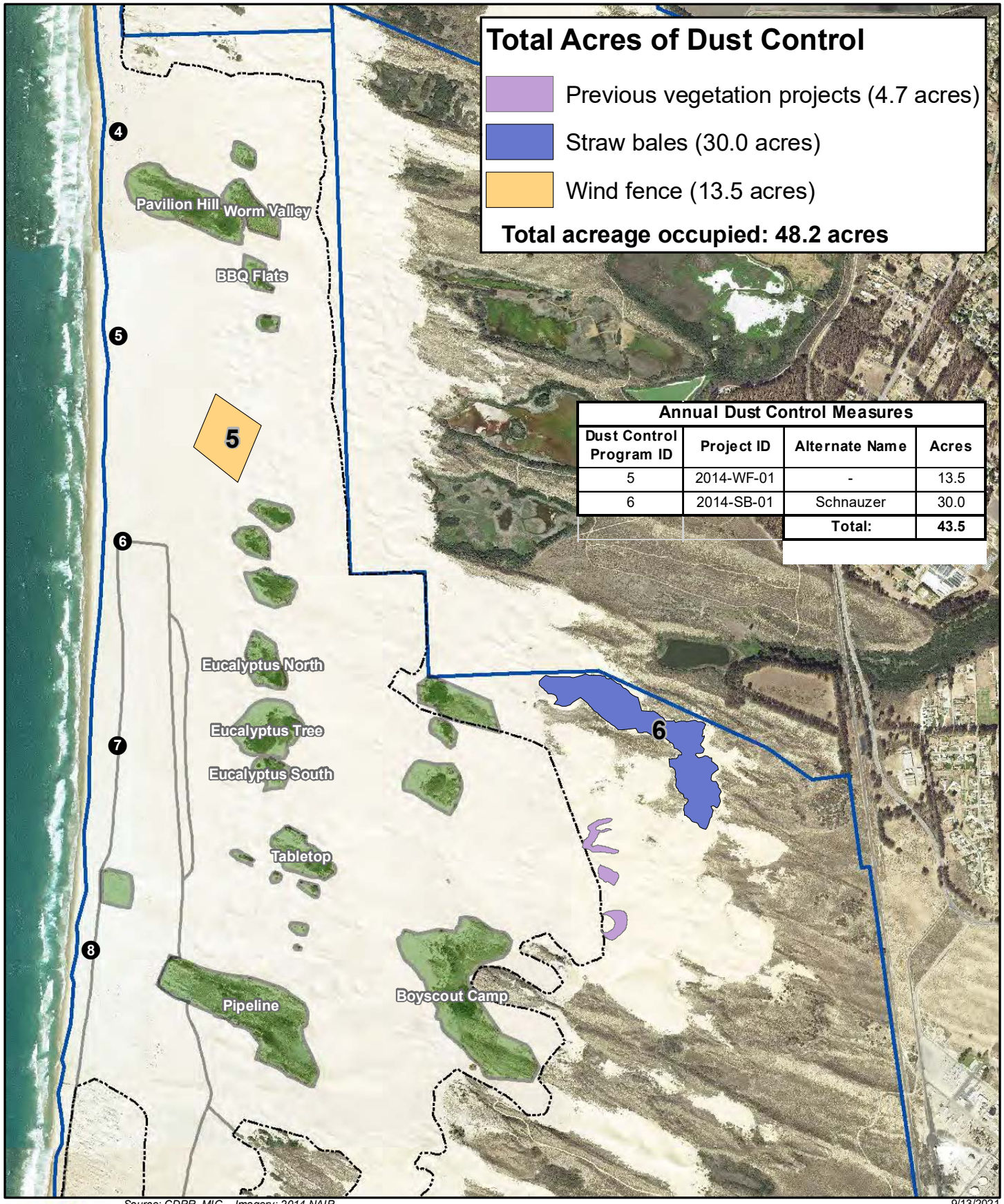
Marker post

Existing fenced vegetated islands

Park boundary

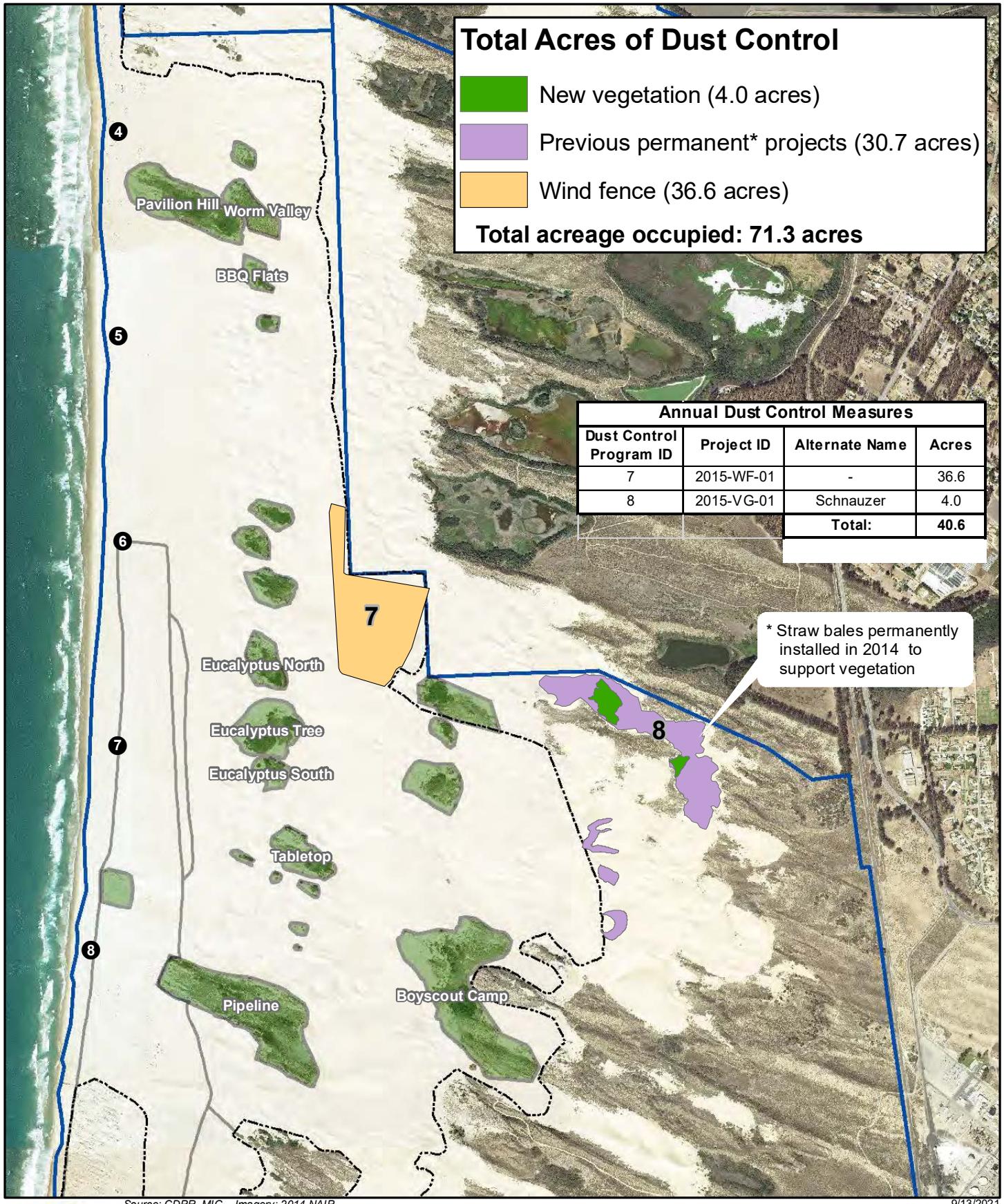
Nesting exclosure from 2020

Open riding and camping area boundary fence



A01-05: 2014 Dust Control Treatment Areas

2025 ARWP



Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
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N

A01-06: 2015 Dust Control Treatment Areas

2025 ARWP

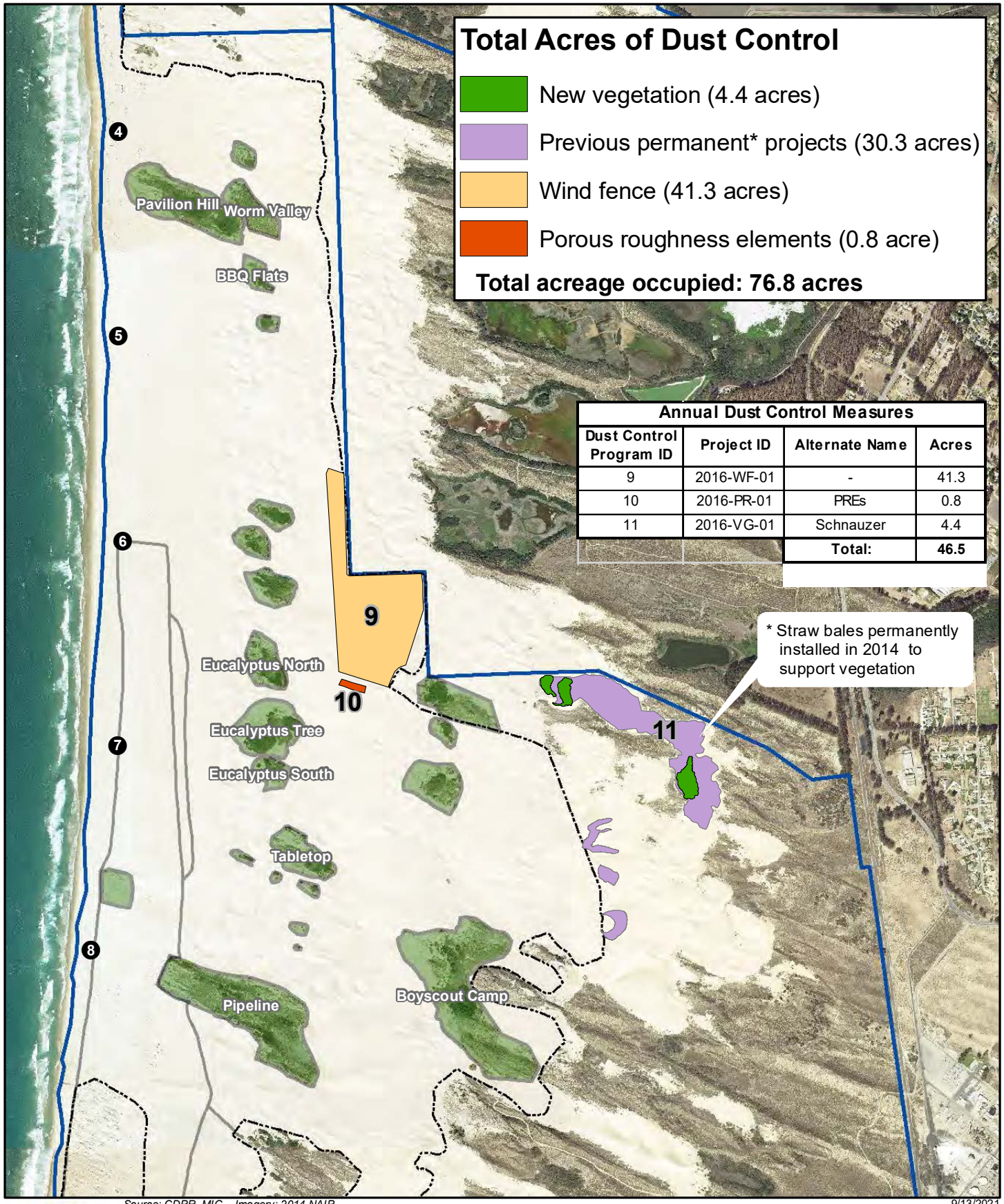
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
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N

A01-07: 2016 Dust Control Treatment Areas

2025 ARWP

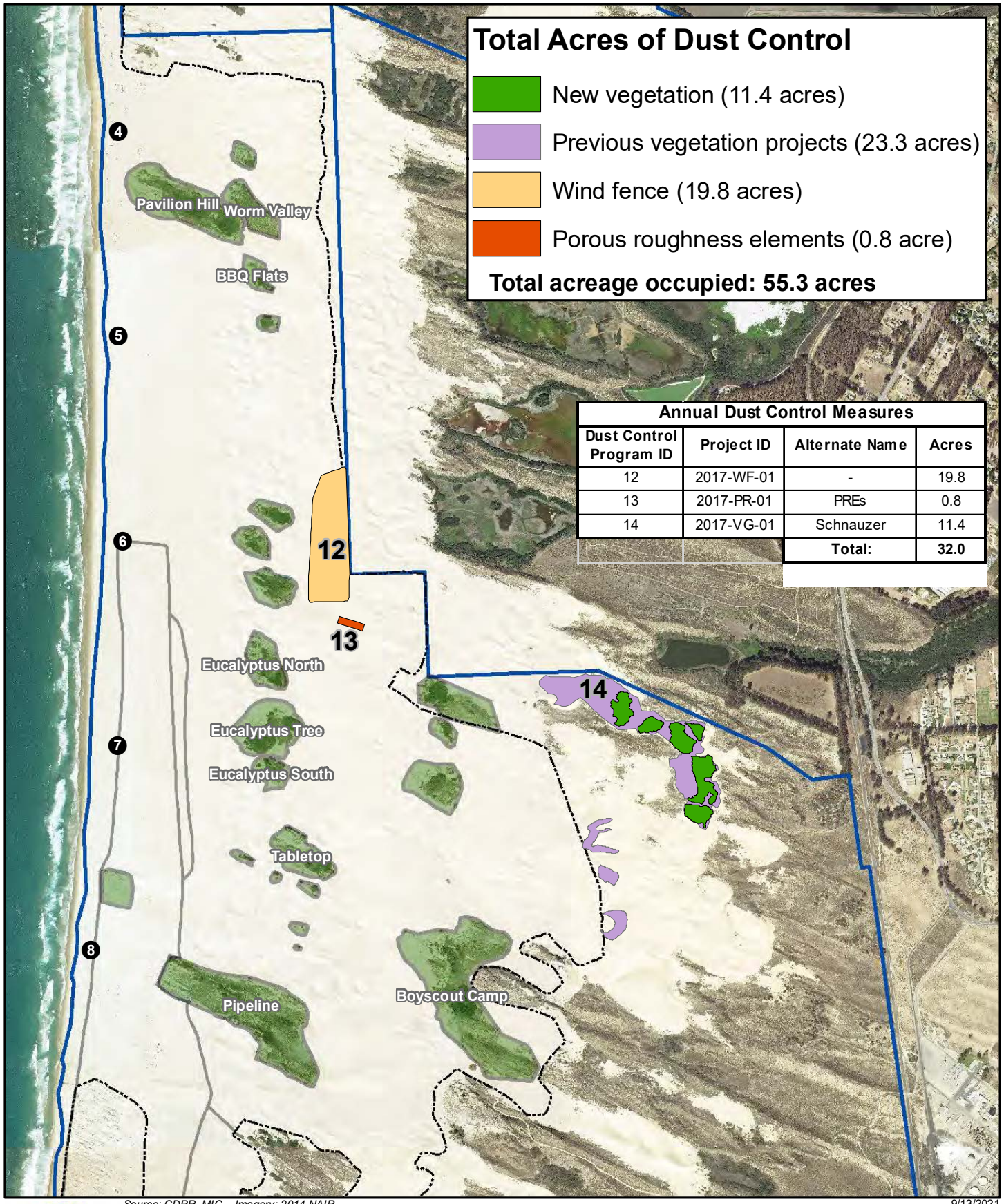
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
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N

A01-08: 2017 Dust Control Treatment Areas

2025 ARWP

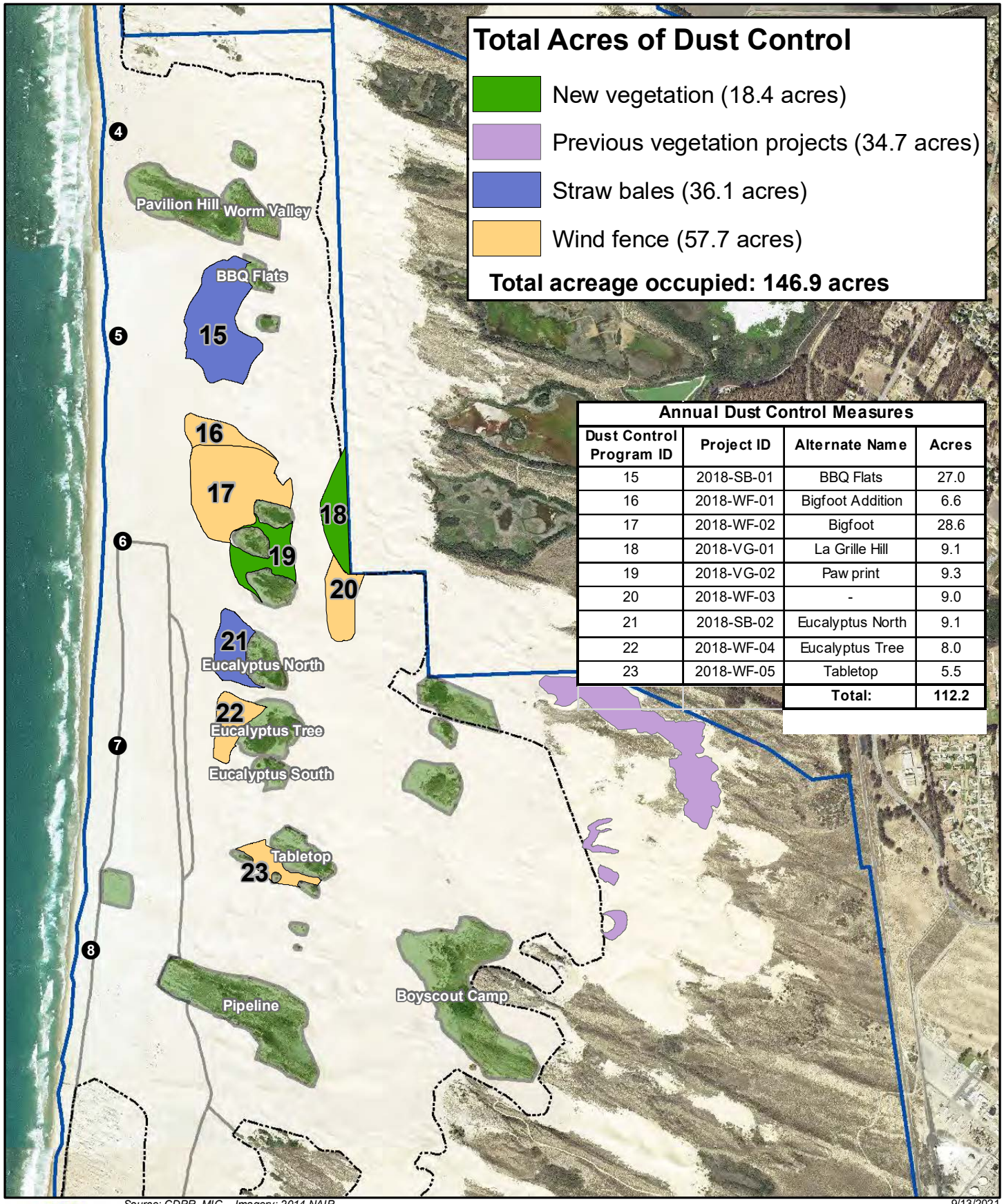
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Annual Dust Control Measures			
Dust Control Program ID	Project ID	Alternate Name	Acres
15	2018-SB-01	BBQ Flats	27.0
16	2018-WF-01	Bigfoot Addition	6.6
17	2018-WF-02	Bigfoot	28.6
18	2018-VG-01	La Grille Hill	9.1
19	2018-VG-02	Paw print	9.3
20	2018-WF-03	-	9.0
21	2018-SB-02	Eucalyptus North	9.1
22	2018-WF-04	Eucalyptus Tree	8.0
23	2018-WF-05	Tabletop	5.5
		Total:	**112.2**

Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
0 500 1,000 2,000

N

A01-09: 2018 Dust Control Treatment Areas

2025 ARWP

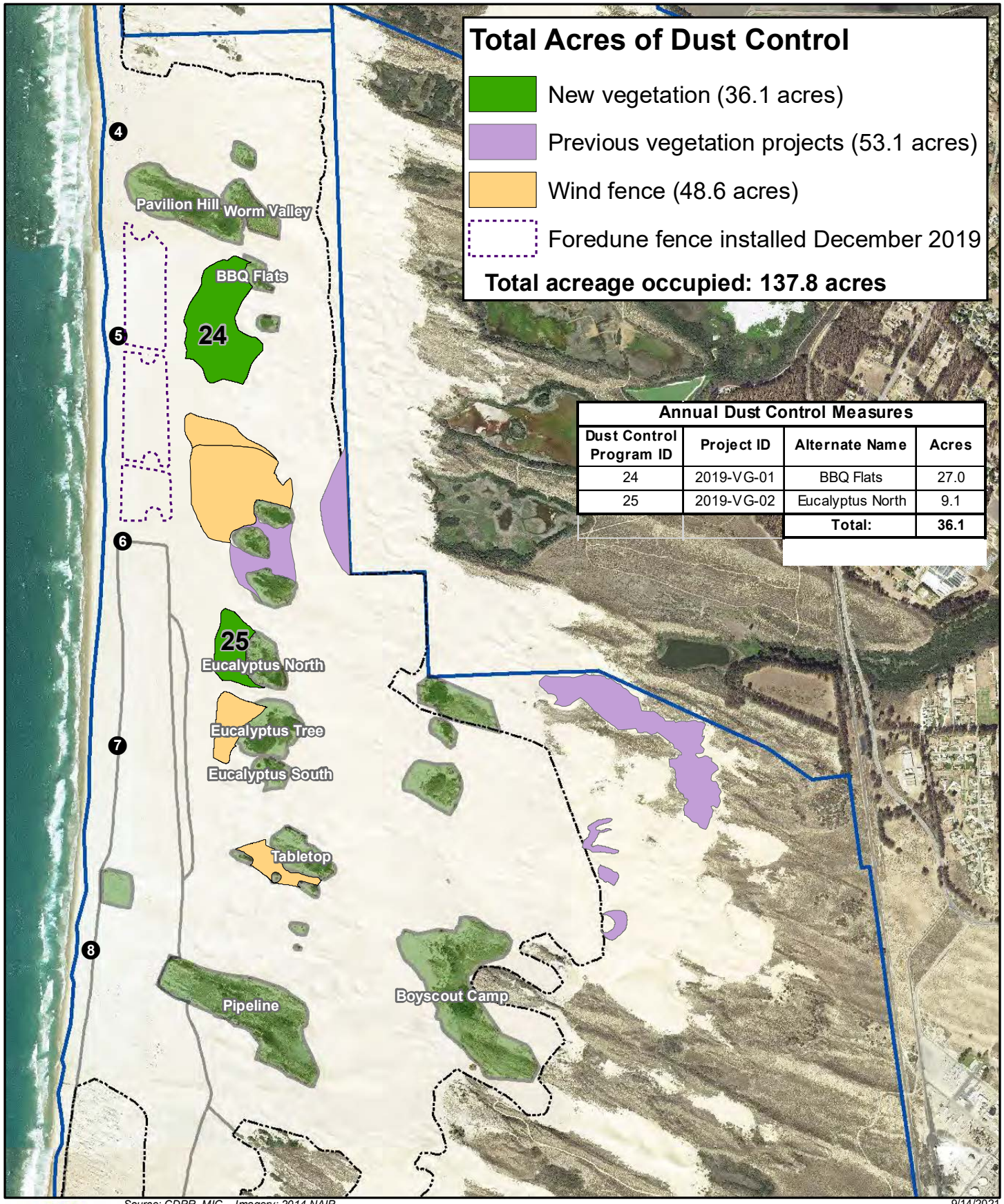
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Source: CDPR, MIG Imagery: 2014 NAIP

9/14/2021

Feet
0 500 1,000 2,000

N

A01-10: 2019 Dust Control Treatment Areas

2025 ARWP

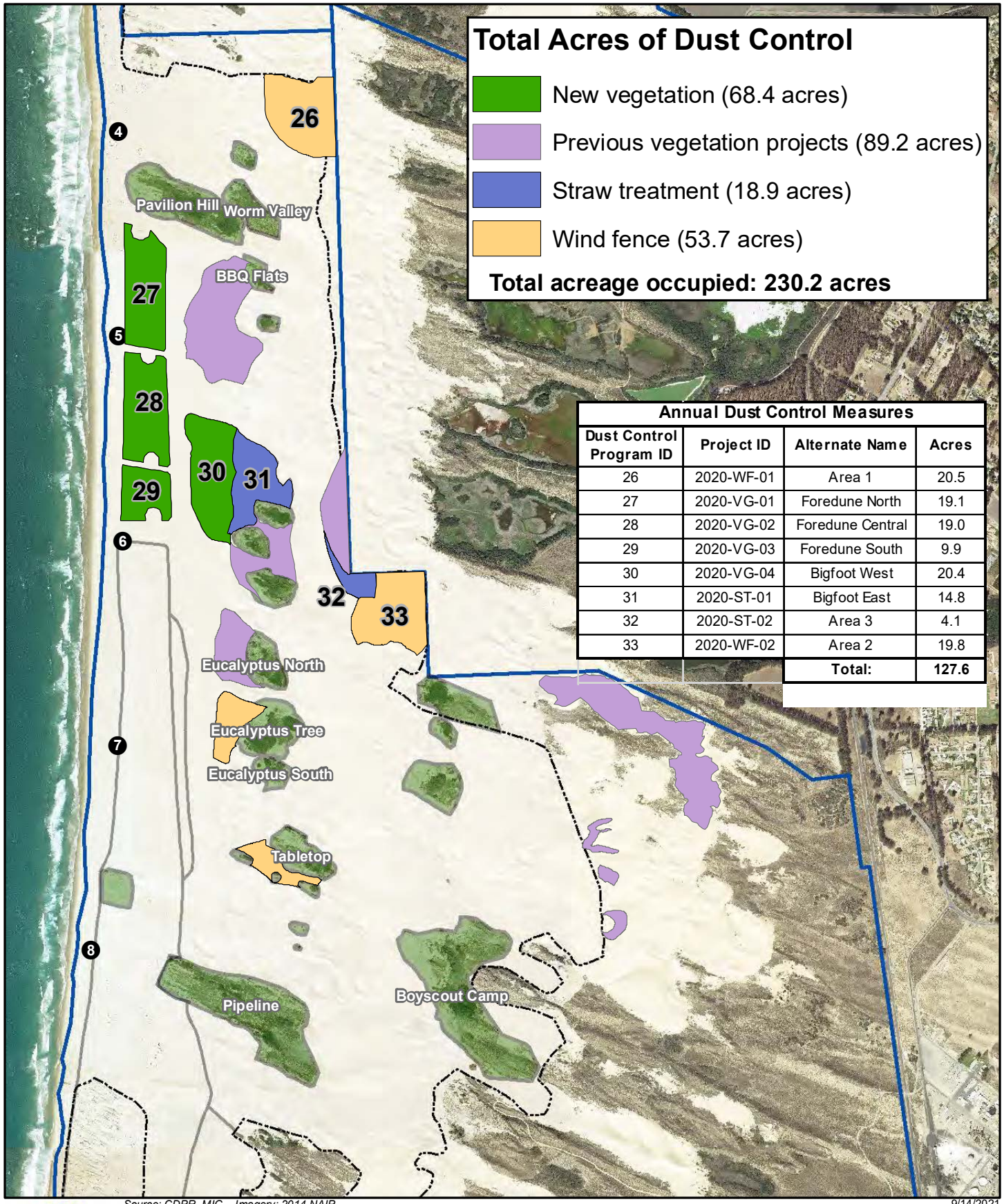
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Annual Dust Control Measures			
Dust Control Program ID	Project ID	Alternate Name	Acres
26	2020-WF-01	Area 1	20.5
27	2020-VG-01	Foredune North	19.1
28	2020-VG-02	Foredune Central	19.0
29	2020-VG-03	Foredune South	9.9
30	2020-VG-04	Bigfoot West	20.4
31	2020-ST-01	Bigfoot East	14.8
32	2020-ST-02	Area 3	4.1
33	2020-WF-02	Area 2	19.8
		Total:	**127.6**

Source: CDPR, MIG Imagery: 2014 NAIP

9/14/2021

Feet
0 500 1,000 2,000

N

A01-11: 2020 Dust Control Treatment Areas

2025 ARWP

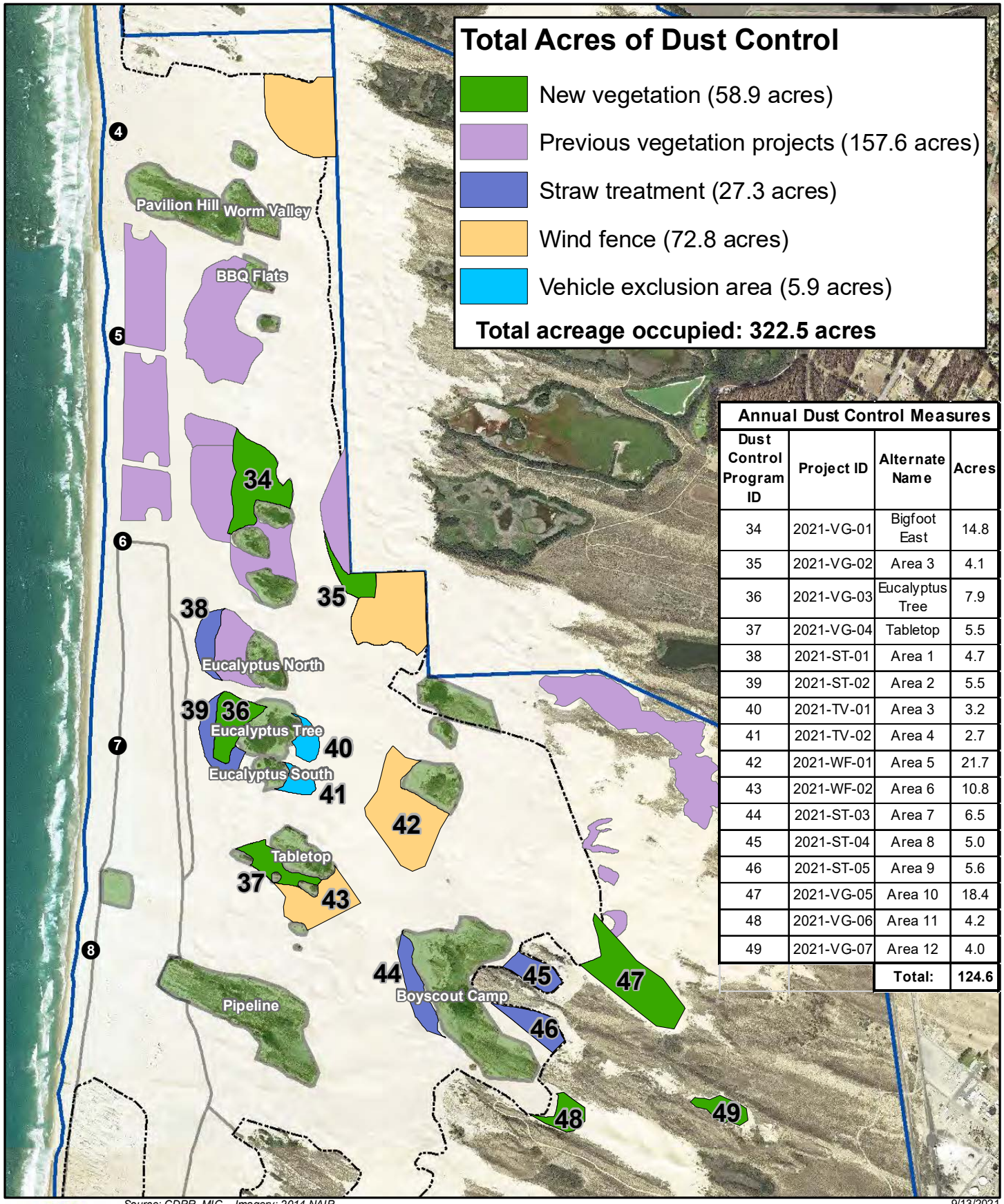
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Annual Dust Control Measures			
Dust Control Program ID	Project ID	Alternate Name	Acres
34	2021-VG-01	Bigfoot East	14.8
35	2021-VG-02	Area 3	4.1
36	2021-VG-03	Eucalyptus Tree	7.9
37	2021-VG-04	Tabletop	5.5
38	2021-ST-01	Area 1	4.7
39	2021-ST-02	Area 2	5.5
40	2021-TV-01	Area 3	3.2
41	2021-TV-02	Area 4	2.7
42	2021-WF-01	Area 5	21.7
43	2021-WF-02	Area 6	10.8
44	2021-ST-03	Area 7	6.5
45	2021-ST-04	Area 8	5.0
46	2021-ST-05	Area 9	5.6
47	2021-VG-05	Area 10	18.4
48	2021-VG-06	Area 11	4.2
49	2021-VG-07	Area 12	4.0
		Total:	124.6

Source: CDPR, MIG Imagery: 2014 NAIP

9/13/2021

Feet
0 500 1,000 2,000

N

A01-12: 2021 Dust Control Treatment Areas

2025 ARWP

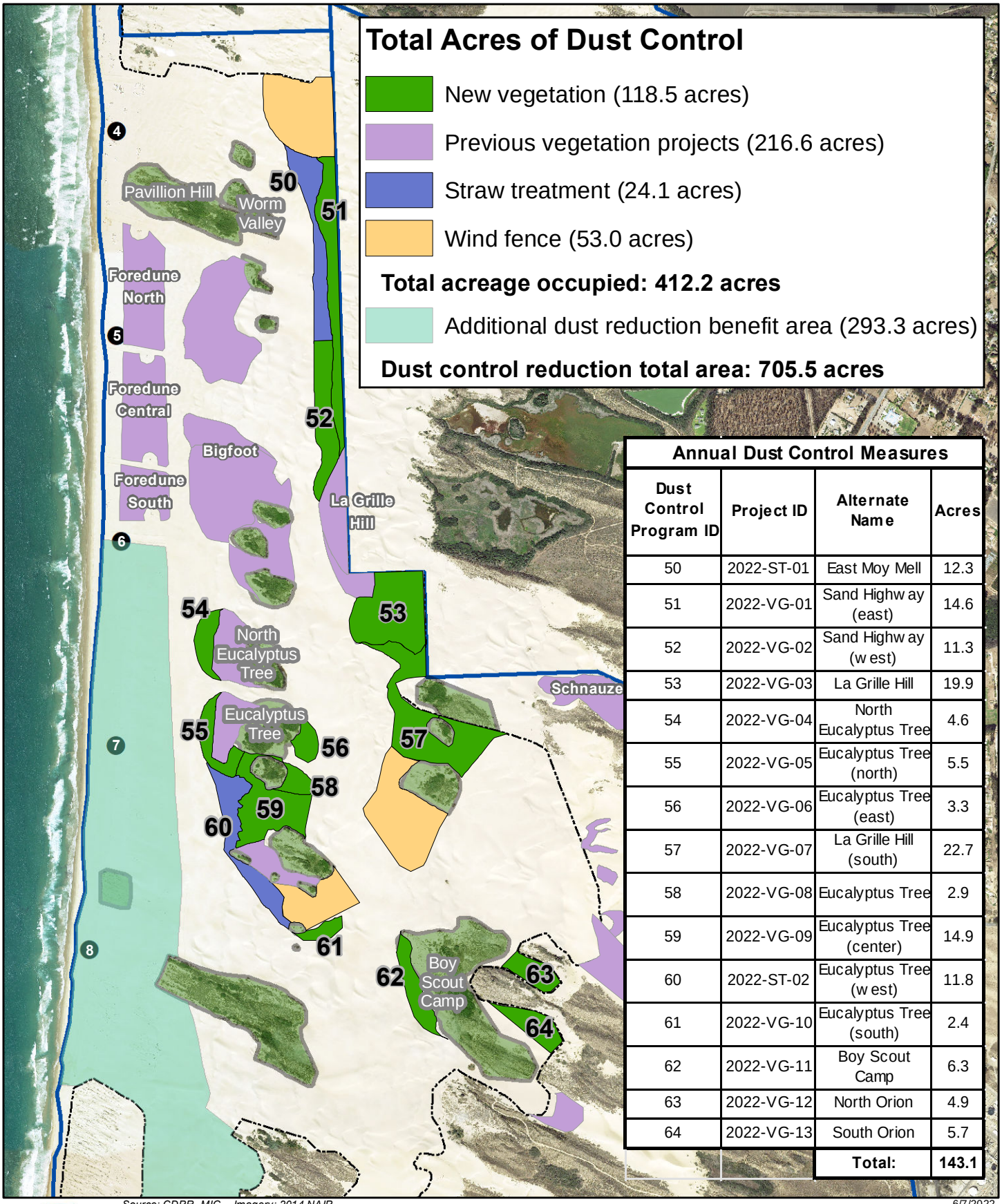
Marker post

Existing fenced vegetated islands

Park boundary

Nesting exclosure from 2020

Open riding and camping area boundary fence



Annual Dust Control Measures			
Dust Control Program ID	Project ID	Alternate Name	Acres
50	2022-ST-01	East Moy Mell	12.3
51	2022-VG-01	Sand Highway (east)	14.6
52	2022-VG-02	Sand Highway (west)	11.3
53	2022-VG-03	La Grille Hill	19.9
54	2022-VG-04	North Eucalyptus Tree	4.6
55	2022-VG-05	Eucalyptus Tree (north)	5.5
56	2022-VG-06	Eucalyptus Tree (east)	3.3
57	2022-VG-07	La Grille Hill (south)	22.7
58	2022-VG-08	Eucalyptus Tree	2.9
59	2022-VG-09	Eucalyptus Tree (center)	14.9
60	2022-ST-02	Eucalyptus Tree (west)	11.8
61	2022-VG-10	Eucalyptus Tree (south)	2.4
62	2022-VG-11	Boy Scout Camp	6.3
63	2022-VG-12	North Orion	4.9
64	2022-VG-13	South Orion	5.7
		Total:	**143.1**

Source: CDPR, MIG Imagery: 2014 NAIP

6/7/2022

0 500 1,000 2,000 Feet

N

A01-13: 2022 Dust Control Treatment Areas

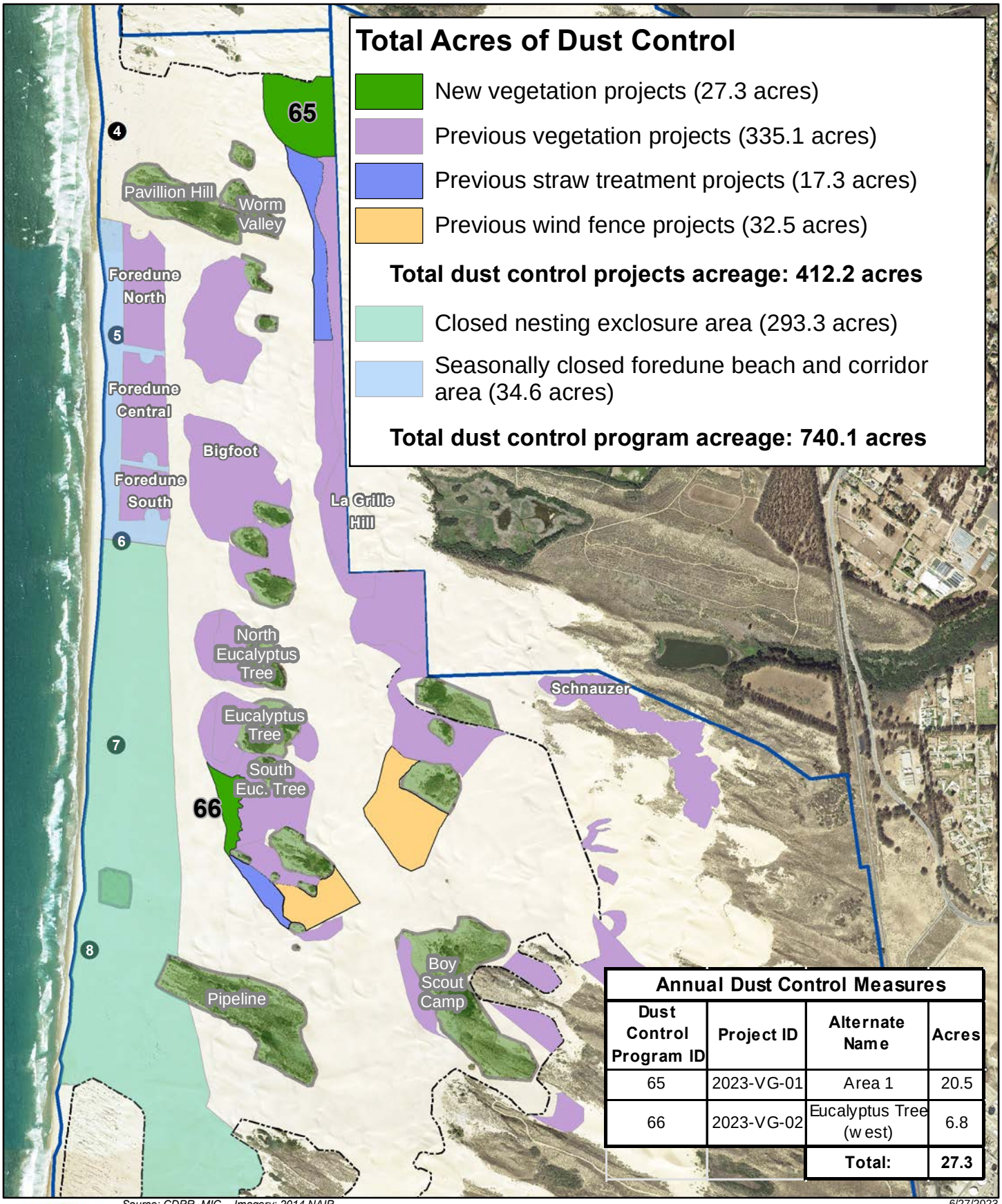
2025 ARWP

Marker post

Existing fenced vegetated islands

Park boundary

Open riding and camping area boundary fence



Annual Dust Control Measures			
Dust Control Program ID	Project ID	Alternate Name	Acres
65	2023-VG-01	Area 1	20.5
66	2023-VG-02	Eucalyptus Tree (west)	6.8
		Total:	27.3

Source: CDPR, MIG Imagery: 2014 NAIP

6/27/2023

0 500 1,000 2,000 Feet

N

Figure A01-14: 2023 Dust Control Treatment Areas

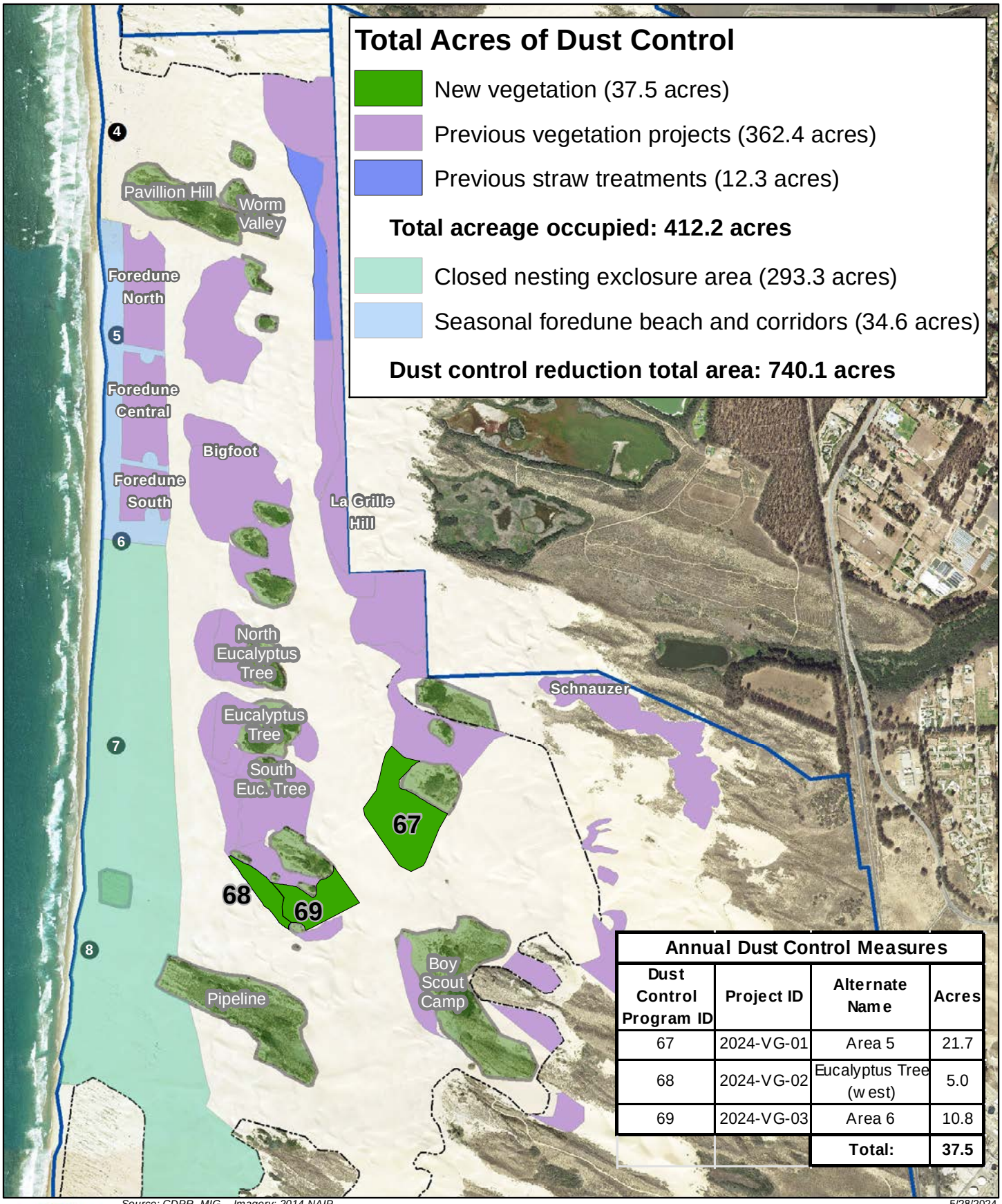
2025 ARWP

Marker post

Existing fenced vegetated islands

Park boundary

Open riding and camping area boundary fence



Annual Dust Control Measures			
Dust Control Program ID	Project ID	Alternate Name	Acres
67	2024-VG-01	Area 5	21.7
68	2024-VG-02	Eucalyptus Tree (west)	5.0
69	2024-VG-03	Area 6	10.8
		Total:	37.5

Source: CDPR, MIG Imagery: 2014 NAIP 5/28/2024

0 500 1,000 2,000 Feet

N

Figure A01-15: 2024 Dust Control Treatment Areas

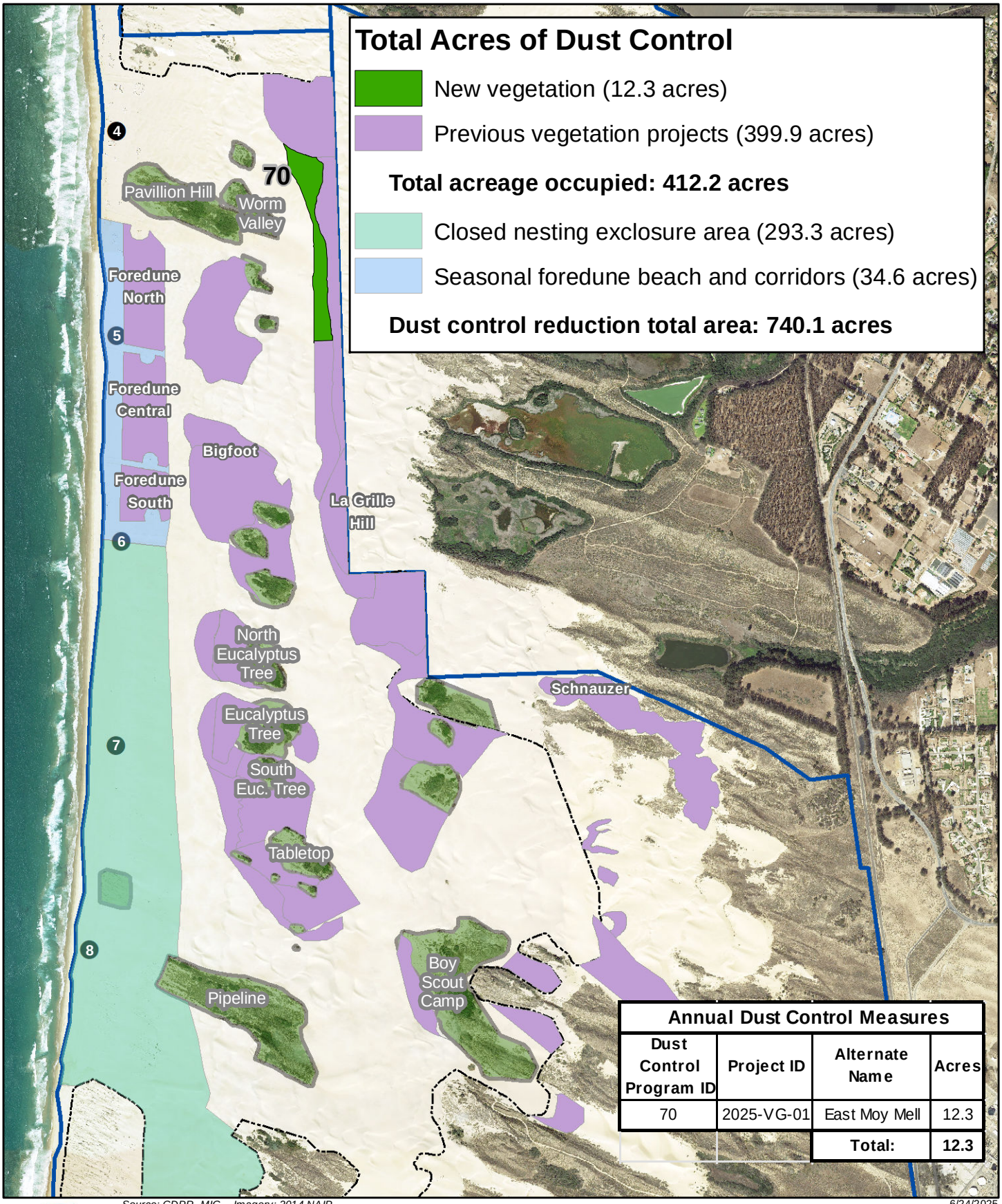
2025 ARWP

Marker post

Existing fenced vegetated islands

Park boundary

Open riding and camping area boundary fence



Annual Dust Control Measures			
Dust Control Program ID	Project ID	Alternate Name	Acres
70	2025-VG-01	East Moy Mell	12.3
		Total:	12.3

Source: CDPR, MIG Imagery: 2014 NAIP

6/24/2025

0 500 1,000 2,000 Feet

N

Figure A01-16: 2025 Dust Control Treatment Areas

2025 ARWP

Marker post

Existing fenced vegetated islands

Park boundary

Open riding and camping area boundary fence

ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 02

2024/2025 ODSVRA Dust Control Program Vegetation Restoration Projects

(State Parks' ARWP Work Product)

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2024/2025 ODSVRA Dust Control Program - Restoration Projects							
Scientific Name Common Name	Plant Counts Native Seed (lbs)	Season Totals	Moy Mel East 2022-ST-01 (New Planting)	Sand Highway East 2022-VG-01 (Supplemental Planting)	Sand Highway West 2022-VG-02 (Supplemental Planting)	BBQ Flats 2019-VG-01 (Supplemental Planting)	North Eucalyptus Tree 2022-VG-04 (Supplemental Planting)
Acreage		41.2	12.3	14.6	11.3	1.0	2.0
Straw - (large bales)		479	128	179	160	12	-
Fertilizer (lbs) - 15-15-15		2000	600	750	550	50	50
Triticale Seed (lbs) - sterile		950	300	375	250	8	17
Total plants		121,013	35,544	46,936	31,224	2,495	4,814
Total Native Seed (lbs)		495.34	152.03	174.83	140.69	9.27	18.53
Abronia latifolia		230	100	-	100	10	20
Yellow sand verbena		2.40	1.00	-	1.10	0.10	0.20
Abronia maritima		305	125	-	150	10	20
Sticky sand verbena		40.80	18.00	-	19.80	1.00	2.00
Abronia umbellata		-	-	-	-	-	-
Beach sand verbena		0.30	0.30	-	-	-	-
Acmispon glaber		1,127	294	735	98	-	-
Deerweed		18.10	5.30	7.50	4.40	0.30	0.60
Achillea millefolium		10,556	3,136	3,969	2,744	245	462
Common yarrow		52.00	15.00	18.75	13.75	1.50	3.00
Ambrosia chamissonis		2,401	980	-	980	147	294
Beach bur		48.00	20.00	-	22.00	2.00	4.00
Amsinckia spectabilis		-	-	-	-	-	-
Seaside fiddleneck		0.85	0.10	0.75	-	-	-
Castilleja affinis		459	32	378	49	-	-
Indian paintbrush		0.85	0.10	0.75	-	-	-
Camissoniopsis cheiranthifolia		6,027	1,911	1,470	2,058	196	392
Beach evening-primrose		-	-	-	-	-	-
Castilleja exserta		-	-	-	-	-	
Owl's clover		0.62	0.18	0.23	0.17	0.02	0.03
Chenopodium californica		-	-	-	-	-	-
California goosefoot		3.80	1.20	1.50	1.10	-	-
Corethrogyne filaginifolia		3,542	784	2,205	553	-	-
Common sandaster		16.30	4.00	7.50	3.30	0.50	1.00
Cryptantha clevelandii		-	-	-	-	-	-
Common cryptantha		0.80	0.20	0.60	-	-	-
Dudleya lanceolata		882	98	735	49	-	-
Southern California dudleya		-	-	-	-	-	-
Erigeron blochmaniae		5,334	1,470	2,205	1,225	147	287
Blochman's leafy daisy		3.38	0.75	1.50	0.83	0.10	0.20
Eriastrum densifolium		1,778	294	1,386	98	-	-
Giant eriastrum		-	-	-	-	-	-

2024/2025 ODSVRA Dust Control Program - Restoration Projects							
Scientific Name Common Name	Plant Counts Native Seed (lbs)	Season Totals	Moy Mel East 2022-ST-01 (New Planting)	Sand Highway East 2022-VG-01 (Supplemental Planting)	Sand Highway West 2022-VG-02 (Supplemental Planting)	BBQ Flats 2019-VG-01 (Supplemental Planting)	North Eucalyptus Tree 2022-VG-04 (Supplemental Planting)
Ericameria ericoides		8,107	2,450	3,381	2,156	49	71
Mock heather		80.20	17.70	45.00	13.75	1.25	2.50
Eriogonum parvifolium		9,111	2,450	3,675	2,205	245	536
Coastal buckwheat		42.85	13.10	18.75	11.00	-	-
Eriophyllum staechadifolium		10,373	2,891	3,675	3,185	196	426
Seaside golden yarrow		40.20	12.70	15.00	11.00	0.50	1.00
Erysimum suffrutescens		5,074	1,372	2,940	762	-	-
Suffrutescent wallflower		1.28	0.15	1.13	-	-	-
Horkelia cuneata		-	-	-	-	-	-
Wedge leaved horkelia		0.85	0.10	0.75	-	-	-
Lupinus chamissonis		29,498	9,212	10,290	7,742	784	1,470
Dune bush lupine		24.30	6.80	10.50	5.50	0.50	1.00
Malacothrix incana		1,396	735	-	588	25	48
Dunedelion		-	-	-	-	-	
Monardella undulata ssp crispa		8,028	2,597	3,234	2,107	49	41
Crisp monardella		19.00	6.00	6.00	5.50	0.50	1.00
Phacelia distans		-	-	-	-	-	-
Common phacelia		0.85	0.10	0.75	-	-	-
Phacelia ramosissima		8,587	2,352	3,381	2,156	245	453
Branching phacelia		57.10	17.20	22.50	16.50	0.30	0.60
Salvia columbariae		-	-	-	-	-	-
Chia sage		0.43	0.05	0.38	-	-	-
Salix lasiolepis		310	120	139	51	-	-
Arroyo Willow		-	-	-	-	-	-
Senecio blochmaniae		7,644	2,107	2,940	2,156	147	294
Dune ragwort		40.10	12.00	15.00	11.00	0.70	1.40
Silene laciniata		244	34	198	12	-	
Cardinal catchfly		-	-	-	-	-	-

ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 03

Report on Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024

- Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024 (DRI Document)
- SAG Review of Desert Research Institute (DRI) "Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024" (SAG Memo)

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Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024

J.A Gillies* and G. Nikolich**
Division of Atmospheric Sciences, Desert Research Institute, *Reno and **Las Vegas, Nevada

State Parks' meteorological and PM_{10} monitoring network varies slightly from year to year depending on specific goals, objectives, and dust control measures identified in the annual ARWP cycle. From approximately April 1, 2024, to September 30, 2024, State Parks maintained the meteorological and PM monitoring network shown in Fig. 1, consisting of fifteen (15) stations located throughout and downwind of the ODSVRA. The network has been in operation since 2020 but prior to 2021 there were fewer stations. Moreover, the ODSVRA was closed to OHV activity in 2020 due to COVID-related closure restrictions. Thus, the period of record considered herein, with a full complement of stations and active OHV activity, is restricted to 2021 through 2024.

Each station has a MetSens500 instrument that measures wind speed and wind direction (ultrasonically), ambient temperature, atmospheric pressure, and relative humidity (RH), a MetOne 212 particle profiler to measure PM_{10}, and stations on open sand areas had Sensit saltation sensors. The MetOne instrument is calibrated against a Beta Attenuation Monitor (BAM) in a dust chamber prior to deployment and after removal from the field in October.

The environmental data collected by these stations provides a means to examine spatial trends in PM_{10} concentrations ($\mu g\ m^{-3}$) across the ODSVRA in relation to wind speed ($m\ s^{-1}$) and wind power density ($W\ m^{-2}$), and to evaluate if these relations have changed through time.

Wind power density (WPD, $W\ m^{-2}$) is defined as (e.g., Kalmikov, 2017):

$$WPD=0.5\ \rho_a\ u_z^3 \quad (1)$$

where ρ_a is air density (assumed to be a constant 1.225 $kg\ m^{-3}$), and u_z ($m\ s^{-1}$) is wind speed at the measurement height z (m) above ground level (AGL), a unit area of 1 m^2 is assumed in this application. For comparison among different locations and between different years, the height of measurement of wind speed and the lower limit of mean hourly wind speed for summation of Total Wind Power Density (TWPD) must be the same. To standardize the calculation of TWPD a lower limit of wind speed is chosen that corresponds with the lowest speed where the relation between increasing wind speed and simultaneous increase in PM_{10} is observed at a

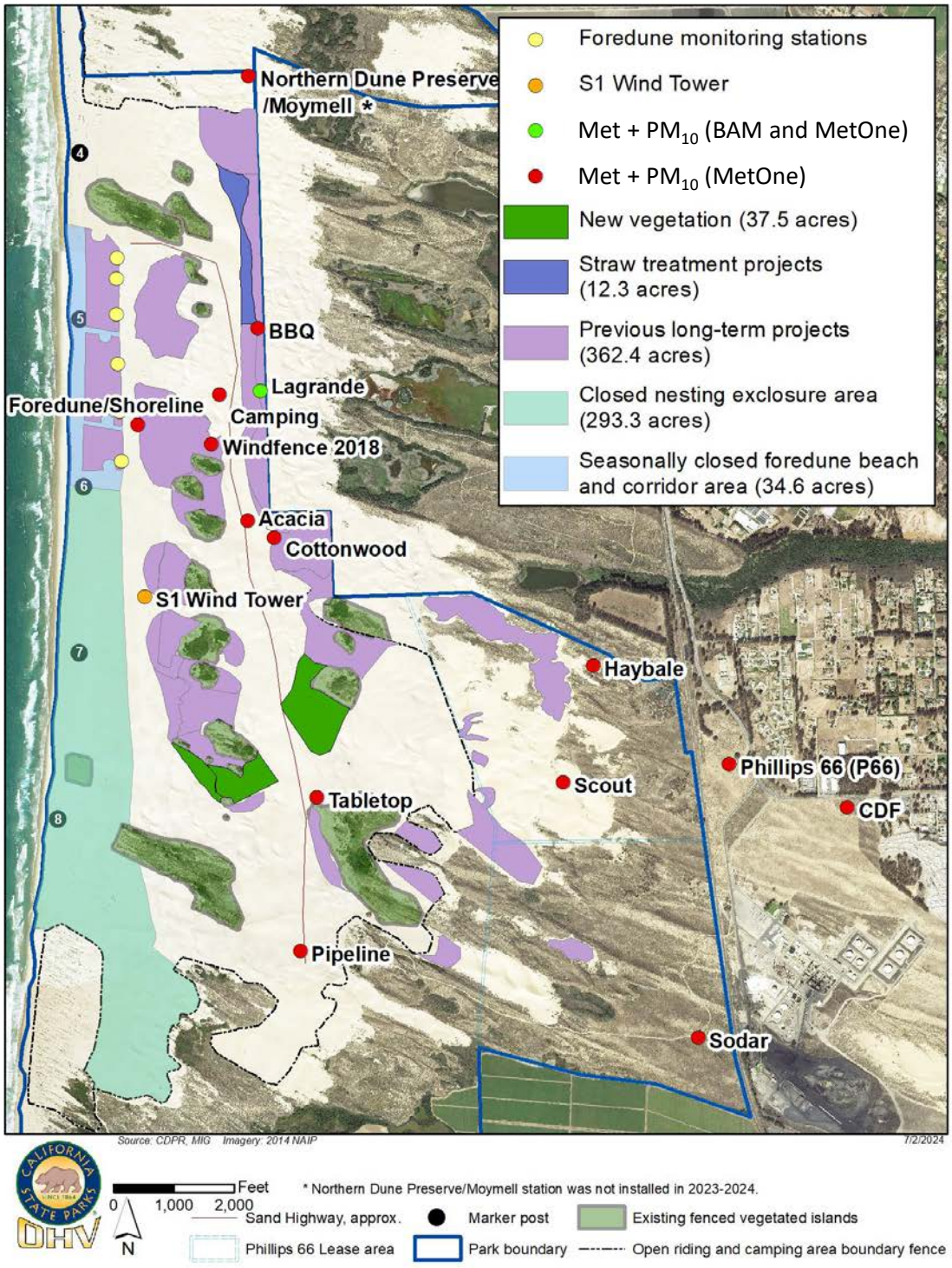


Figure 1. The locations of the monitoring stations.

monitoring station. For the stations on sand-sheet areas of the ODSVRA this wind speed is chosen to be 5.5 m s^{-1} measured at 3.5 m AGL. Figure 2 shows typical response relations between mean hourly wind speed measured at 3.5 m AGL for four stations on sand-sheet areas of the ODSVRA covering the north to south extent of the monitoring network in 2024 for the period April through September. A wind speed of 5.5 m s^{-1}, measured at 3.5 m AGL is indicative of a wind speed of ≈8.5 m s^{-1} measured at 10 m AGL at the S1 tower. That 10 m AGL wind speed has been used to define a lower limit that indicates a correlation with increasing PM_{10} concentration observed at CDF and Mesa2 as noted in the Increments of Progress reporting (Gillies et al., 2024a, 2024b).

Figure 2 also shows that along the north-south dimension of the network, for stations located on the sand sheet areas of the ODSVRA (including NDP), higher mean hourly PM_{10} concentrations are observed in the north (Acacia) (NDP excepted) than in the south (Pipeline) for lower wind speeds.

TWPD and TPM_{10} at each station is quantified by summing the hourly mean values for the hours when MetOne 212 PM_{10} concentrations are paired with the station-measured wind speed. The lower limit for summation was set at 5.5 m s^{-1} for mean hourly wind speed, as this wind speed indicates that PM_{10} concentration begins to increase and correlate with increasing wind speed with further increases in wind speed (Fig. 2). A wind directional filter of 248°to 326° was applied to ensure that the PM_{10} measured at the stations was being transported from the ODSVRA towards the air quality monitoring locations CDF and Mesa2.

TWPD, by month, for the period April to September in 2021 through 2024 for each station on sand-sheet areas of the ODSVRA is shown in Figs. 3a and 3b. Through this period greater amounts of TWPD are observed in the months April, May, and June as compared with the summer months July, August, and September, and higher wind speeds in the south give rise to greater amounts of TWPD than is observed in the northern stations.

The trends in TWPD by month for the period April to September in 2021 through 2024 for the stations located to the east of the sand-sheet areas of the ODSVRA, i.e., Haybale, P66, CDF, and SODAR, are shown in Fig. 4. The same seasonal pattern, i.e., greater TWPD in April, May, and June as compared with the summer months July, August, and September, was observed in these stations as occurs for the stations on sand-sheet areas. The TWPD range is smaller for the stations east of sand-sheet areas as the wind speed is slowed moving inland due to the frictional resistance due to the vegetated surfaces. The CDF station farthest inland has the lowest range of TWPD compared with the other three stations that are farther to the west.

The change in TPM_{10}:TWPD for all stations for available data from April to September 2021 through 2024 is shown in Fig. 5. The mean seasonal TPM_{10}:TWPD ratio for stations on sand sheet areas (including NDP) is variable as a function of position. The stations with the greatest TPM_{10}:TWPD ratio have consistently been the northern stations BBQ through to Acacia and

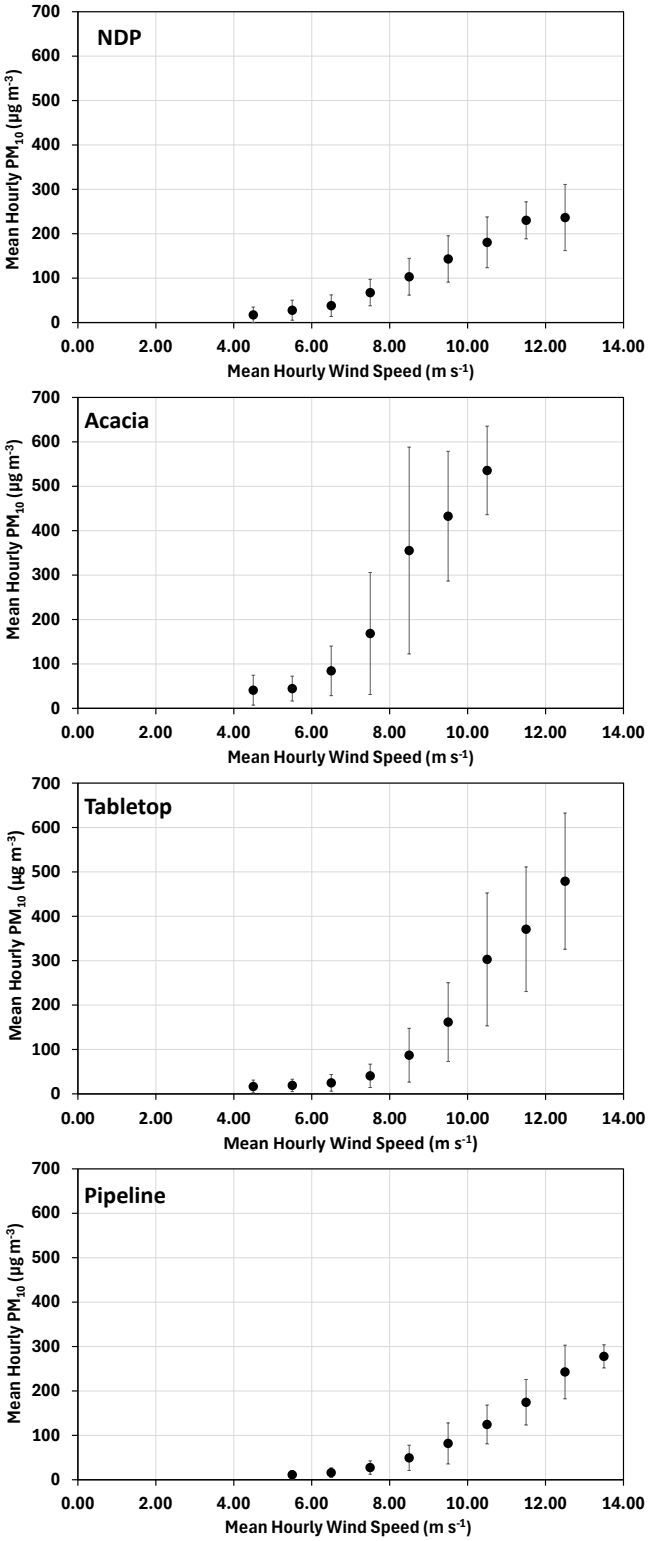


Figure 2. Relation between mean hourly PM_{10} concentration and mean hourly wind speed for select stations on sand-sheet areas of the ODSVRA (April-September 2024) spanning the network distance from north (NDP) to south (Pipeline).

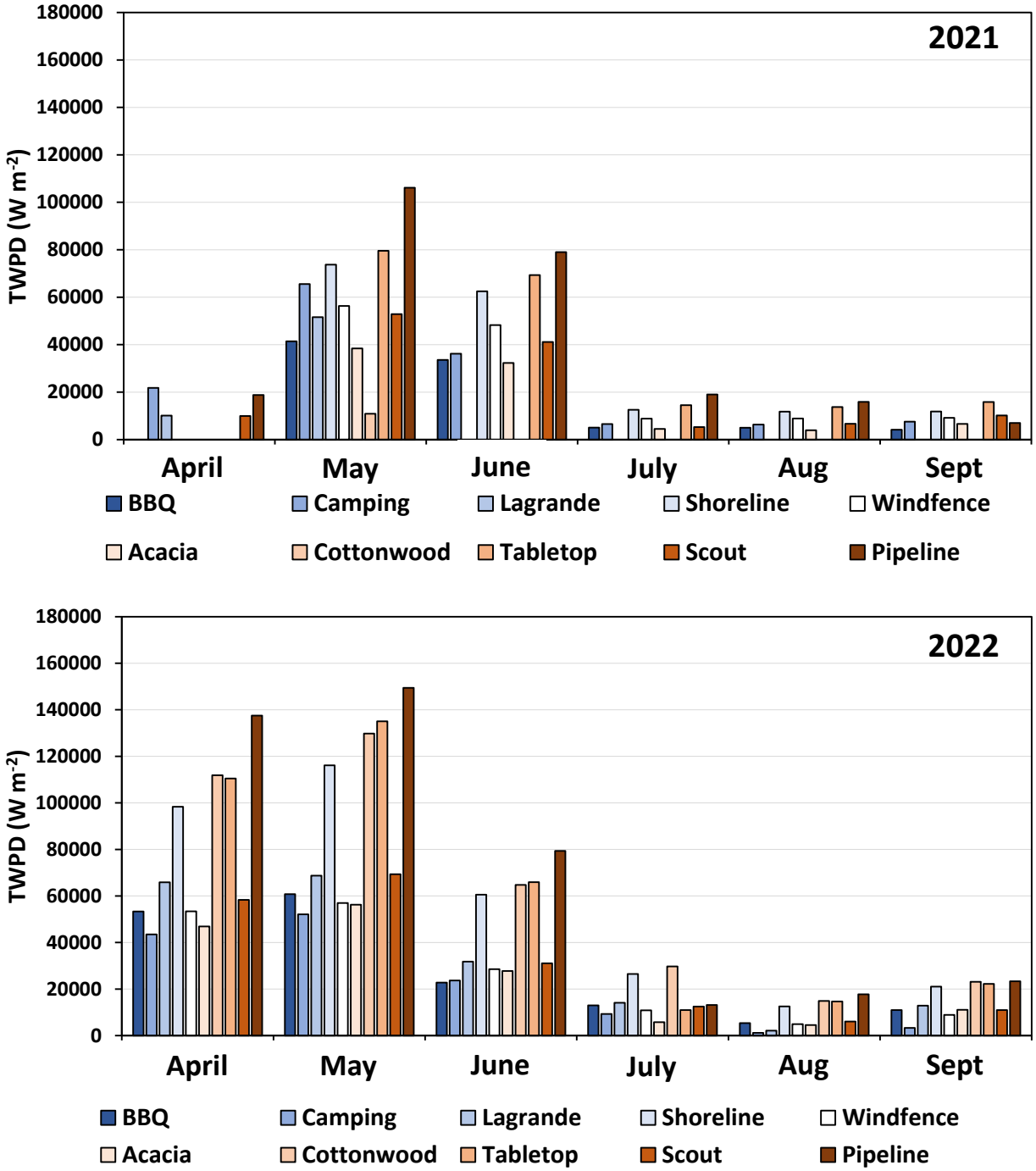


Figure 3a. The monthly TWPD (W m^{-2}) for the stations on sand-sheet areas within the ODSVRA, 2021 and 2024. The order of stations is approximately north to south.

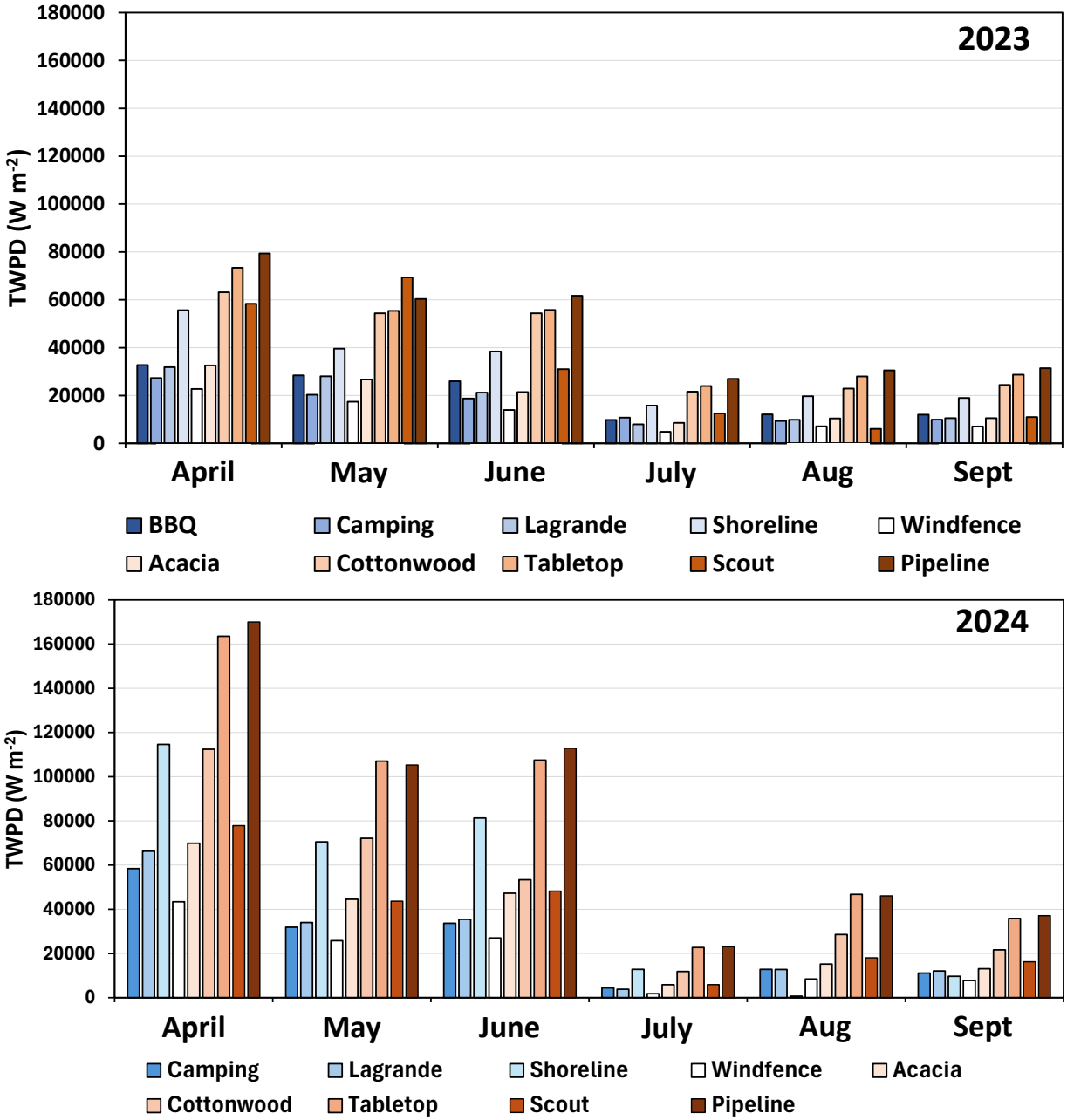


Figure 3b. The monthly TWPD (W m^{-2}) for the stations on sand-sheet areas within the ODSVRA, 2023-2024. The order of stations is approximately north to south. Note in 2024 BBQ had a high degree of instrument issues and was not included in the 2024 plot.

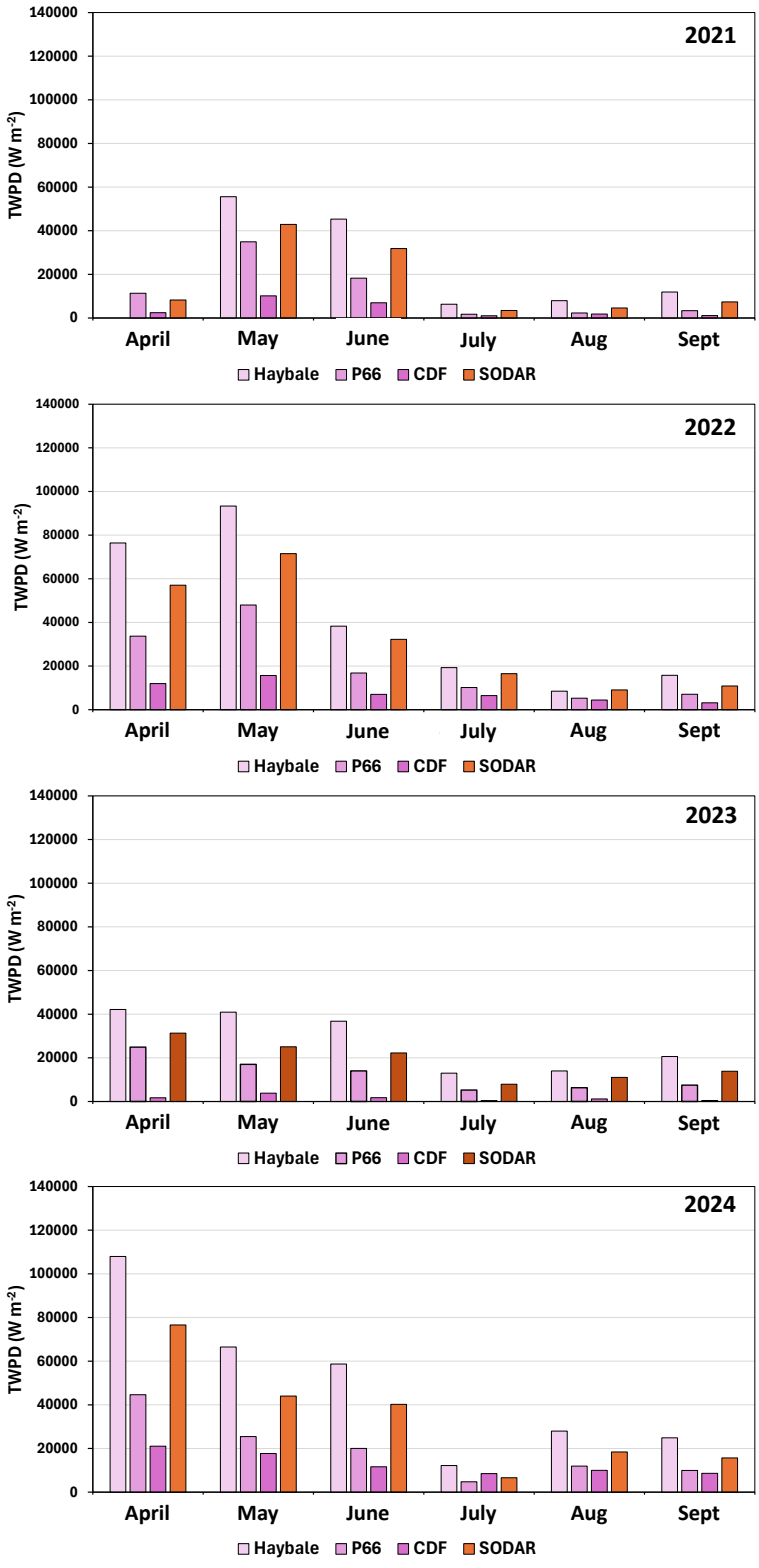


Figure 4. The monthly TWPD (W m^{-2}) for the stations located downwind of ODSVRA sand-sheet areas.

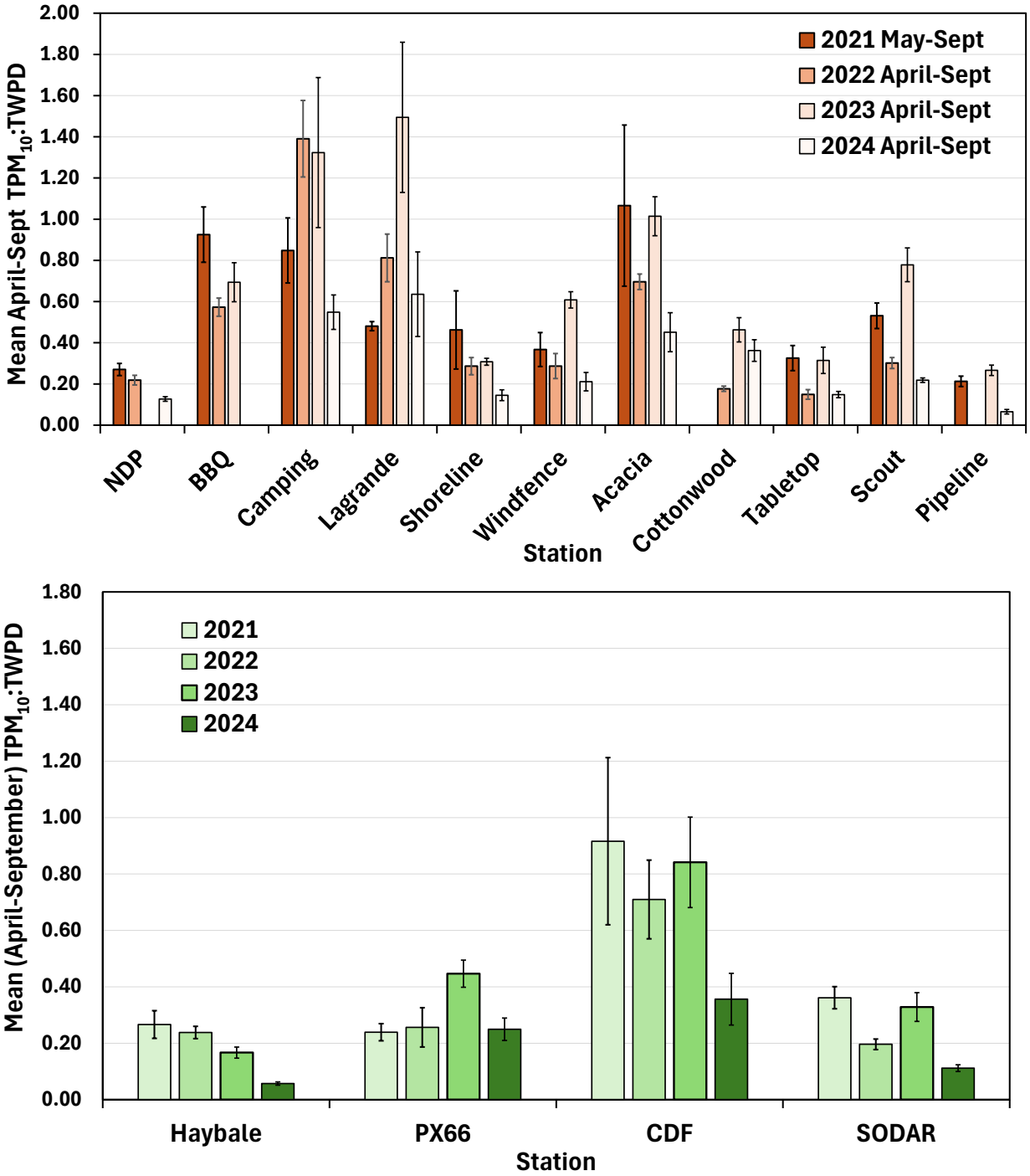


Figure 5. The monthly TPM_{10}:TWPD ratio, 2021-2024, (based on the summation of mean hourly data) for the stations that are located on sand-sheet areas of the ODSVRA (top panel) and the stations that are located downwind of ODSVRA sand-sheet areas (bottom panel). The values represent the mean ratio based on the 6 (individual) monthly ratio values. The error bar represents the standard deviation of the mean value. Note (top panel): BBQ had a high degree of instrument issues in 2024 and was not included in the plot.

Cottonwood. These stations (BBQ through to Acacia and Cottonwood) are all on the downwind (eastern) side of the "sand highway" route that is consistently used by OHV riders to access the ODSVRA riding areas that meet their personal preferences. NDP station in the non-riding area dune preserve and on a sand-sheet has lower ratio values than the stations in the northern zone of the ODSVRA where OHV activity is allowed (Fig. 5).

The data shown in Fig. 5 suggest that, in most cases, the 2024 TPM_{10}:TWPD ratios for the stations located on sand-sheet areas of the ODSVRA are the lowest values over this four-year period, except for Lagrande and Cottonwood stations. This suggests that the ODSVRA emissivity, in general, has decreased through time that is supported by the PI-SWERL emissivity data (SAG, 2025).

The stations downwind of ODSVRA sand-sheet areas (Haybale, Philips 66, Sodar, and CDF,) also show variability in the TPM_{10}:TWPD ratio across the four-year record. CDF registered the highest TPM_{10}:TWPD ratio as it has the lowest TWPD values on a monthly basis, but still has PM_{10} concentration levels similar to the monitoring stations farther to the west that experience higher wind speeds. The network based TPM_{10}:TWPD ratio for CDF is not directly comparable to the ratio reported in the Increments of Progress Reporting (Gillies et al., 2022, 2023, 2024a 2024b) as the measurement instruments, measurement heights, and measurement locations of the wind speed instruments are different (see Gillies and Nikolich, 2024 for further explanation). The stations located on sand-sheet areas of the ODSVRA characterize the relation between wind speed and PM_{10} for more localized areas of the sand surface emitting PM_{10} during periods of saltation.

The station data provides a means to examine longitudinal and latitudinal trends in PM_{10} as well as upwind and in the lee of vegetation islands. The stations Shoreline, Windfence, Acacia, Cottonwood, Haybale, Phillips 66, and CDF define a west-east transect ≈4.2 km long at an azimuth of ≈300°. The change in normalized mean hourly PM_{10} concentration (Note that the PM_{10} has been normalized by dividing by mean hourly PM_{10} concentration at a station by the mean hourly PM_{10} concentration at the Acacia station) along this transect for wind in the directional range 248°-326° and when wind speed measured at the Shoreline station was ≥5.5 m s^{-1} (same as lower limit of wind speed for defining TPM_{10}:TWPD ratio), is shown in Fig. 6 for 2021, 2022, 2023, and 2024 for each of these stations.

The normalized mean hourly PM_{10} for the six months (i.e., April through September) over these four years show Acacia has consistently had the highest mean hourly PM_{10} concentration along this transect, except in 2024 when Cottonwood had the highest mean hourly PM_{10} concentration (Fig. 6). The highest concentrations of PM_{10} are observed at Acacia and Cottonwood, with a decrease in mean concentration towards the shoreline. For these four years of normalized mean hourly PM_{10} concentration, the normalized concentration decreases

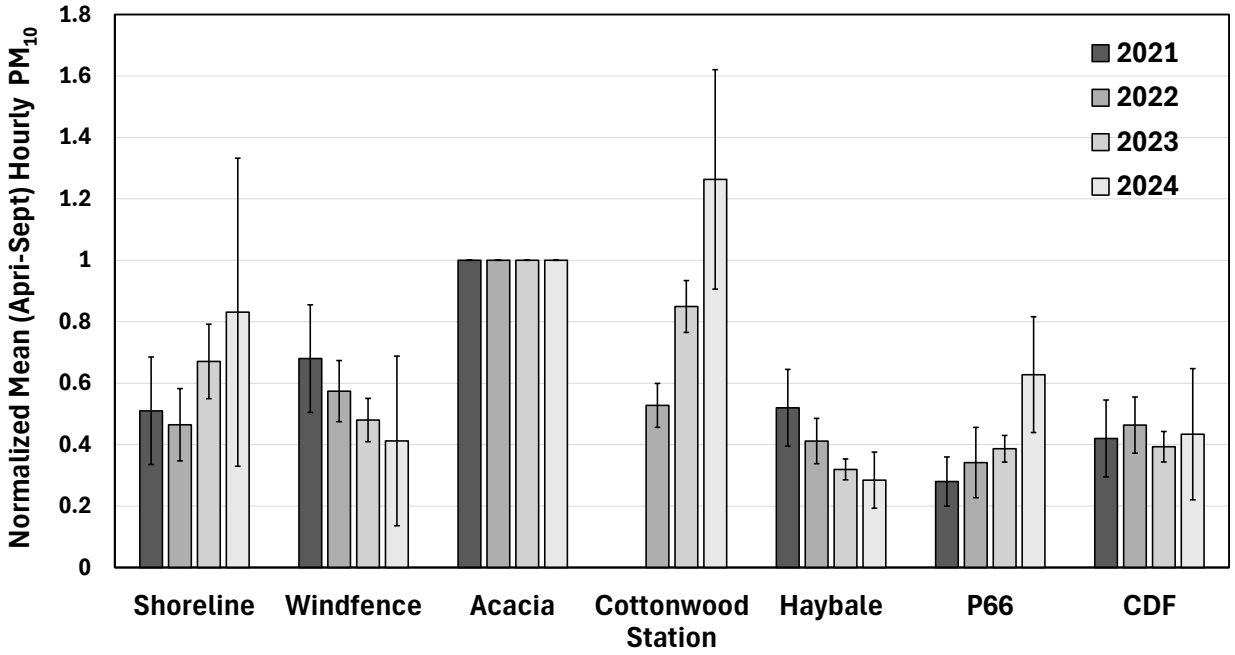


Figure 6. Normalized (to Acacia) mean hourly PM_{10} concentration for wind in the directional range 248°-326° and when wind speed measured at the Shoreline station was ≥5.5 m s^{-1}, for the combined period April-September 2021, 2022, 2023, and 2024. The values represent the mean for all the hours that meet the data filter criteria for wind speed and wind direction. The error bar represents the standard deviation of the mean value. There are no data for Cottonwood in 2021.

appreciably beginning at Haybale, which marks the eastern edge of areas with open sand upwind of this station in a non-riding area.

The stations not located on emissive surfaces and aligned on a general west to east transect, i.e., Haybale, Phillips 66, and CDF, are in the zone where dispersion and deposition processes affect the concentration of PM_{10} as emission of particles from the surface has ceased. For Phillips 66 (0.63 ±0.19) and CDF (0.43 ±0.21), the normalized mean hourly PM_{10} values under these wind direction and wind speed limitations are 40%-60% lower than those at Acacia during active dust emission conditions. The difference is lower than in previous years because the measured PM_{10} concentrations at Acacia were generally lower in 2024 than in previous years. Why Haybale station (0.28 ±0.09) is lower than Phillips 66 is not readily discernable, but this difference has now persisted for two years (2023 and 2024). It may be due to some effect of position in the landscape and the generally higher mean hourly wind speed at Haybale compared to Phillips 66 and CDF that induces more turbulent mixing.

The stations located on emissive sand surfaces in riding areas, i.e., Lagrande, Acacia, Cottonwood, Tabletop, and Pipeline align in an approximate north-south direction (azimuth

from Pipeline to Acacia is ≈356°). Along this series of stations, the increase in wind speed from north to south is demonstrated in Fig. 7, which shows the TWPD (six-month summation) for each station. Using the same six month summation period for TPM_{10}, the TPM_{10}:TWPD ratio for these six stations is shown in Fig. 8. Figure 8 illustrates that between Acacia station in the north and Pipeline station in the south there is a consistent decrease in PM_{10} concentration for equivalent wind power density levels, which indicates that the emissivity of the sand surface decreases towards the south. This further corroborates the PI-SWERL emissivity measurements spatial trend (SAG, 2023, 2025), which have also indicated the decrease in emissivity moving from north to south in the riding area. There is also a trend of increasing mean particle size for sand moving from north to south in the ODSVRA, which may also play a role in lowering emissivity moving south.

Shoreline and Windfence stations (Fig. 1) are positioned to examine the effect of a large area of vegetation on the concentration of PM_{10} in an upwind-downwind configuration (Shoreline and Windfence). The dust control/revegetation area identified as Bigfoot (Fig. 1, purple polygon with Shoreline on the west and Windfence on the east) was initiated in 2019. Gillies et al. (2024a) reported that in 2023 the mean hourly concentration of PM_{10} for the wind direction and wind speed constraints of 284°-300° and wind speed ≥5.5 m s^{-1} at the Shoreline station, the mean hourly PM_{10} concentrations at the Windfence station had become lower for the same comparable hours. Prior to 2023 the mean hourly PM_{10} concentrations at the Windfence station were higher than the Shoreline station (see Gillies and Nikolich, 2024, Fig. 10). In 2024, the pattern between the mean hourly PM_{10} concentrations for these two stations is the same as observed in 2023. The mean hourly PM_{10} concentration at Windfence (for the same wind direction and wind speed constraints) is 0.60 (±0.24) when normalized against Shoreline. This decrease in normalized mean hourly PM_{10} at Windfence compared with Shoreline in 2024 adds support that the Bigfoot revegetation dust control area is modulating the PM_{10} concentrations (i.e., lowering the PM_{10}) as the dust-laden air passes over it. This result supports that the re-vegetation management method is a critically important tool to both modulate the air flow by slowing the wind as it passes over the vegetation and demonstrably lowering the PM_{10} concentration in the dust-laden air.

Conclusions

The in-Park stations show that the concentration gradient of PM_{10} along an approximately 4.5 km long west to east transect (Shoreline to CDF) shows a consistent peak concentration occurring at the Acacia and Cottonwood stations, reflecting the greater emissivity of the sand in this area that is highly influenced by the sand highway to the west of these stations. The concentration of PM_{10} diminished by, on average, 68% (±21%) in April-September 2024 for the stations Haybale, Phillips 66, and CDF compared to the Acacia station, which are east of the open sand areas of the riding and non-riding areas of the ODSVRA. This decrease in concentration reflects the change from an area where emissions of PM_{10} are occurring, i.e., on

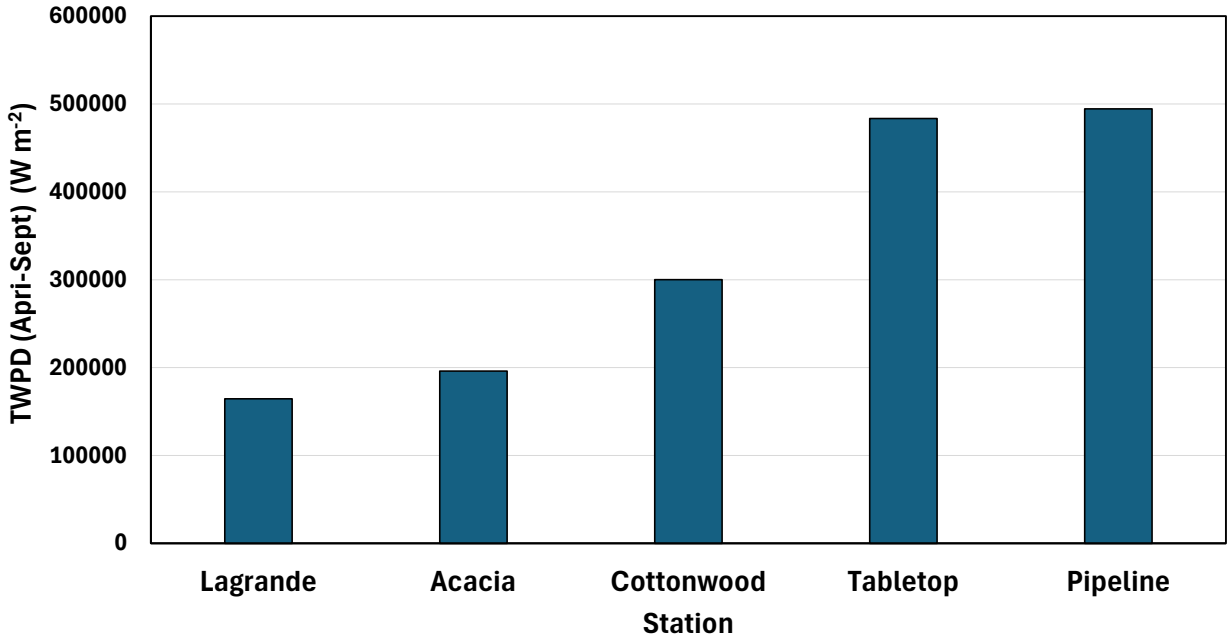


Figure 7. TWPD (W m^{-2}) (summed for April-September 2024) along a north to south transect from Lagrande in the north to Pipeline in the south.

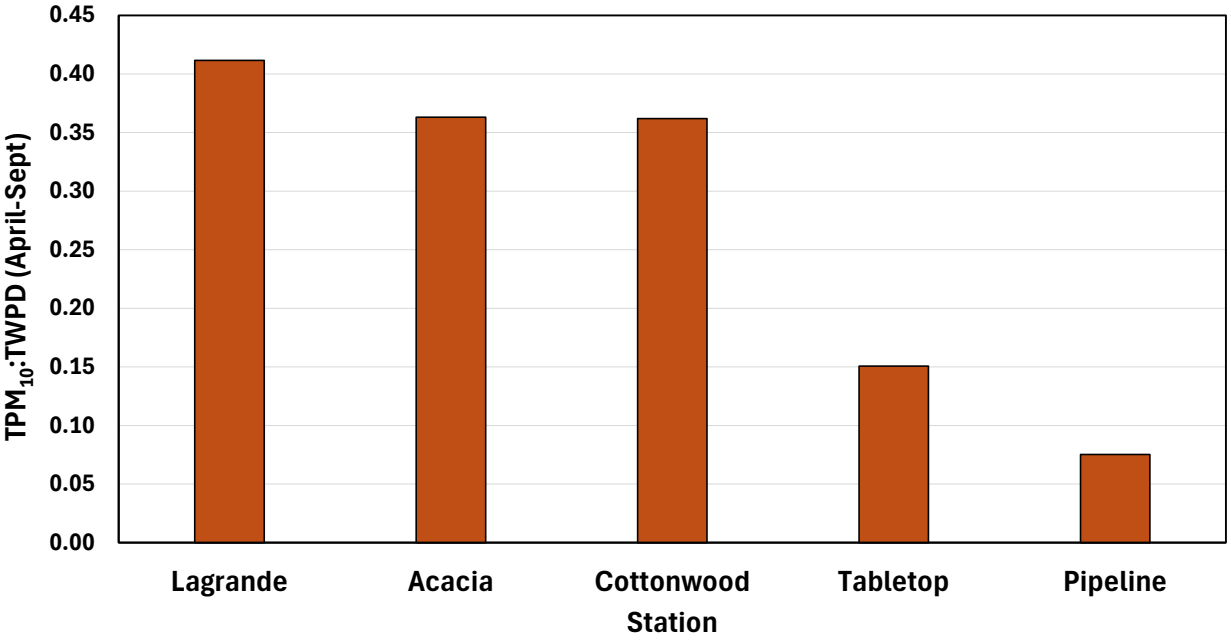


Figure 8. TPM_{10}:TWPD (summed for April-September 2024) along a north to south transect from Lagrande in the north to Pipeline in the south.

the sand sheet areas, to one in which dispersion and deposition dominate the transport process. Beginning at Haybale and extending to CDF the surface becomes non-emissive with respect to dust emissions as it is covered by vegetation. Across the distance from Haybale to CDF dispersion and deposition processes will tend to decrease particulate matter concentration with increasing travel distance.

The 2024 wind speed and wind power density data (Figs. 2 and 7) show that for the north-south distance covered by the network the wind speed was higher in the south than the north, which corroborates what has previously been reported and indicates that this pattern has persisted since monitoring was initiated. The station PM_{10} and wind speed data combined also show (Fig. 8) that the PM_{10} concentrations for the same wind power density are higher in the northern stations indicating that the emissivity of the sand surfaces upwind of these stations remains high in relation to the other stations and is still a rich source area for PM_{10} emissions. The high PM_{10} concentrations and emissivity in this area may be due to the presence of the "sand highway", which remains a high use area for OHV. The gradient of decreasing emissivity from north to south has also been observed in the PI-SWERL data. The 2024 TPM_{10}:TWPD data (Fig. 8) indicates that this pattern has persisted since the monitoring was initiated.

The difference in the PM_{10} concentration data between the stations Shoreline and Windfence, which lie on either side of a large re-vegetation area, show that in 2023 and 2024 the downwind station Windfence has lower mean hourly PM_{10} concentrations than Shoreline. This supports the suggestion made by Gillies and Nikolich (2024) that the re-vegetated area is of sufficient size, plant cover density, and low (or zero) emissivity to influence the dispersion and deposition processes such that the downwind concentrations are lower than the upwind. This further supports that the re-vegetation method for reducing dust emissions from the ODSVRA is highly effective.

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May 15, 2025

Memo: SAG Review of Desert Research Institute (DRI) "Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024"

From: Scientific Advisory Group (SAG)

To: Jon O'Brien, California Department of Parks and Recreation

Cc: Ronnie Glick, California Department of Parks and Recreation

The Scientific Advisory Group (SAG) received a copy of the Desert Research Institute (DRI) "Report of Findings: ODSVRA Meteorological and PM_{10} Monitoring Network, 2024" on April 17, 2025 via e-mail, and SAG members have had the opportunity to review the document. This memo provides feedback on the DRI report[1].

The report summarizes the latest results, acquired in 2024, from the wind and dust monitoring network, which comprises multiple stations distributed within the ODSVRA and supplemented with additional stations downwind of the ODSVRA. The results from 2024 are contextualized using similar data collected in 2021, 2022, and 2023. The data were presented in summary form using hourly values that are averaged over monthly and seasonal (April – September) periods.

The key findings of the report are that:

1. The data trends in 2024 are consistent with those from earlier years (2021 – 2023), recognizing that there is year-to-year variability in wind strength as represented by Total Wind Power Density (TWPD);
2. There is a marked decrease in TWPD from the spring months of April, May, and June (large TWPD) to the summer months of July, August, and September (small TWPD);
3. There is a general increase in wind speed from the north to the south;
4. There is a general decrease in normalized PM_{10} concentrations from north to south, as represented by the ratio of Total PM_{10} divided by Total Wind Power Density (TPM_{10}/TWPD), consistent with results from multiple PI-SWERL campaigns showing that surface dust emissivity decreases from north to south (likely due to grain size trends);
5. There is a persistent local maximum of normalized PM_{10} concentrations at the Acacia and Cottonwood stations, located at the eastern margin of ODSVRA in the central-north zone of the riding area, as well as at the northern stations known as BBQ, Camping, and Lagrande, all of which are situated immediately downwind of an intensely used OHV corridor known as the 'sand highway';
6. There is a general west-east trend in TPM_{10}/TWPD that indicates that dust emissions increase from the shoreline in the inland direction across the ODSVRA and then decrease beyond the Park boundary toward monitoring stations such as CDF; and,

[1] Standard procedure for SAG review of DRI reports is for Dr. Jack Gillies to recuse himself from the discussions due to a potential conflict of interest. Despite being a SAG member in good standing, Dr. Gillies did not participate in this review in any manner nor was DRI consulted about any aspect of this review.

7. There is compelling evidence, when comparing the results from the Shoreline station with those from the Windfence station, suggesting that dust concentrations immediately downwind of vegetated treatment zones are smaller than those measured upwind of the treatment zones, indicating the potential effectiveness of surface vegetation cover in both reducing surface dust emissions and trapping or capturing near-surface dust coming from upwind sources.

In last year's review of the 2023 DRI report, SAG members made the following recommendations for possible improvement of the DRI report:

A. In future reports (or as a separate exercise), an analysis should be undertaken of dust dynamics during specific wind events. This might involve using hourly values across a 24-hour period or perhaps 10-minute averages across an 8-hour period when dust concentrations are particularly high. The intent would be to understand how dust plumes are generated and eventually make their way to monitoring stations such as CDF.
B. In future reports, it would be useful to tie the metrics used in the current report (e.g., monthly averages of TWPD and TPM_{10}/TWPD) to measures used by regulatory agencies to define exceedance events (i.e., 24-hr PM_{10} concentrations). The objective is to use the scientific results to inform management and regulatory efforts directly in ways that are meaningful and easy to understand.

These recommendations have not been addressed in this report, but the SAG suggests that attention to them would provide value-added to this, and future, reports.

In reviewing two DRI reports (Increments of Progress; Meteorological and PM10 Monitoring Network), the SAG noted some inconsistencies that cause confusion. Foremost among these is the use of a different directional window for filtering the wind speed data that are used in the analysis. Is this a typo or were different windows used? If the latter, why? Is it not possible to be consistent in how the data are analyzed? On a related matter, some of the data presented in the Monitoring Network report seem to cover a four-year period (2021 – 2024) whereas for other graphics only three years are covered (e.g., Figure 6), and in another case the data from 2024 were not included, which is the subject of this report (e.g., Figure 5).

In general, the SAG would encourage DRI to be more careful in presenting the results and to proof-read the document thoroughly before submission. A marked-up copy of the original report will be sent under separate cover, which will indicate where in the document improvements are possible. The final report will be a welcome addition to the body of knowledge that informs the air quality program at the ODSVRA.

Respectfully,

The Scientific Advisory Group

Bernard Bauer (Chair), Jenny Hand, Leah Mathews, Ian Walker

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ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 04

ODSVRA Emissivity PI-SWERL Update Report (2013 – 2024) (SAG Report)

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ODSVRA PI-SWERL Emissivity Update Report (2013-2024)

Introduction

The Desert Research Institute (DRI) has collected PI-SWERL emissivity measurements in the Oceano Dunes State Vehicular Recreation Area (ODSVRA) since 2013, and undertook another comprehensive sampling campaign in 2024. The 2024 campaign was conducted in two stages (May and September), consisting of measurements at 981 locations distributed across the ODSVRA, with some locations repeat-sampled. This report summarizes the results from the 2024 campaign and places them in the context of prior measurements.

Overview of the 2024 Measurement Campaign

The 2024 campaign was conducted in two stages in May and in September following protocols adopted in prior measurement years, particularly the 2019 campaign**. A total of 365 locations were sampled in May, 2024, with primary focus on the Riding Area (n = 277) and Non-Riding Area (n = 88).** The month of May tends to have less precipitation than earlier months, making it ideal for a PI-SWERL sampling, which often lasts two weeks or longer. A second series of PI-SWERL measurements was undertaken in September, 2024, shortly after the restrictions on access to the sensitive plover nesting and rearing habitat was lifted. **The September campaign consisted of 308 measurement locations with focus on the Non-Riding Area (n = 105), Foredune Restoration Area (n = 67), Plover Exclosure (n = 30), and Seasonal Exclosure Area (n = 44).** Additional measurements were taken in the Central-South zone of the Riding Area (n = 62) to duplicate measurements made at sites during the May campaign to further investigate seasonal influences on potential dust emissions. Several of the sites in the Non-Riding Area were sampled during May and September for the same purpose.

A separate series of PI-SWERL measurements (n = 135) was taken in May, 2024, to examine the potential impact on emissivity of mechanical raking of the beach. These measurements are discussed in an internal DRI report, and will not be considered herein. Given that the data from this experiment were clustered in a very small area over a relatively short period, a decision was made not to incorporate them into the global data set of measurements used to develop power emissivity curves. These 135 measurements will not be considered further in this report.

PI-SWERL Measurement Locations in 2024

The locations of PI-SWERL measurements during the May, 2024, and September, 2024, campaigns are shown in Figure 1. Many sites were duplicated during both campaigns, especially those in the Non-Riding Area (north, central, south) as well as along two extensive west-east transects within the Riding Area. The sampling design mimicked that of the 2019 campaign to the extent that access and logistics allowed for re-sampling of specific sites. Many locations were no longer accessible or presented

hazardous conditions for the field crew. Overall, 2024 was the most comprehensive campaign undertaken to date, with broad coverage of the entire ODSVRA to the extent logistically feasible.

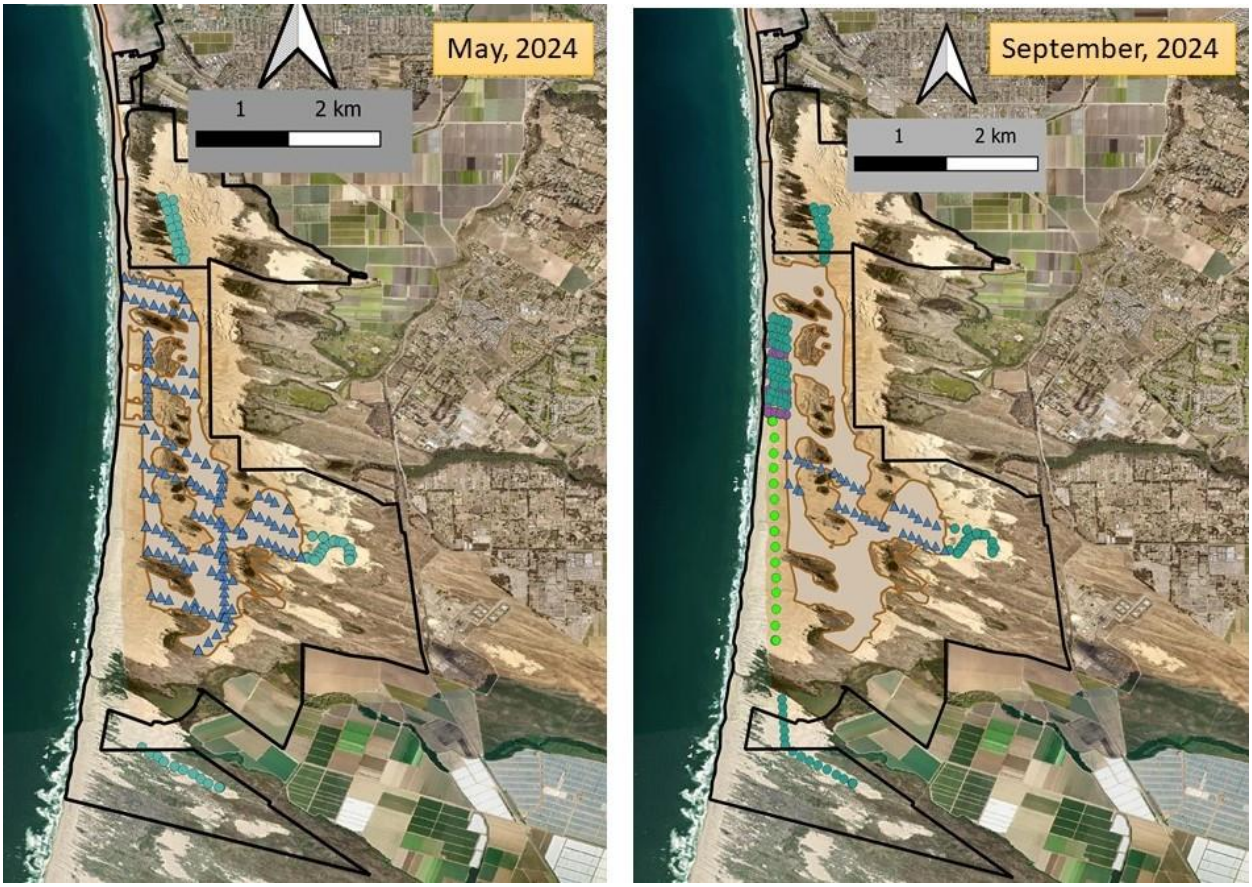


Figure 1: PI-SWERL measurement locations for the May, 2024 (left) and September, 2024 (right) sampling campaigns. Circles indicate sites within zones designated as non-riding; triangles are for sites designated for OHV riding access, either all year around or seasonally. Light tan polygon shows the extent of the riding area. Black line indicates ODSVRA boundary.

The footprint of the Riding Area (RA) and the Non-Riding Area (NRA) has changed since 2013 as a consequence of dust-mitigation efforts by the California Department of Parks & Recreation (CDPR), leading to closure of some areas that used to be OHV-accessible and are now designated as non-riding. Such closures were invariably followed by surface treatment such as covering of open sand surfaces by straw and/or vegetation planting, which complicates direct analysis of temporal changes in surface emissivity[1]. Specifically, some locations associated with measurements during which OHV access was allowed are now in areas designated as non-riding. And, in many cases, those locations are no longer accessible for PI-SWERL measurement because they are completely covered in vegetation. Other management zones such as the Foredune Restoration Area (FRA) and the Plover Exclosure (PE) are now

[1] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/SAG%20Memo_Emissivity%20Grids%20for%20Future%20Modeling%20of%20Excess%20Emissions%20-%2020231219.pdf

closed permanently but there was OHV access (either all year or seasonally) in prior years. Thus, each of these zones needs to be treated independently, and the precise locations (and categorization) of the PI-SWERL measurements needs to be tracked using GIS software.

Trends in Emissivity Values between 2013 and 2024

Areas designated as Riding (RA) or Non-Riding (NRA)

Table 1 shows the number of PI-SWERL measurement locations in the RA and NRA for each of the sampling campaign years from 2013 to 2024, disaggregated according to the zones used for management and modeling (refer to 2024 ARWP). The majority of measurements were taken in the Central-South zone of the RA (n = 828), followed by the Central-North zone of the RA (n = 495) and then by the Central zone of the NRA (n = 313). Overall, there were 1323 measurement locations in the RA and 592 in the NRA, reflecting the need for critical information from OHV-influenced sand surfaces but also the fact that the NRA is increasingly inaccessible for PI-SWERL sampling.

		RIDING AREA			NON-RIDING AREA			
YEAR	MONTH	Central-North	Central-South	ALL	North	Central	South	ALL
2013	8	76	110	186	66	36	41	143
2014	9	19	26	45		35		35
2015	6	13	87	100		2		2
	10	49	116	165		6		6
2016	3	47	11	58		34		34
2019	5	154	183	337	35	89		124
	10	42		42		2	26	28
2022	5	15	36	51	10	17		27
2024	5	80	197	277	27	46	15	88
	9		62	62	32	46	27	105
	SUM	495	828	1323	170	313	109	592

Table 1: Distribution of PI-SWERL measurement locations according to campaign year for the management/modeling zones in the RA and NRA.

The statistical distribution of PI-SWERL results for the RA Central-North zone and RA Central-South zone are represented as box-and-whisker plots for each of the campaign years in Figure 2, for three different PI-SWERL shear velocities (u_*). As noted in a previous SAG report[2], the 2013 measurements are statistically different from all other campaign years, with much larger emissivity values, especially in the Central-North zone. Since then, there have been only minor variations from year-to-year, many of which are not statistically different from one another. The 2024 emissivity values are very similar to those in 2019, with both campaigns covering most of the ODSVRA using a large number of sampling locations. For the Central-South zone, the measurements taken in May, 2024, have the smallest emissivity values, on average, relative to all other campaign years. This was not the case for the Central-North zone. However, the emissivity values in the Central-South zone increased from May to September, 2024, returning to levels similar to those in prior years. No measurements were taken in the Central-North zone during the September, 2024 campaign, so there is no direct comparison for assessment of the trend increase from spring to fall in 2024.

The statistical distribution of PI-SWERL results for the three zones (North, Central, South) of the NRA are presented in Figure 3. There is a gradual decline in emissivity values from north to south, and this is evident for 2013, 2019, and 2024 when large numbers of measurements were taken in each of the three zones in each year (see Table 1). Measurements in the Central and South zones during the two campaigns in 2024 indicate that the May averages were smaller than the September values, which was also the case for the RA Central-South zone (see Figure 2). Similarly, the May, 2024, values were the smallest overall, while the September, 2024, values were in line with those measured in 2019. It is noteworthy that the measurement spread (variance) is relatively small in the NRA South zone and also for the 2024 measurements in the NRA Central zone, but this may simply be a function of the limited spatial coverage of the sampling points (refer to Figure 1) relative to previous years when there was better access to many other sampling locations. In other words, this may be due to a sampling bias rather than a real temporal trend in emissive potential. This is clearly not the case for the RA samples, which are greater in overall number as well as more widespread in spatial coverage.

Finally, it should be noted that the emissivity values in the RA are substantially greater (up to three times) on average than those in the NRA, as indicated by the scales of the vertical axes in Figure 2 versus Figure 3.

[2] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/SAG%20Memo_Emissivity%20Grids%20for%20Future%20Modeling%20of%20Excess%20Emissions%20-%2020231219.pdf

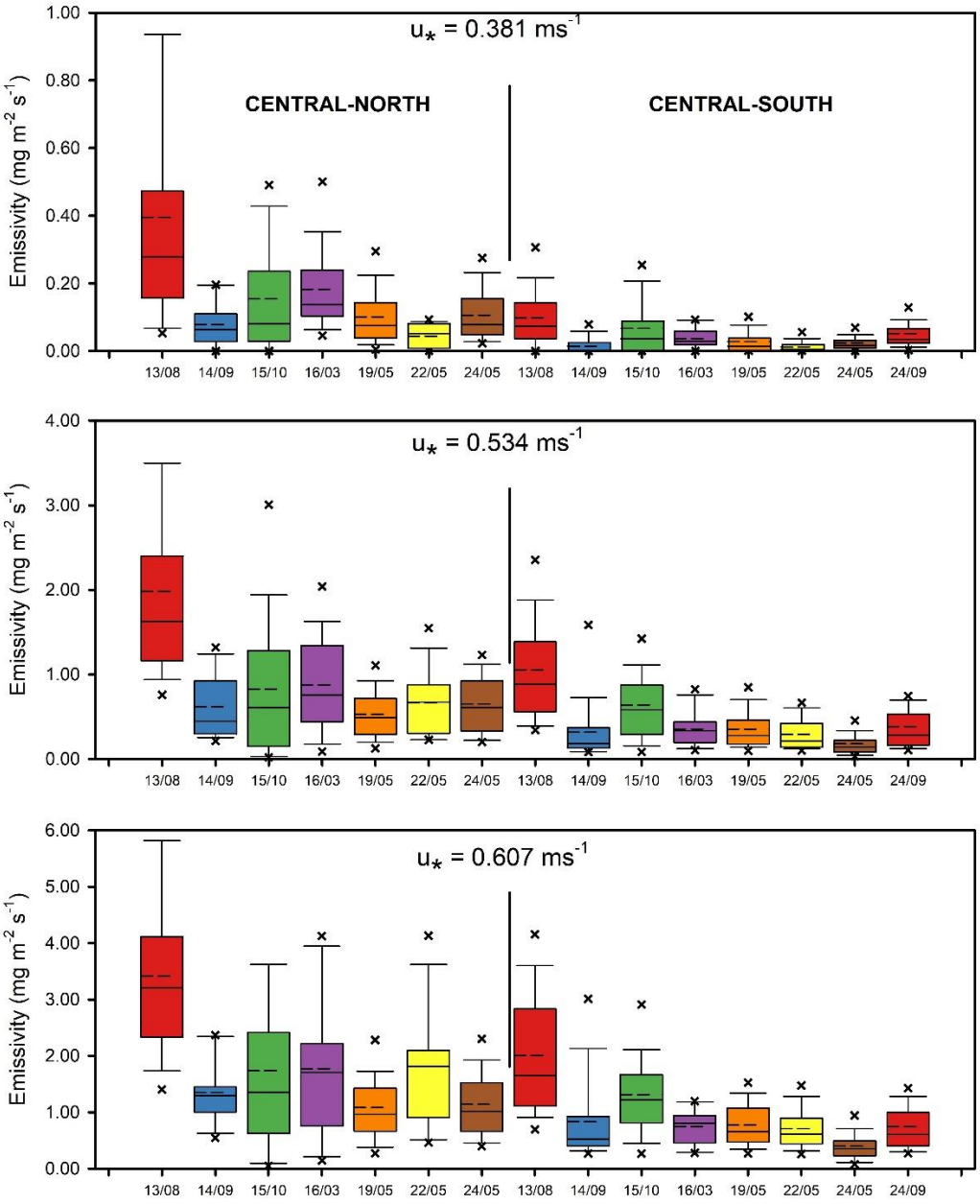


Figure 2: Box-and-whisker plots of PI-SWERL emissivity measurements in the RA for all sampling campaigns between 2013 and 2024, inclusive. Horizontal axes show dates given as year and month (yy/mm). The colored boxes define the range of the 25th and 75th percentiles; the whiskers correspond to the 10th and 90th percentiles; and the outer symbols (x) indicate the 5th and 95th percentiles (note that 95th percentile for 2013 falls above the graph range). The median value is given by the horizontal solid line within the box, whereas the arithmetic mean (average value) is shown by the horizontal dashed line. The black vertical line separates Central-North zone from the Central-South zone. The three panels (upper middle, lower) correspond to the three RPM speeds (low, medium, high) used in the PI-SWERL device to characterize dust emissions at any single measurement location. The measurements from two campaigns in both 2015 and 2019 were combined in this graph, whereas the May and September, 2024, campaigns are represented separately.

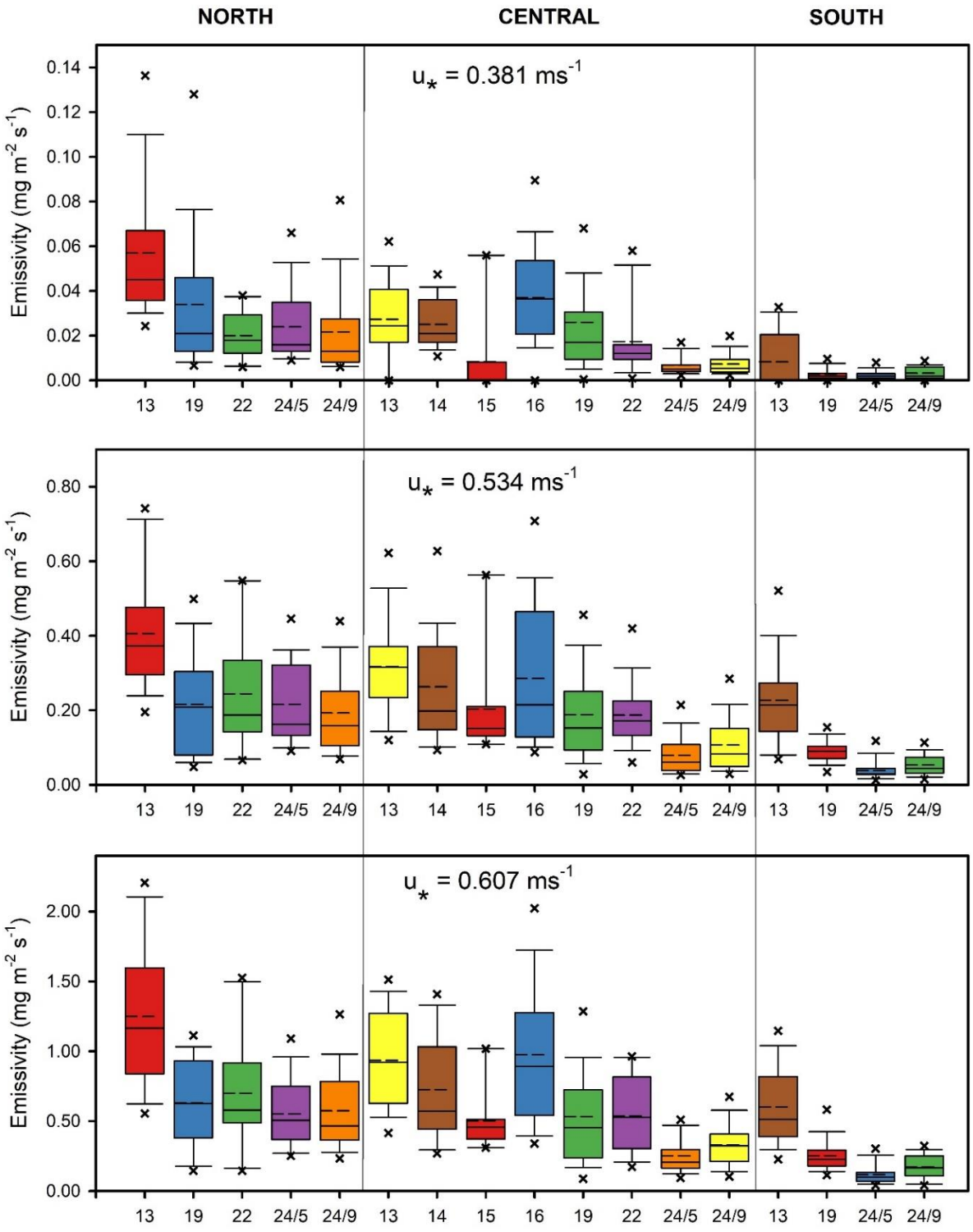


Figure 3: Box-and-whisker plots of PI-SWERL emissivity measurements in the NRA for all sampling campaigns between 2013 and 2024, inclusive. See Figure 2 for explanation of symbols and interpretation of box plots. Horizontal axis shows dates given as year only (yy) except for the 2024 campaign which has year and month (yy/mm). Note that the Central zone was sampled during every campaign year but the North and South zones were not (see Table 1).

Foredune Restoration Area (FRA)

The FRA was fenced off in December, 2019, and subsequently treated with experimental plantings in February, 2020. Prior to closure, this zone was accessible to OHV traffic and camping activities throughout the entire year, and hence the footprint of the FRA was designated as a riding area prior to late 2019. The surface emissivity was measured at 72 sampling sites in this zone using the PI-SWERL during the riding period, and these measurements are all included in the pooled data for the RA Central-North zone for purposes of calculating emissivity power relations. These 72 measurements (designated by italics in Table 2) were not used to calculate emissivity power relations for the FRA. A total of 110 sampling sites in the FRA were measured in September, 2022, 33 months following closure, and another 67 sites were sampled in September, 2024, bringing the total to 177 measurements points for purposes of calculating the FRA emissivity power relations.

		FRA		
YEAR	MONTH	RA Before FRA	Post-closure	
2013	8	*8*		
2014	9	*3*		
2015	6			
	10	*19*		
2016	3	*8*		
2019	5	*18*		
	10	*16*		
2022	9		110	
2024	9		67	
	SUM	*72*	177	249

Table 2: Distribution of PI-SWERL measurement locations according to campaign year for the FRA.

The statistical distribution of PI-SWERL results for the FRA are presented in Figure 4 for three periods: (1) pre-2019 when riding was allowed; (2) September, 2022; and (3) September, 2024. It is clearly evident that the period of OHV access and camping had much larger emissivity values than those following closure and treatment. Statistically, the values in 2022 are identical to those in 2024.

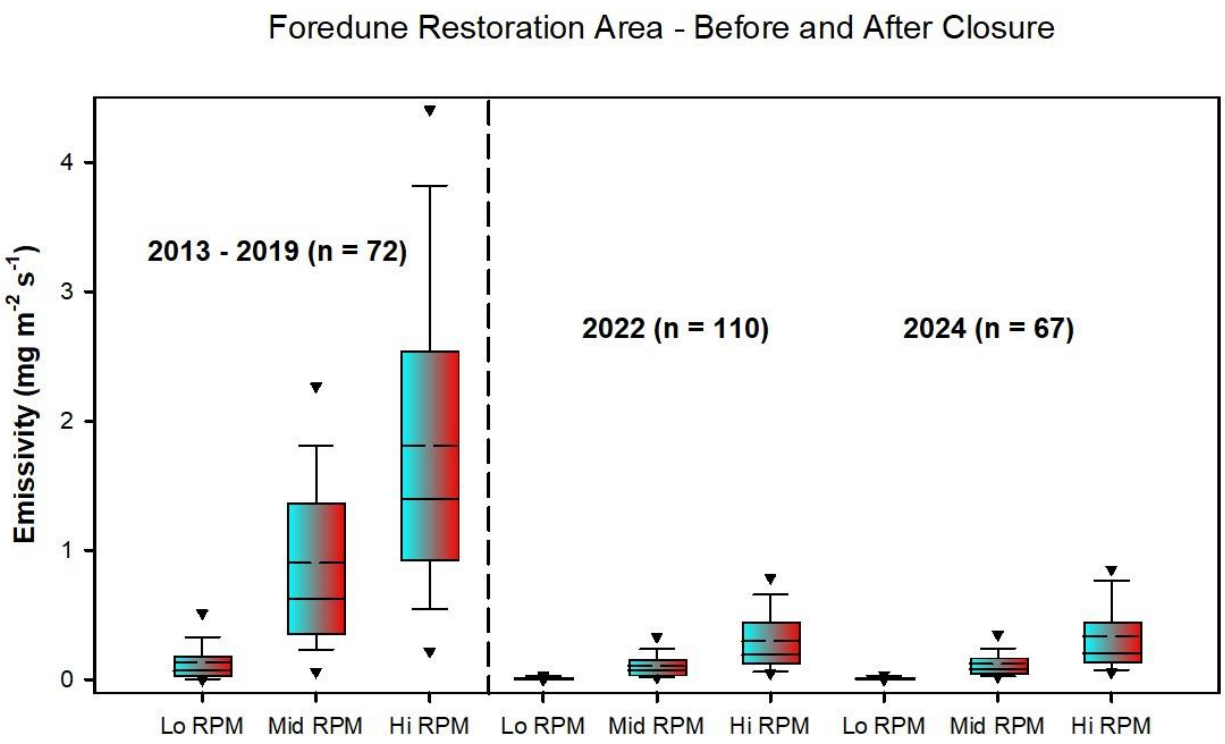


Figure 4: Box-and-whisker plots of PI-SWERL emissivity measurements in the FRA for all sampling campaigns between 2013 and 2024, inclusive. The 'Lo', 'Mid', and 'Hi' RPM settings correspond to shear velocities of 0.381 ms^{-1}, 0.534 ms^{-1}, and 0.607 ms^{-1}, respectively, as shown in Figures 2 and 3. Measurements between 2013 and 2019 reflect the influence of OHV traffic prior to implementation and closure of the FRA. See Figure 2 for explanation of symbols and interpretation of box plots.

Plover Exclosure (PE)

As per the conditional approval of the 2022 ARWP[3], dust emissions from the PE area were to be calculated using PI-SWERL emissivity measurements made in late September, 2022 (n = 23). The rationale for this was that, prior to October 1, 2021, the PE was not permanently closed to OHV traffic and camping. Previously, the area was 'seasonally exclosed' meaning that OHV traffic was not allowed between March 1 and September 30 of every year, but the area was open to recreational riding in the winter season between October 1 and February 28. Thus, the September 2022 data set was the first one available that characterized this zone during a management regime of permanent closure. Given that the area was closed to OHV access between March 1, 2021, through September 30, 2021, as part of the standard seasonal exclosure management regime, the September, 2022, measurements reflect 18 months of post-disturbance adjustment.

A series of measurements (n = 198) were made in the footprint of the current PE area between 2013 and 2019 during the seasonal closure period. However, since this area could not be classified as

[3] https://storage.googleapis.com/slocleanair-org/images/cms/upload/files/Final%20Conditional%20Approval%20-%20Revised.pdf

exclusively 'riding' or 'non-riding' for purposes of analysis, these data were not used to generate emissivity power relations for either the riding or non-riding areas, as reported in a SAG document entitled '***Updated SAG Recommendations for Establishing Emissivity Grids to be used in Modeling of Pre-Disturbance Conditions and Future Excess Emissions Reduction'*** (December 19, 2023). The SAG undertook a detailed analysis of those 198 PI-SWERL measurements in the Plover Exclosure (PE), and the results were discussed in a 2024 report to the APCD and CDPR[4].

Table 3 presents the number of samples taken in the footprint of the PE during every campaign year when there was seasonal exclosure (2018 – 2021) and after the PE was closed to OHV traffic (2022 through 2024). The 2024 data were collected in a north-south transect down the middle of the PE that loosely follows the one used since 2015.

		PLOVER EXCLOSURE		
YEAR	MONTH	Seasonal	Closed	
2013	8	19		
2014	9	39		
2015	6			
	10	90		
2016	3	23		
2019	5			
	10	27		
2022	9		23	
2024	9		30	
	SUM	198	53	251

Table 3: Distribution of PI-SWERL measurement locations according to campaign year for the PE.

Figure 5 shows the statistical distribution of PI-SWERL measurements for each campaign year, represented as box-and-whisker plots. Since closure in 2021, the measured emissivity values have been very small relative to prior years (also in contrast to other areas, with the exception of the FRA). The values in 2024 are only slightly greater, on average, than those in 2022, but these are both much smaller than those measured during the seasonal exclosure period. The measurements in 2013, 2014, and 2015 were made immediately after the end of the summer exclosure period, when access was first allowed

[4] SAG Memo data January 12, 2024. 'Analysis of PI-SWERL Measurements in Plover Exclosure Area.'

for PI-SWERL emissivity measurements but before significant disturbance by OHV traffic. The 2019 measurements were made after a few weeks of OHV access, and the larger spread in the data would seem to reflect sampling of both OHV-disturbed and relatively undisturbed sites. In contrast, the campaign in 2016 was undertaken at the end of the riding period and before closure, as reflected in the significantly larger mean emissivity values than any other year.

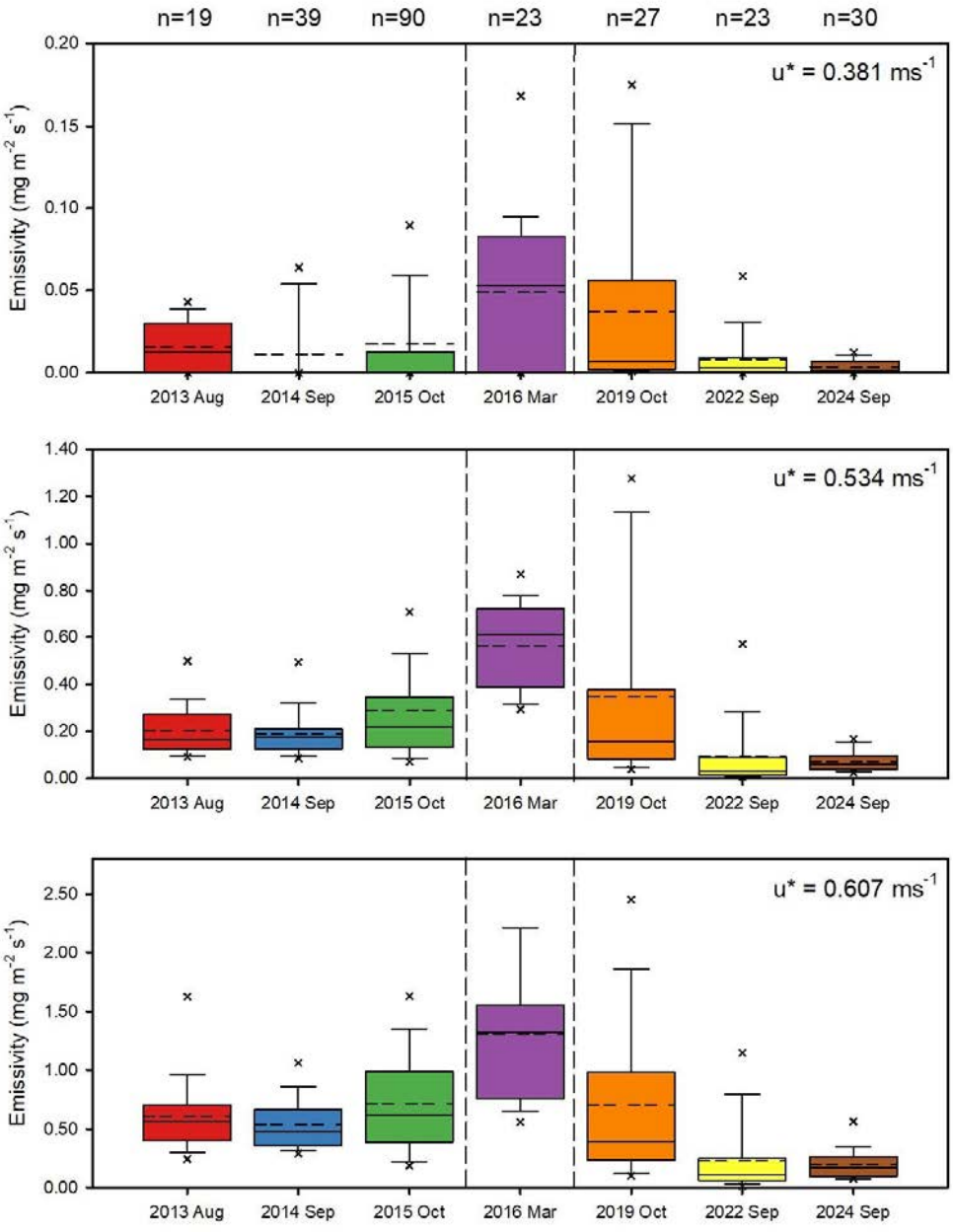


Figure 5: Box-and-whisker plots of PI-SWERL emissivity measurements in the PE for all sampling campaigns between 2013 and 2024, inclusive. See Figure 2 for explanation of symbols and interpretation of box plots. Note that the PE was closed permanently in 2021, so earlier campaigns reflect seasonal exclosure with OHV access between October 1 and February 28. Vertical dashed lines isolate the March, 2016, measurements from all others as being different (see text for details).

Seasonal Exclosure (SE) Area

Figure 6 shows the areas adjacent to the experimental FRA that have been managed for Seasonal Exclosure (SE) since 2020, which means that OHV access is allowed during part of the year (October 1 through February 28) followed by a period of closure (March 1 through September 30) when there is no vehicle access. Thus, this area is neither exclusively 'riding' nor 'non-riding' and requires separate consideration from other areas in the ODSVRA, similar to the FRA and PE.

There are two sub-zones within the current SE area: (1) a continuous, narrow beach strip that lies to the west of the FRA; and (2) three access corridors, two of which divide the FRA and a third, situated at the southern-most access corridor separating the PE and FRA. The beach strip and the western sections of the three corridors are managed for seasonal access only, but the eastern entry areas to the corridors are OHV accessible year-around to facilitate access to toilets (situated in the semi-circular cut-outs in the corridors). It is essential to separate out those PI-SWERL measurements made in the eastern entry areas and to tag them consistently as riding influenced, whereas all other measurement locations are tagged as either riding influenced or not-influenced depending on the season.



Figure 6: Map of the SE area (in grey) with locations of PI-SWERL measurements (purple circles) during the September 2024 campaign. Light green shows the FRA.

Table 4 shows the number of PI-SWERL emissivity measurements made in the footprint of the SE area since 2013. Until establishment of the FRA in December, 2019, the SE area was not defined as a separate management zone—it was part of the riding area with OHV access all-year around. A small handful of measurements made in the footprint of the SE between 2013 and 2020 were classified as 'riding' and they were aggregated with the RA data set (these measurements are indicated as italicized numbers in the table). The first extensive measurement campaign following establishment of the SE area was conducted in September, 2022, at the end of the closure period. Of the 69 measurements from that campaign, 24 of them were made in the eastern entry areas with all-year access or noted to have been disturbed by maintenance operations immediately prior to sampling. Thus, these 24 measurements were designated as riding-influenced. Another extensive campaign was conducted in September, 2024, with 15 of them in the riding-influenced corridors and 29 in the closed areas.

		SEASONAL EXCLOSURES		
YEAR	**MONTH**	**Open Riding**	**Closed**	
2013	**8**	*3*		
2014	**9**	*5*		
2015	**6**			
	10	*4*		
2016	**3**	*12*		
2019	**5**	*2*		
	10	*7*		
2022	**9**	24	45	
2024	**9**	15	29	
	SUM	**72**	**74**	**146**

Table 4: Distribution of PI-SWERL measurement locations according to campaign year for the SE areas. Italicized numbers between 2013 and 2019 indicate measurements prior to establishment of the SE in December, 2019, all of which are designated as 'riding-influenced'.

Figure 7 shows the statistical distribution of PI-SWERL measurements for the two campaign years (2022 and 2024) after the SE was established as a distinct management zone. The riding-influenced measurements (two left plots) have larger means (medians) and broader distributions than the

measurements made at the end of the closure period (two right plots). The measurements in 2024 appear to have slightly smaller emissivity values than those in 2022, but this difference is small and has not been tested statistically.

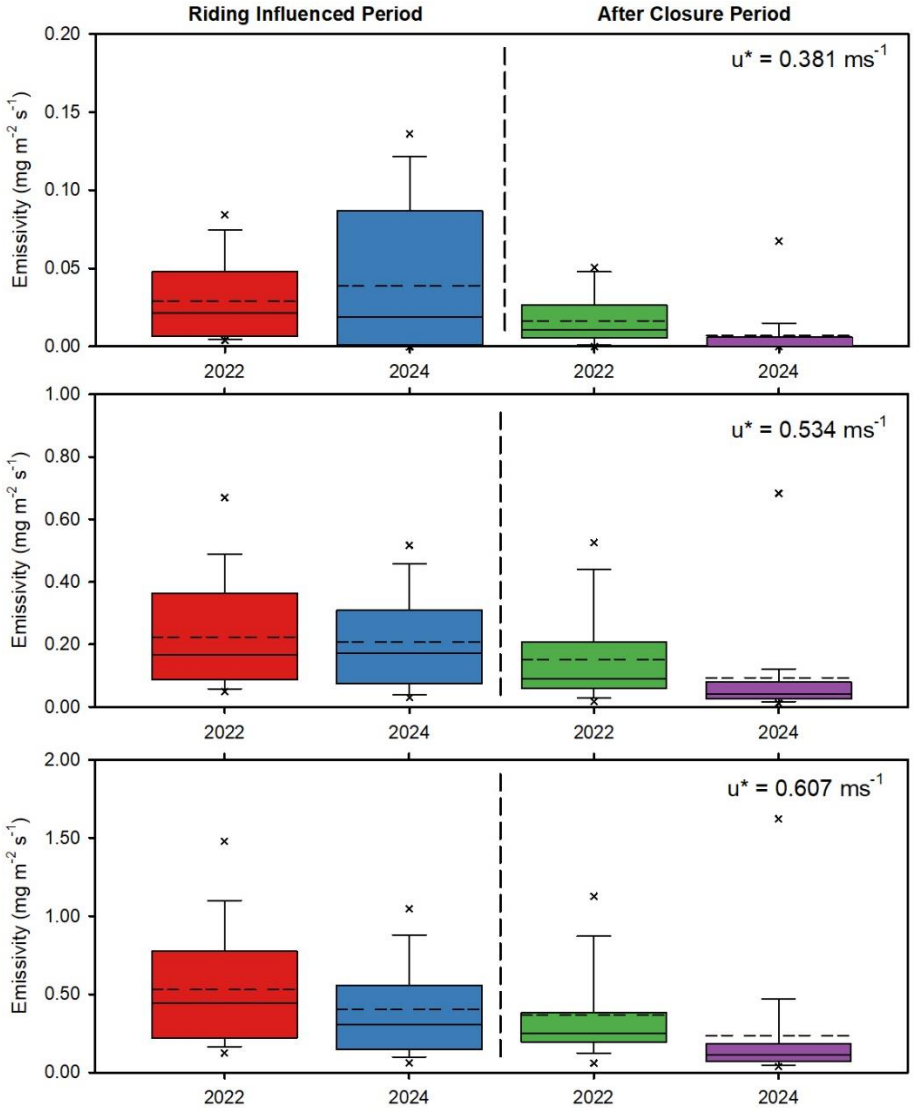


Figure 7: Box-and-whisker plots of PI-SWERL emissivity measurements in the SE from the 2022 and 2024 sampling campaigns. See Figure 2 for explanation of symbols and interpretation of box plots. The two box-and-whisker plots on the left show measurements made at the end of the open riding period (October 1 through February 28). The two box-and-whisker plots on the right show measurements made at the end of the closure period (March 1 through September 30).

Emissivity Power Relations

The model created and managed by DRI has eight (8) distinct management zones[3], and each of these zones is characterized by a different emissivity power relation that is calculated based on the PI-SWERL emissivity measurements made in the footprint of those zones. In the majority of the zones (NRA North, NRA Central, NRA South, RA Central-North, RA Central-South) the data set comprises all measurements made between 2013 and 2024. The FRA and PE zones use measurements from 2022 and 2024 given that these areas were established in late 2019 and late 2021, respectively. The SE is a hybrid case for which measurements made prior to establishment of the SE, but in the footprint of the SE, are used to characterize the riding-influenced periods (2013 – 2024; see Table 4) while the seasonally closed periods are characterized by measurements made in 2022 and 2024. The median values for the riding-influenced period (n = 72) and the seasonally closed period (n = 74) are averaged for each PI-SWERL RPM test setting or shear velocity (u_*, m s^{-1}), and the resultant values (average of two medians) are used to calculate the emissivity power relation for the SE.

Following recommendations in the 2024 ARWP, the median value rather than the mean value is used as the measure of central tendency to describe the statistical distribution of emissivity values for each of the three PI-SWERL test shear velocities for each of the zones. These values are presented in Table 5. Also shown in Table 5 are the power relation coefficients calculated using a non-linear, least-squares curve-fitting algorithm as per recommendations in the 2024 ARWP.

	NRA North	**NRA Central**	**NRA South**	**RA C-North**	**RA C-South**	**FRA**	**PE**	**SE Average**
n =	***170***	***313***	***109***	***495***	***828***	***177***	***53***	***72R + 74NR***
u_* (m s^{-1})	median	median	median	median	median	median	median	median
0.381	0.033	0.015	0.001	0.093	0.024	0.006	0.002	0.024
0.534	0.277	0.15	0.09	0.651	0.317	0.072	0.054	0.166
0.607	0.755	0.461	0.251	1.296	0.752	0.205	0.145	0.348
a	35.646	35.232	14.411	19.732	22.635	11.858	7.080	6.197
b	7.724	8.687	8.111	5.451	6.817	8.129	7.787	5.768
Rsqr	0.999	1	0.999	1	1	1	1	1

Table 5: Median emissivity (mg m^2 s^{-1}) values for each of the three PI-SWERL speeds (shear velocities, u_*) used to fit power relations characterizing the eight (8) distinct management zones in the simulation model. Power function coefficients (a, b) are for the power relation, $F = a\ (u_*)^b$ where F is the flux (emissivity) magnitude (mg m^{-2} s^{-1}). Power regression results calculated using SigmaPlot© software.

The curves representing the emissivity power relations from Table 5 are portrayed graphically in Figures 8 and 9. The curves for each of the three zones in the NRA (Figure 8, upper panel) shifted downward

(smaller emissivity) as a consequence of the 2024 measurements by approximately equal amounts. The NRA South has the smallest emissivity values while the NRA North has the largest emissivity values for the areas designated as non-riding. The curves for the two zones in the RA (Figure 8, lower panel) also shifted downward but not equally. The RA Central-North barely shifted at all (mostly at the higher end of shear velocities), whereas the RA Central-South shifted a substantial amount. With inclusion of the 2024 measurements, the curve for the RA Central-South (least emissive of the riding designated area) is almost the same as the curve for the NRA North (most emissive of the non-riding designated area).

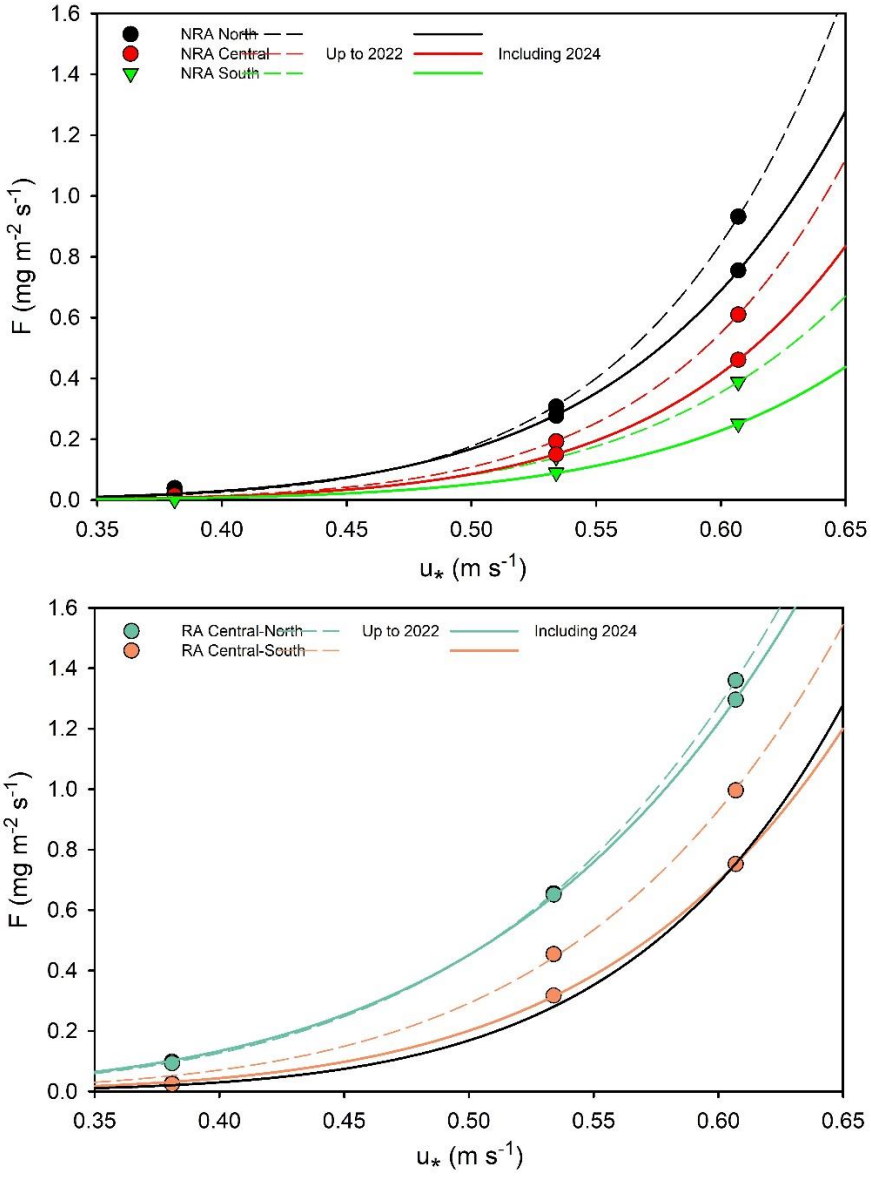


Figure 8: Curves for the emissivity power relations associated with the three NRA zones (upper panel) and two RA zones (lower panel). Dashed lines represent the relations calculated for the period 2013 – 2022, whereas solid lines also include the measurements from the 2024 sampling campaign. In the lower panel, the curve for the NRA North (2013-2024) is shown as a dark black line for reference purposes.

As noted earlier, the emissivity values for the FRA and PE are among the smallest found in the ODSVRA, with the PE having slightly smaller values than the FRA (Figure 9, upper panel). Whereas most management zones saw reductions in overall emissivity with the inclusion of measurements from 2024, the FRA increased slightly while the PE increased significantly. Nevertheless, both of these management zones are less emissive than all of the RA and NRA zones. In contrast, the SE emissivity values (Figure 9, lower panel) decreased with the inclusion of the 2024 measurements (similar to all the RA and NRA zones), and the most recent curve is intermediate between the NRA North and the NRA South, approximately similar to the NRA Central.

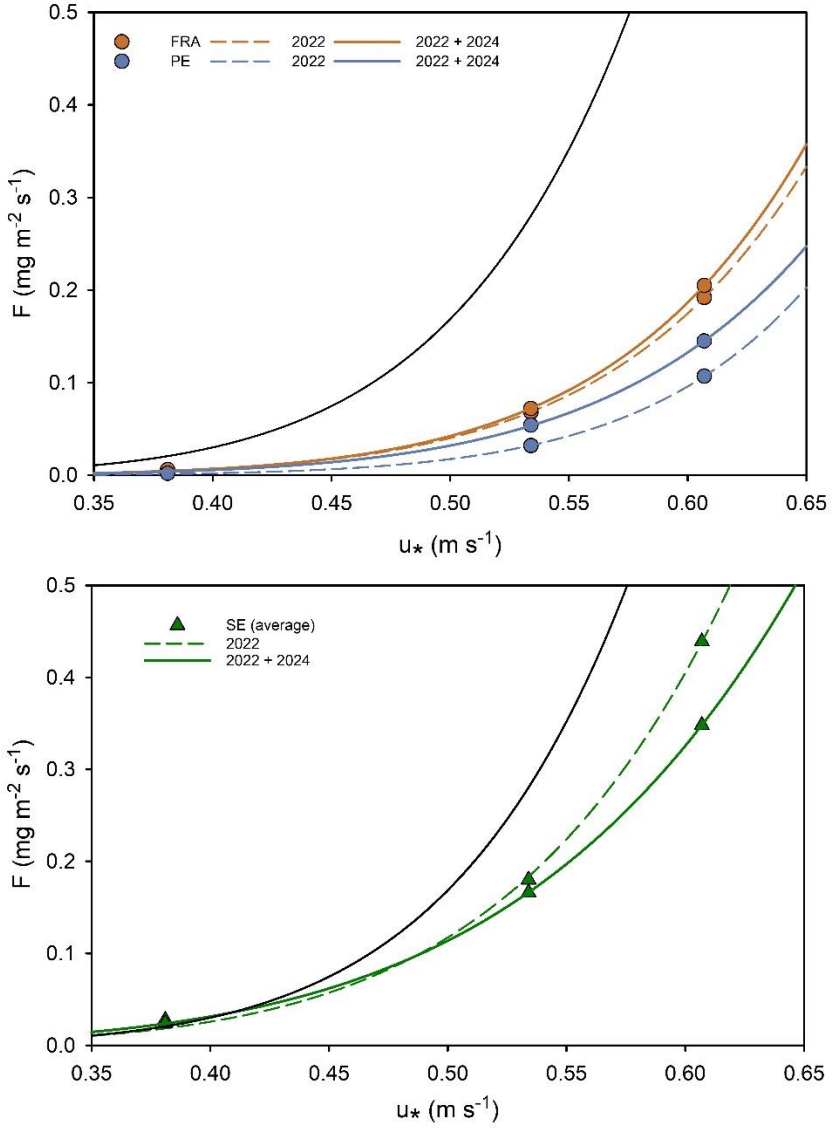


Figure 9: Curves for the emissivity power relations associated with the FRA and PE (upper panel) and the SE Area (lower panel). Dashed lines represent the relations calculated for the period 2013 – 2022, whereas the solid lines also include the measurements from the 2024 sampling campaign. The curve for the NRA North (2013-2024) is shown in both panels as a dark black line for reference purposes.

ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 05

Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking of ODSVRA Beach Areas

- Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking of ODSVRA Beach Areas (DRI Document)
- SAG Review of DRI Document "Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking of ODSVRA Beach Areas" (SAG Memo)

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Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking of ODSVRA Beach Areas

J.A. Gillies and G. Nikolich, Division of Atmospheric Sciences, Desert Research Institute

In the *Draft Environmental Impact Report* (dated February 2020) for the *Habitat Conservation Plan for the Ocean Dunes District*, there is recognition that there may be potential effects on dust emissions from areas of beach subject to mechanical raking. The process of mechanical trash removal actively disturbs the surface of the sand and removes debris and organic material from the top approximately 2 to 6 inches of the sand surface. If mechanical raking becomes an established beach management process the expectation is that selected areas would be raked between February and May and September through December, and no more than twice a year, unless extenuating circumstances (large amounts of broken glass, etc.) require additional mechanical trash removal (CDPR, 2024a).

The physical process of raking the sand for trash removal has the potential to create changes in sand that may be similar to that caused by existing recreational and maintenance activities. Gillies et al. (2022) demonstrated that Off-Highway Vehicle (OHV) activity increased the PM10 emissivity of the sand, compared with areas where OHV activity was prohibited. The potential for beach raking to increase emissivity of the sand has been reported by Dugan et al. (2010), however, uncertainty remains whether this effect can be observed at the ODSVRA and if so, how long might it persist following raking. In recognition that there may be potential effects on dust emissions from areas subject to mechanical raking and in consideration of:

a) the desire by the OHMVR Division to conduct mechanical raking of the heavily used OHV riding and camping areas;

b) the requirement imposed by the Stipulated Order of Abatement (SOA Case No. 17-01 with amendments) to demonstrate compliance with dust regulations regardless of management plans implemented for purposes of park maintenance, safety, or habitat conservation,

c) the recognized need to understand the potential impacts of mechanical raking on the dust emission potential of the treated areas; and

d) the necessity to establish a monitoring program to assess potential impacts of mechanical raking on dust emission potential,

a study was designed by the Science Advisory Group (SAG) to evaluate if mechanical beach raking could result in a measurable change in the emissivity of a selected beach area of the ODSVRA. The PI-SWERL instrument (Etyemezian et al., 2007, 2014) was used to measure emissivity (mg m^{-2} s^{-1}) in the test areas following protocols applied for PI-SWERL measurements made across the ODSVRA (e.g., Gillies et al., 2022).

Following SAG's methodology (memo of May 7, 2024), an area of beach was identified for testing that is actively used by OHVs (Fig. 1). A second area in the northern dune preserve was

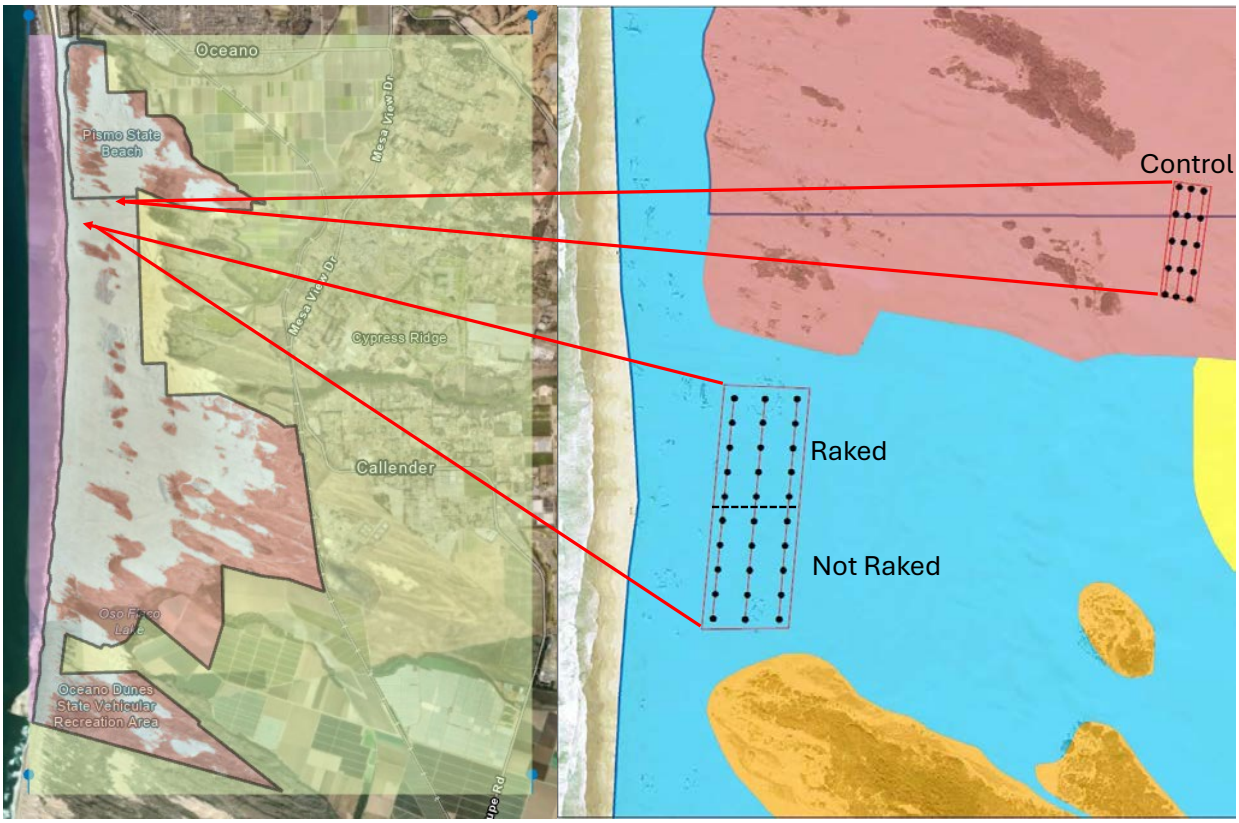


Figure 1. The locations of the beach raking test areas within the ODSVRA. The raked and un-raked areas are within the Riding Area Central North emissivity zone and the control area is within the Non-Riding Area North emissivity zone (Table 1 and Fig. 2). The black circles in the image on the right indicate the approximate positions of the PI-SWERL tests in the areas that were raked, not raked, and the area that was established in the northern dune preserve as the control site (i.e., an area that was not raked and not subject to OHV activity).

also identified to serve as a control site where no raking or OHV traffic activity would impact the sand surface (Fig. 1).

Methodology

The methodology followed by Parks and DRI was:

1) Identify and mark an area of the beach with two approximately equivalent-sized areas, one that would be raked, the other that would not be raked and both would be exposed to OHV activity.
2) Identify an area of equivalent size in the northern dune preserve (NDP Control) that would not be raked or experience any OHV activity.
3) Beach area 1 (MR) was treated with mechanical raking (May 21, 2024).
4) Beach area 2 (U) was not raked.

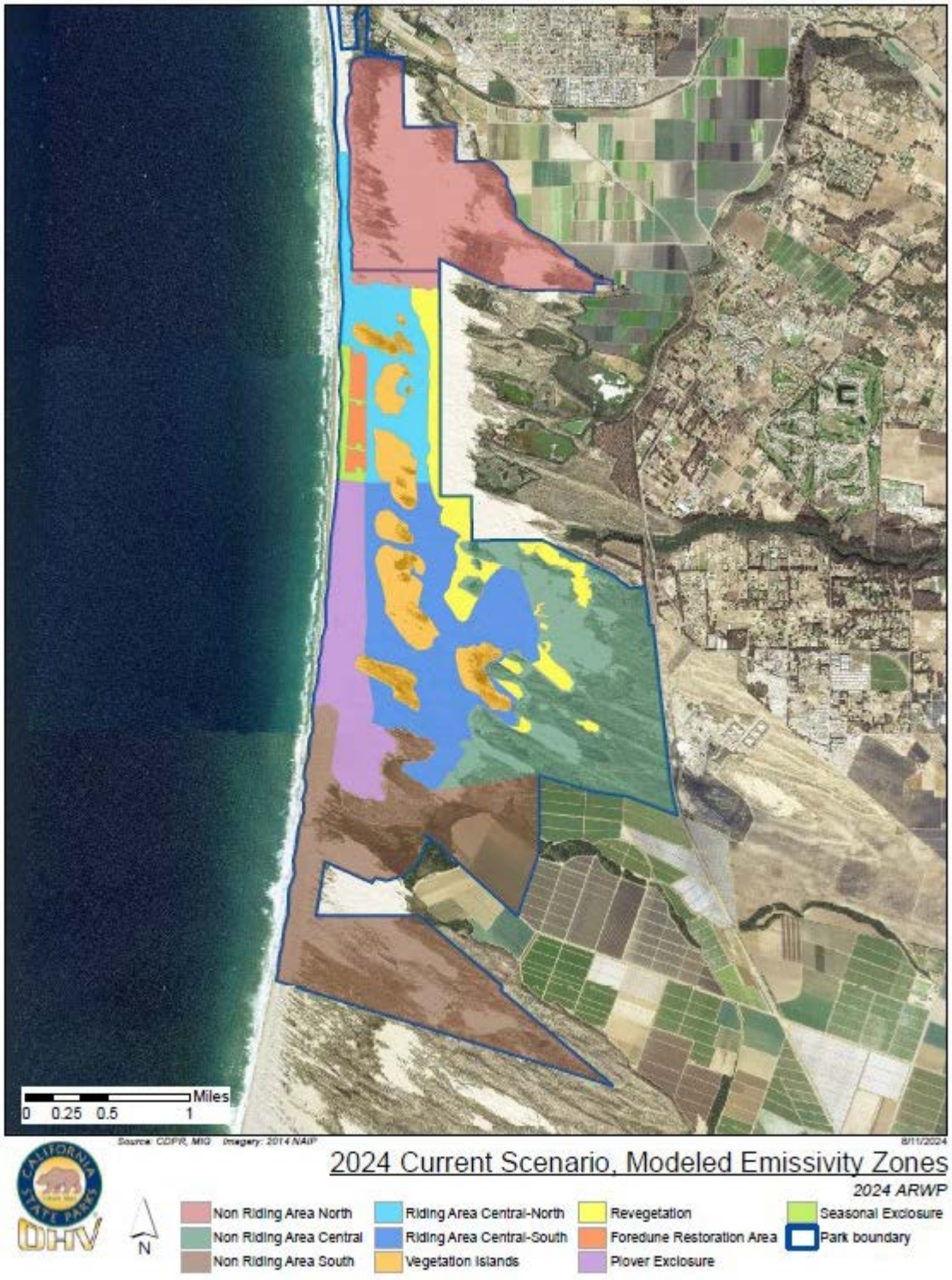


Figure 2. The emissivity zones of the ODSVRA used for estimating the condition of excess emissions (CDPR, 2024b).

Figure 1 shows the locations of the test areas and the target locations for the PI-SWERL tests. The first set of PI-SWERL measurements were made on May 20, 2024, the day prior to the mechanical beach raking on area 1. Figure 2 shows the emissivity zones within the ODSVRA as defined for estimating the condition of excess emissions as prescribed by the Stipulated Order of Abatement (CDPR, 2024b). Fifteen locations, following an equal-spaced grid pattern, were identified in each of the sampling areas and emissivity at each site was measured using the Hybrid 3500 PI-SWERL test (Gillies et al., 2022) (Fig. 1). As the handheld GPS units are accurate to 3-5 m, upon returning to test locations there is a certain degree of randomization in position.

The raking of the test area was carried out by Park's personnel on May 21, 2024, between the hours of 08:00 a.m. and 10:00 a.m. The raking implement, two Barber Surf Rake Model 600HD units linked together (Fig. 3) was towed by a John Deere 9430T tractor (Fig. 3) at a speed of approximately 5-10 mph. The 10 inch long tines of the raking implement spaced 2 inches apart were set to a penetration depth of 6 inches. The tracked vehicle pulled the raking implement in a north-south or south-north direction covering the test area.

These locations were measured for emissivity (mg m^{-2} s^{-1}) again on May 22, 2024, approximately 24 hours after the raking. The tests were carried out within the defined areas, at least 3 m from the boundary. The third and final measurements were made on May 31, 2024. The SAG had recommended a 14 day period between measurement days, post-raking, however, DRI could not accommodate this due to logistical constraints.

The PI-SWERL emissivity data were QA/QCed by DRI. Briefly, this procedure is:
Prior to and after field use the air flow (m^3 s^{-1}) through the PI-SWERL and Revolutions Per Minute (RPM) of the circular blade that generates the shearing stress are checked against a lab standard instrument to verify that PI-SWERL instruments maintain correct levels. The airflow rate through the PI-SWERL is maintained at 100 liters per minute (0.00167 m^3 s^{-1}) based on the reading from the electronic mass flow sensor built into the PI-SWERL. Readings at 100 liters per minute were compared against a lab standard instrument and verified less than 2% deviation before and after the fieldwork over a duration of a standard H3500 test. The RPM decoder is used similarly to maintain the correct RPM level between 0 and 3500 RPM and the decoder was checked before and after the study at 1000, 2000, 3000, 4000, and 5000 RPM and the RPM decoder deviation was less than 1% on both PI-SWERL instruments.

Each day of testing prior to using a PI-SWERL, the PM10 measurement instrument (TSI DustTrak2, Model 8530) was cleaned and zero-checked. If the reading with the zero-air filter in place is >0 mg m^{-3}, the instrument was re-zeroed following the procedure described in the manual provided by the manufacturer.



Figure 3. The raking implement and tow vehicle.

Results

Forty-five PI-SWERL tests were conducted on each sampling day, 15 per site. Following the QA/QC for data completeness and determining operational parameters were within accepted ranges (e.g., flow and RPM values during periods where the RPM is held constant during an H3500 test cycle vary <2%), all tests were determined to be valid for analysis. Data were reduced to calculate the mean emissivity (mg m^{-2} s^{-1}) for the periods when the PI-SWERL RPM is held constant. The RPMs of 2000, 3000, and 3500 are associated with shear velocities ($u*$, m s^{-1}) of 0.381, 0.534, and 0.607 m s^{-1} assuming the roughness of the surface is equivalent to flat sand (Etyemezian et al., 2018).

For context, the median emissivity (i.e., the median value for the 15 readings when the RPM is held constant) for each $u*$ value for the raking test areas, by test day are compared with the emissivity relations assigned to the zones defined for the ODSVRA as shown in Table 1 (SAG, 2023, Table 3) and Fig. 2 (CDPR, 2024b). Specifically, the Non-Riding Area (NRA) North, and the Riding Area (RA) Central-North, where the raking test areas were located, are compared in Figs. 4 and 5, respectively, plotted with the median emissivity values for each PI-SWERL test $u*$ for the NDP control (Fig. 4) and U and MR tests (Fig. 5).

As Fig. 4 shows, the NDP Control area is less emissive for each of the test $u*$ values than the NRA North zone, which represents a multi-year period of PI-SWERL emissivity data from 2013 through 2022 (SAG, 2023), thus providing a comparison of the test areas to the long-term emissivity record for this zone. The beach test areas U and MR for the pre-raking test day (May 20, 2024) and one day post-raking (May 22, 2024) align closely with the current Riding Area

Table 1. The power function coefficients (*a*, *b*) for the zones defining the ODSVRA emissivity (SAG, 2023) in which the U, MR, and NDP test areas are located.

	Non-Riding Area North	Riding Area Central-North
$E\ (mg\ m^{-2}\ s^{-1}) = a\ u_*^{b}$		
a	66.376	24.34
b	8.547	5.795
r^2	0.999	1.000

North-Central relation, which is based on analysis of a compilation of PI-SWERL emissivity data from 2013 through 2022 (SAG, 2023). The U and MR median emissivity values for equivalent values of u_* are lower than the current NRA North relation on the 10th day post-raking (Fig. 5).

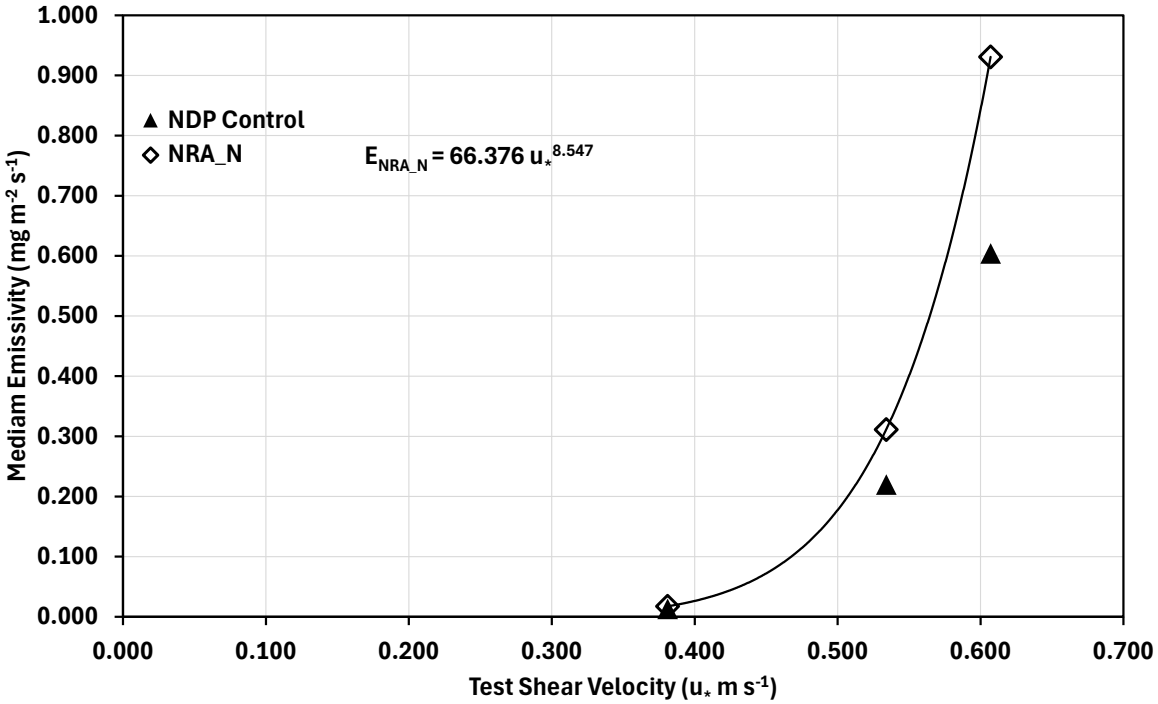


Figure 4. The median emissivity values as a function of u_* for the Northern Dune Preserve Control area (NDP Control) and the median emissivity relation of the Non-riding Area North as defined in Table 1 (sourced from SAG (2023), Table 3) represented by the white diamonds and showing the best-fit regression line.

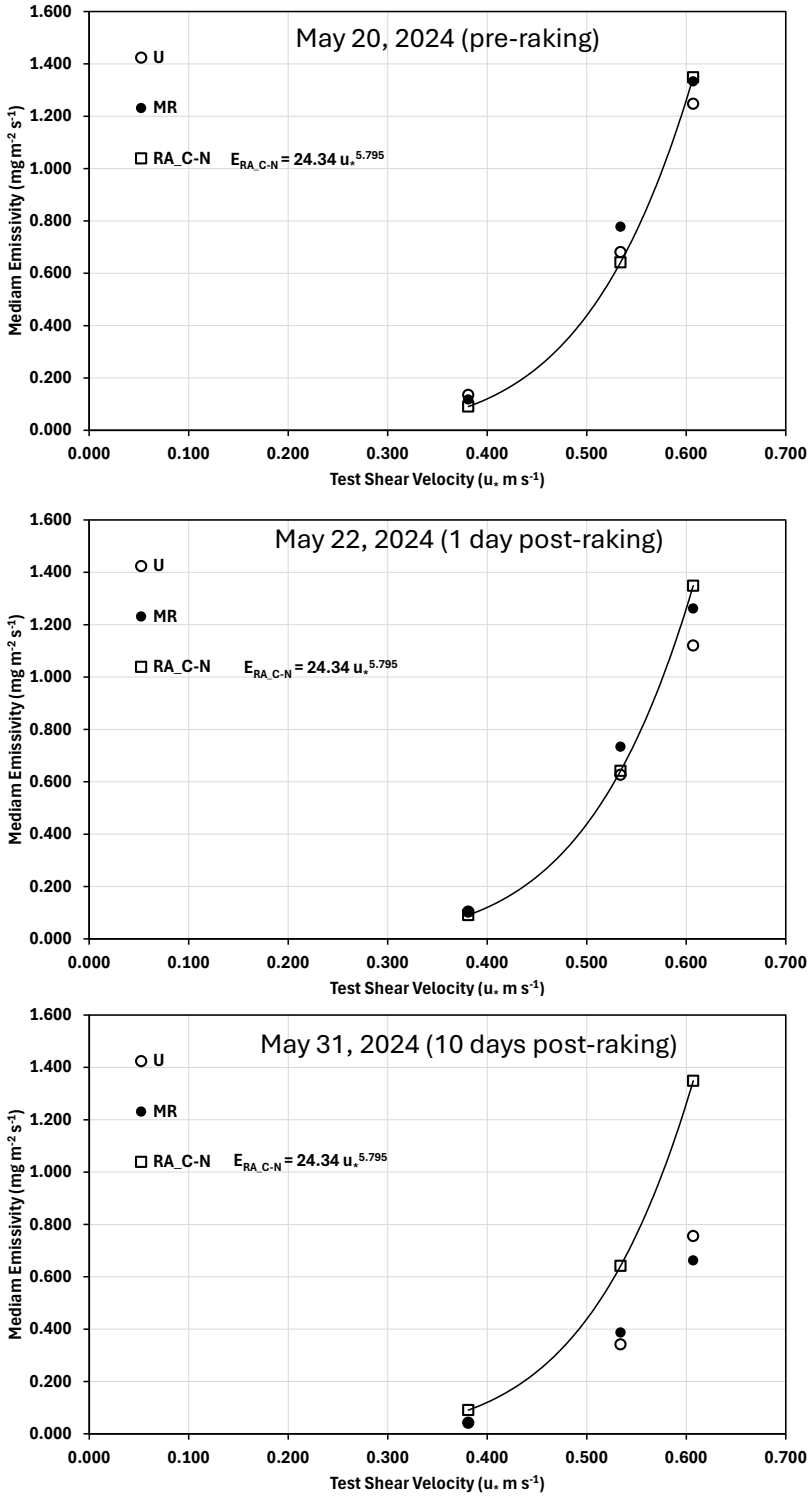


Figure 5. The median emissivity values as a function of u_* for the beach test areas, Unraked (U), Raked (MR) for each test day, and the median emissivity relation of the Riding Area Central North (RA_C-N) as defined in Table 1 (sourced from SAG (2023), Table 3) represented by the white squares and showing the best-fit regression line.

During a PI-SWERL test the RPM of the rotating blade is held constant at the three RPM settings (2000, 3000, and 3500), which generates three $u*$ (0.381, 0.534, and 0.607 m s^{-1}). The emissivity (mg m^{-2} s^{-1}) is calculated for each second. In post-processing the PI-SWERL data, a mean emissivity for each of the test $u*$ values was calculated.

The 15 PI-SWERL tests in the U, MR, and NDP areas were grouped by test $u*$ to estimate the median emissivity values for each test area for each day of testing. Comparing the median emissivity values as a function of $u*$ between test days and test areas follows from the analysis of the long-term emissivity data by the SAG (2023). The SAG (2023) recommended testing differences in emissivity among areas be done by comparing median emissivity values as the distribution of emissivity as a function of $u*$ were observed to typically be not normally distributed (SAG, 2023). The distribution of emissivity as a function of $u*$ for the test areas are shown in Figs. 6 and 7. The plots in these figures show that the emissivity as a function of test area and day of testing were variable and not well characterized by a normal distribution.

Because the distributions are not normal in form, the nonparametric Wilcoxon Signed Rank test was used to determine if the median emissivity values for each test $u*$ were statistically similar or different. This statistical test is suitable for evaluating data from a repeated-measures design in a situation where the prerequisites for a dependent samples difference of means T-test are not met, e.g., data are not normally distributed.

The null hypothesis for the Wilcoxon Signed Rank test was that there was no difference between median values and the significance test (alpha) was set at 0.05. Under these conditions if the two tail P value was >0.05, the hypothesis was accepted as true, and the medians were not statistically different. Two test matrices were developed. The first compared median emissivity as a function of $u*$ for the same test area for the three test days (Table 2) and the second among the test areas for the three test days (Table 3).

Table 2 shows that between the measurements made on May 20, 2024 (pre-raking) and May 22, 2024 (one day after raking), there was no statistical difference in median emissivity for all three $u*$ values for the same test surface. Ten days later, May 31, 2024, the median emissivity for each $u*$ was significantly different between the one day and 10-day measurements for the un-raked (U) and the raked (MR) surfaces. The result of the Wilcoxon Rank test was inconclusive for the MR surface at the test $u*$ of 0.607 m s^{-1} between May 22 and May 31. The change in median emissivity between May 22 and May 31 suggests that some environmental factor caused the emissivity to decrease significantly by May 31. The most likely candidate factor is moisture. On May 31, the sky remained overcast, which kept humidity levels higher than on previous days and there was reduced solar insolation heating/drying the sand. Although there was no direct precipitation at the time of testing and the sand was warm to the touch, and no patches of moist sand were left exposed following the PI-SWERL testing, the difference in the meteorological conditions was the likely cause of the lower emissivity. The decrease in median emissivity between May 22 and May 31, 2024, was also observed for the NDP Control site (Table 2), only however for $u*$=0.381 m s^{-1} and $u*$=0.607 m s^{-1}.

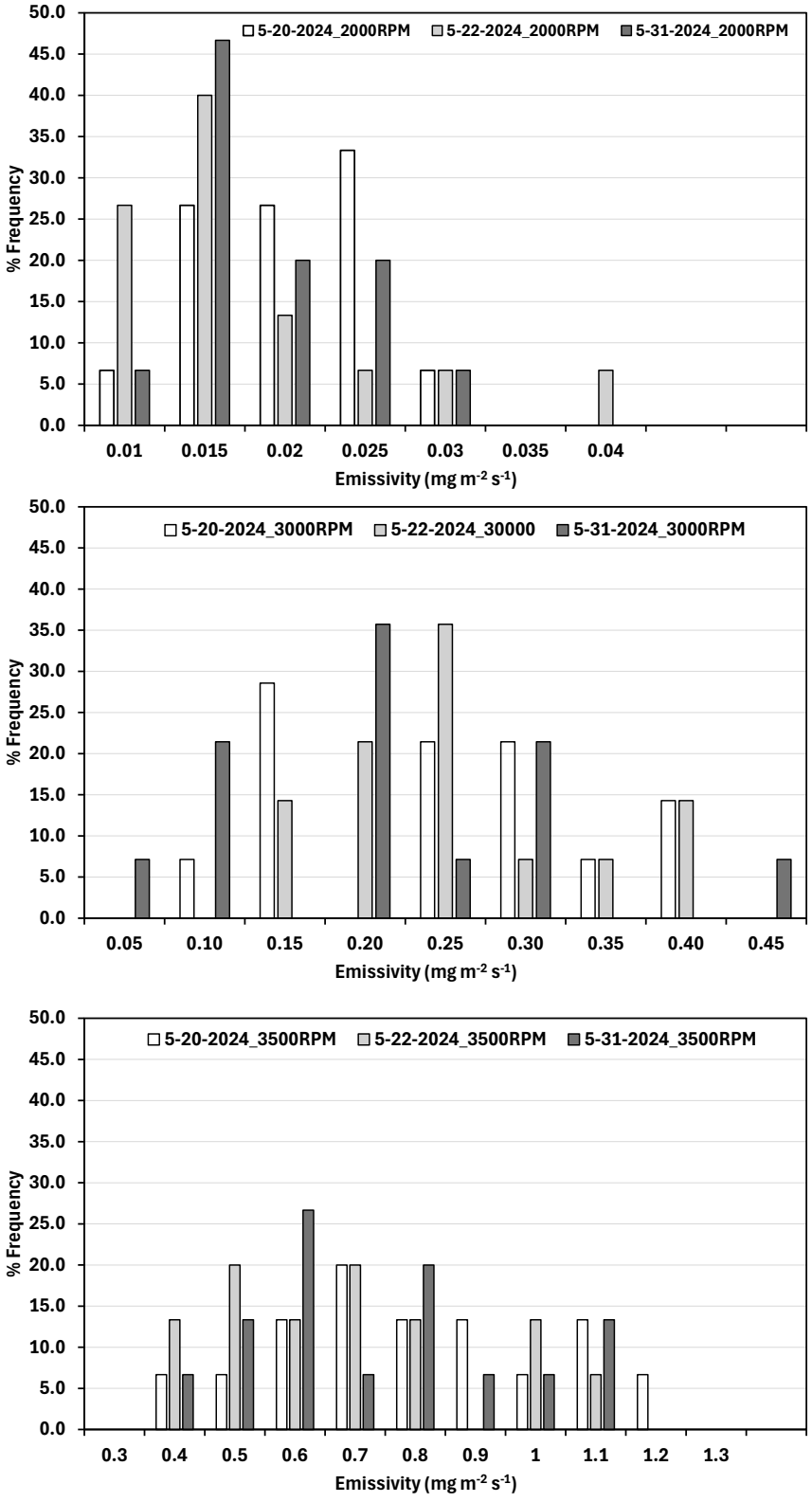


Figure 6. The distributions of emissivity (mg m^{-2} s^{-1}) as a function of PI-SWERL test RPM for the control site (C) for the three days of testing.

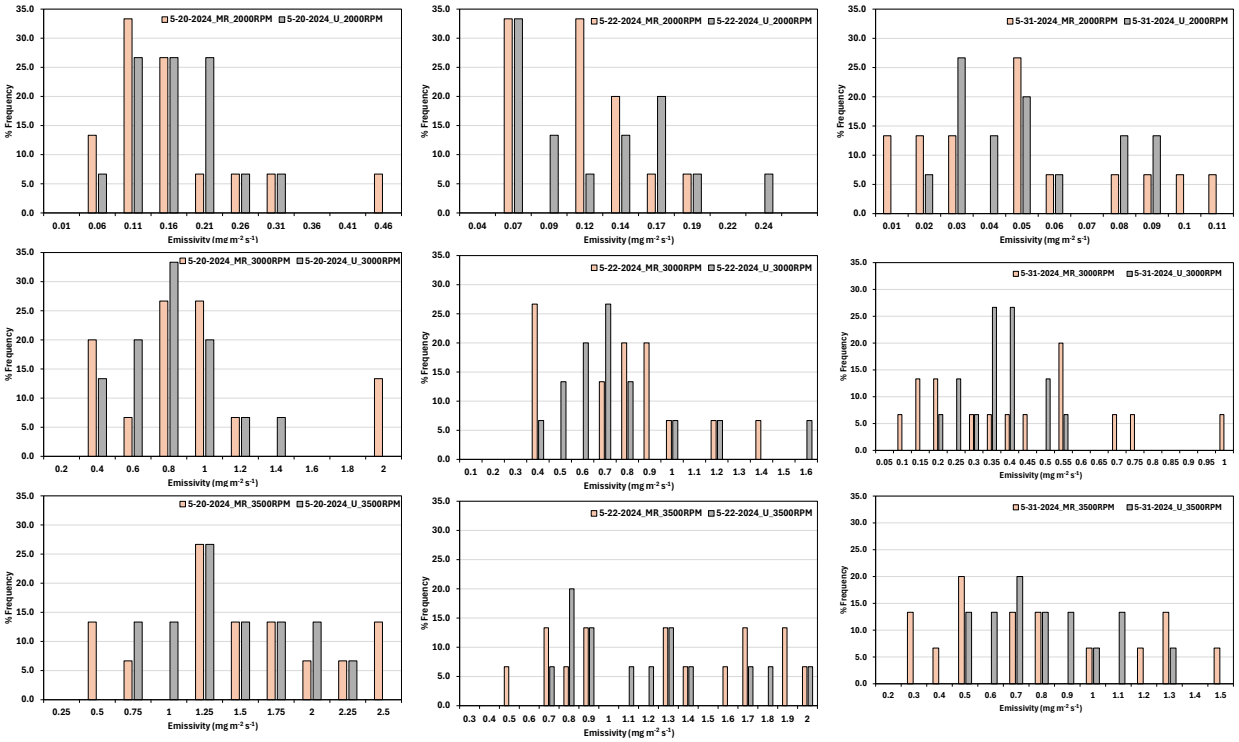


Figure 7. The distributions of emissivity (mg m^{-2} s^{-1}) as a function of PI-SWERL test RPM for the raked area MR (pink bars), and the unraked U site (grey bars) for the three days of testing.

Table 2. Results of the difference in median emissivity testing as a function of u_* for the same areas for the three test days. Significance testing was at alpha=0.05.

	Median Emissivity (mg m^{-2} s^{-1})			
Test Shear Velocity (m s^{-1})	**Un-Raked (U)**	**Un-Raked (U)**	**Wilcoxon Signed-Rank Result[1, 2, 3, 4]**	
	5/20/2024	5/22/2024		
0.381	0.135	0.104	0.156	A
0.534	0.681	0.627	0.533	A
0.607	1.247	1.120	0.211	A
	5/22/2024	5/31/2024		
0.381	0.104	0.042	0.0018	R
0.534	0.627	0.342	0.0006	R
0.607	1.120	0.756	0.0037	R
	Raked (MR)	**Raked (MR)**		
	5/20/2024	5/22/2024		
0.381	0.118	0.103	0.211	A
0.534	0.778	0.734	0.497	A
0.607	1.333	1.262	0.424	A
	5/22/2024	5/31/2024		
0.381	0.103	0.044	0.001	R
0.534	0.734	0.387	0.001	R
0.607	1.262	0.663	N/A	N/A
	NDP Control (C)	**NDP Control (C)**		
	5/20/2024	5/22/2024		
0.381	0.019	0.013	0.147	A
0.534	0.229	0.222	0.976	A
0.607	0.719	0.619	0.211	A
	5/22/2024	5/31/2024		
0.381	0.013	0.010	0.004	R
0.534	0.222	0.179	0.064	A
0.607	0.619	0.443	0.012	R

[1] Numerical P value for WSR result

[2] Letter A means "Accept Null Hypothesis", no difference in median emissivity (P>0.05)

[3] Letter R means "Reject Null Hypothesis", medians are different (P<0.05)

[4] N/A data includes tied values, sample size is too small to allow a reliable calculation

The NDP control site was farther from the ocean, higher in elevation, and on the lee side of the foredune. This position may have ameliorated the moisture effect on emissivity at the NDP control site compared with the U and MR sites. That median emissivity values were smaller on May 31 compared with May 22 for the U and C test areas, which were not raked, suggest that the effect could not be related to raking.

Table 3 shows the median emissivity for the three PI-SWERL test u_* settings and the results of the difference of medians test for emissivity as a function of u_* for the different test areas for the three test days. The difference of medians testing shows that there was no difference in the median emissivity for each u_* between the un-raked (U) and raked (MR) test areas for all three test days. Critically, that no difference was observed between May 20 and May 22, suggests that raking did not create a measurable change in median emissivity between the two test areas that initially had the same median emissivity. Ten days after raking, and although the median emissivity as a function of the test u_* had decreased in both the U and MR test areas, there was still no difference between the median emissivity as a function of the test u_* for the U and MR test areas.

Table 3. Results of the testing the difference in median emissivity as a function of u_* for the different test areas for the three test days. Significance testing was at alpha=0.05.

Date	Test Shear Velocity (m s^{-1})	Median Emissivity (mg m^{-2} s^{-1})			Wilcoxon Signed-Rank Result[1, 2, 3]					
		Un-Raked (U)	Raked (MR)	NDP Control (C)	U vs MR		U vs C		MR vs C	
5/20/2024	0.381	0.135	0.118	0.019	1.000	A	0.001	R	0.001	R
(pre-raking)	0.534	0.681	0.778	0.229	0.459	A	0.001	R	0.001	R
	0.607	1.247	1.333	0.719	0.459	A	0.003	R	0.003	R
5/22/2024	0.381	0.104	0.103	0.013	0.728	A	0.001	R	0.001	R
(post-raking)	0.534	0.627	0.734	0.220	0.912	A	0.001	R	0.001	R
	0.607	1.120	1.262	0.619	0.865	A	0.003	R	0.010	R
5/31/2024	0.381	0.042	0.044	0.010	0.912	A	0.001	R	0.003	R
(post-raking)	0.534	0.342	0.387	0.179	0.424	A	0.003	R	0.020	R
	0.607	0.756	0.663	0.443	0.689	A	0.012	R	0.061	A

[1] Numerical P value for WSR result

[2] Letter A means "Accept Null Hypothesis", no difference in median emissivity (P>0.05)

[3] Letter R means "Reject Null Hypothesis", medians are different (P<0.05)

Conclusions

The emissivity testing indicated that the median emissivity of the unraked (U) and raked (MR) test areas were significantly different compared with the median emissivity of the Northern Dune Preserve control area for all three PI-SWERL test u_* values for each testing day. The lower emissivity of the non-riding area compared with the riding area has been documented previously (Gillies et al., 2022; SAG, 2023).

The similarity of the median emissivity values for the unraked (U) and raked (MR) test areas to each other (Fig. 3) and to the current (Table 1) median emissivity relation of the Riding Area

Central North suggests that the beach raking did not alter, to the limit of measurement resolution, the emissivity between the two conditions. Further evidence that beach raking did not affect the emissivity is found in the results applying the Wilcoxon Rank to determine if the median emissivity values of the U and MR (Tables 2 and 3) test areas were significantly different. For all available comparisons among the test u_* values for each test day, the median emissivity values were not statistically different.

We note that this study, designed to quantify the effect of beach raking on the potential emissivity of the raked surface, was relatively short term and based on a single raking event and limited in scope. As the expected frequency of beach raking on a selected area is, however, low (proposed to be several times per year) it is unlikely that there would be a cumulative effect of beach raking on emissivity. As no demonstrable effect on emissivity could be quantified one and ten days after raking, it seems reasonable to assume that month-long periods between raking would not have any cumulative effect on emissivity of the beach areas especially as OHV activity on the beach areas is a near-constant source of surface disturbance and its effect on emissivity has been previously demonstrated (Gillies et al., 2022).

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Science Advisory Group (memo of 12-19-2023). Updated SAG Recommendations for Establishing Emissivity Grids to be used in Modeling of Pre-Disturbance Conditions and Future Excess Emissions Reductions. Memo submitted to California State Parks 12-19-2023.

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August 22, 2024

Memo: DRI Responses to SAG Review Comments for the "Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking"

This memo provides DRI's responses to the review comments of the SAG for the 2024 Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking Report by DRI for California State Parks.

July 29, 2024

Memo: SAG Review of Desert Research Institute (DRI) Report on "Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking"

From: Scientific Advisory Group (SAG)

To: Jon O'Brien, California Department of Parks and Recreation

Cc: Ronnie Glick, California Department of Parks and Recreation

The Scientific Advisory Group (SAG) received a copy of the Desert Research Institute (DRI) report of "Evaluation of Potential Changes in Dust Emissions due to Mechanical Raking" on July 18, 2024 via e-mail, and SAG members have had the opportunity to review the document. This memo provides feedback on the DRI report[1].

The report discusses the results from a series of PI-SWERL measurements conducted in May, 2024 with the objective of determining whether mechanical raking of the beach by ODSVRA staff (as part of routine park maintenance) might have an influence on potential dust emissions. The report summarizes the experimental design, the measurement protocols, the data analysis methods, and statistical test results, **concluding that mechanical raking had no discernible effect on altering surface emissivity within the level of uncertainty associated with the methods**.

SAG members appreciated the clear and detailed discussion in this report, noting that it was easy to read and to follow the logic of presentation. A quantitative assessment of changes in surface emissivity using the PI-SWERL instrument is a welcome addition to the knowledge base dealing with dust mitigation efforts at the ODSVRA. Several suggestions for improving the effectiveness of the document appear below:

[1] Standard procedure for SAG review of DRI reports is for Dr. Jack Gillies to recuse himself from the discussions due to a potential conflict of interest. Despite being a SAG member in good standing, Dr. Gillies did not participate in this review in any manner nor was DRI consulted about any aspect of this review.

1. Pg.1, Para. 2 – The first sentence has "…similar to that caused by…" which should be "…similar to those caused by….". The last sentence has "…. that that…", one of which needs to stricken.

DRI Response: corrected.

2. Pg. 1, Last Para. – OHV should be pluralized (i.e., OHVs) or alternatively, insert "traffic" after OHV.

DRI Response: changed.

3. Pg.2, Fig. 1 - The caption mentions "Non-Riding Area North emissivity zone" and elsewhere in the document there is reference to similar nomenclature, but the reader won't know where/what these areas are without consulting a different document. It might be worthwhile including a map of the various zones (copied from prior reports) to so that this document can be read as a stand-alone piece.

DRI Response: Figure showing emissivity zones added to report.

4. Pg.2, Bullet Point #3. Beach Area 1 (R) uses the symbol 'R' but the same symbol is used later as meaning Reject for t-test results. Is it possible to use different symbols to avoid confusion?

DRI Response: symbols changed for mechanically raked test area from R to MR.

5. Pg. 3, Para.2 – The last sentence speaking to the serendipity of taking PI-SWERL measurements prior to a rain event on June 1 should be deleted. The fact is that the last measurements were made on May 31 due to logistical constraints, which is an acceptable explanation. The further fact that it rained directly afterward is irrelevant to this report.

DRI Response: sentence removed.

6. Pg. 4, Para. 1 – In the middle of the paragraph, it is stated that the ***mean*** emissivity was calculated from the PI-SWERL data, whereas in the next paragraph it is stated that the ***median*** emissivity was used for the best-fit emissivity relations. Please clarify why both measures of central tendency were calculated and how they were used subsequently. Some rationale and explanation are required as to why both measures are 'valid' for statistical analysis.

DRI Response:

The median emissivity for each PI-SWERL test u_* for the 15 values that represent the U, MR, and CDP sites for each test day were calculated (in Excel) and plotted along with the emissivity power relations (provided in Table 3 of the SAG 2023 PI-SWERL memo) for the emissivity zones in which the test areas were established to provide a visualization how these test data compare with the zonal median emissivity relations.

7. Pg. 4, Para. 2 – Just below the emissivity relation it is stated that a least-squares power fit relation was produced. What software was this done with, and have you followed the SAG recommendation for using a non-linear least squares approach?

DRI Response:

In this revised Report, DRI has chosen not to include best fit lines for the median emissivity as a function of u_* for the tests. The media emissivity values are only compared with the appropriate SAG-derived median emissivity relations (provided in Table 3 of the SAG 2023 PI-SWERL memo).

8. Pg. 4, Last para – Please clarify the first sentence dealing with a 'multi-year period from 2013 through 2022.' Can this be re-phrased so that the reader understands why a multi-year period was used here? Also, were the coefficients for the NDP Control area derived using the same software as the beach test areas?

DRI Response:
The comparison of the median emissivity values as a function of test u_* is provided to show how these newly-acquired data from May 2024 compare with the zonal emissivity relations that are based on the longer term data record. DRI is not including best fit regression information in this revised version.

9. Pg. 5, Table 1 – One of the columns shows data for Non-Riding Area South, but this area is not referred to elsewhere in the document. Consider deleting from table. Similar comment for Riding Area Central-South. Also, why aren't the coefficients for U, R, and NDP Control areas included in this table (for ease of comparison)?

DRI Response:
Table 1 was modified to remove Non-Riding Area South and Riding Area Central South from the table as the test areas are only associated with NRA-North and RA-Central-North. DRI is not including best fit regression information in this revised version, so coefficients were not added to Table 1.

10. Pg. 5, Para. 1 – Second sentence is confusing. "The hypothesized mean difference was that there was no difference between mean values…" What is meant by 'hypothesized mean difference'? Do you mean that the null hypothesis was that there was no difference between mean values? Also, with regard to using the mean value—what is the rationale for this given that SAG has recommended use of median values to describe PI-SWERL data distributions? Are the measurements skewed or normally distributed? Would it be worthwhile showing the data distributions so that the reader can judge the appropriateness of the statistics being applied?

11. Pg. 5, Para. 1 – A Student's t-test for paired samples seems appropriate for assessing the measurements taken before and after treatment (i.e., raking), but it is not clear that the paired test is applicable to comparing different areas on the same day. The unpaired test compares the means of two independent (unrelated) groups, assuming the variance is similar. The paired t-test is used when comparing the means of the same group under two different treatments (variance is not assumed equal).

DRI Response to 10 and 11:
Following the SAG's analysis approach in their 2023 Memo for analyzing PI-SWERL emissivity data, in this updated version of the report the nonparametric Wilcoxon Signed Rank test was used to determine if the median emissivity values for each test u_* were statistically similar or different.

This statistical test is suitable for evaluating data from a repeated-measures design in a situation where the prerequisites for a dependent samples difference of means t-test are not met, e.g., data are not normally distributed. Tables 2 and 3 have been updated to represent this change.

12. Pg. 5, Para. 1 – Last sentence introduces Table 2 and Table 3, but the descriptions of what these tables show is somewhat brief. Consider adding a bit more information about what each of these tables is intended to show, perhaps using two sentences (one each for the two tables). The current language is difficult to penetrate.

DRI Response:
For each Table, 2 and 3, a paragraph of explanation is provided.

13. Pg. 5, Para. 2 – Five lines up from the bottom. Please clarify what the mean percent change in emissivity refers to, especially with regard to u_*.

DRI response:
The percent change in emissivity has been removed from the discussion to avoid confusion.

14. Pg. 5, Para. 2 – Four lines up from the bottom. The date is given as 05-31-2024 but everywhere else dates are given as May 31, 2024. Be consistent throughout. Note that the tables use the numerical format.

DRI response: date format changed.

15. Pg. 6, Figure 3 – Use of symbols is inconsistent. In lower three panels a solid circle is used for R data whereas in the upper panel it is used for NDP Control. Also, the text in the upper panel says May 20, 22, 24 combined, but there were no measurements on May 24 for this experiment. It might be worthwhile separating the first panel as a stand-alone figure because the point seems to be that the control measurements in the NDP were different from the long-term emissivity values from the NRA North. This panel also uses a different vertical scaling.

DRI response:
NDP control plot was separated from U and MR plots. Symbology was updated. Date was corrected.

16. Pg. 7, Table 2 – Several SAG members were confused by the symbology used in the column for "T-test Results." The column includes A, A*, R, and R**, and the footnote only defines the symbols with asterisks. It seems that the intent was to use only A and R to indicate 'accept' or 'reject'. Thus, greater clarity could be achieved by putting the asterisk (or numerical 1) as a superscript on "T-test Result" and in the footnotes to the table indicate that an A means 'accept' and an R means' reject. The column would then only contain either an A or an R (without asterisks). Same comment applies to Table 3. Please include P value for significance test. Also, the table seems to be based on ***mean*** emissivity whereas the power relations are developed with ***median*** emissivity. Some explanation is required.

DRI Response:

The asterisks were removed and the identification of the meaning of the letter codes uses numeric superscripts to guide the reader to the meaning of the numerical value (i.e., the now-provided P-value) and whether the null hypothesis is accepted (A) or rejected (R).

17. Pg. 8, Table 3 – The last entry on lower right shows an 'A' for the test between R vs C on May 31 for the largest u_*. Is this a typo? The mean for R is 0.741 but for C is only 0.488. These are very different values. Should this be a 'reject' the null hypothesis?

DRI response:
Tables have been updated based on the new analysis using the difference in median test.

18. Pg. 8. – Either within the Conclusions or in a separate sub-section above Conclusions, which might be entitled Discussion or Caveats, it is important to present some of the limitations of this study. In particular, this was a very short-term study completed within two weeks and it may be the case that the influence on surface emissivity from raking might manifest after multiple treatments (in cumulative fashion). Moreover, the last series of measurements (May 31) were seemingly affected by moisture conditions (although no measurements are available to support this conjecture) and therefore it is not known how this may have influenced the conclusion that raking has no influence. A few sentences discussing the limitations of this short-term study would be welcome for context, as would some speculation about how long-term monitoring might be of benefit.

DRI Response:
Additional text noting the short-term test methodology has limitations has been added. The observation that the effect that moisture may have had on the emissivity for the 10^{th} day testing is inferential, but DRI feels it reflects the most likely cause in the reduced emissivity. DRI suggests that it is not plausible that 10 days after raking there would be a residual effect that would lower the emissivity of the raked area. As the effect was observed at all three test sites, two that were not raked, this change in emissivity cannot be linked with the mechanical disturbance caused by the raking.
Based on the low frequency of beach raking proposed by Parks, the results of this study showing no demonstrable impact of raking on emissivity, and the high frequency of OHV travel in the beach areas, which has a demonstrable effect on emissivity (Gillies et al., 2022), DRI suggests that no long term monitoring is necessary as raking has potentially no or very limited effect on emissivity of the beach areas.

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ODSVRA Dust Control Program Draft 2025 ARWP

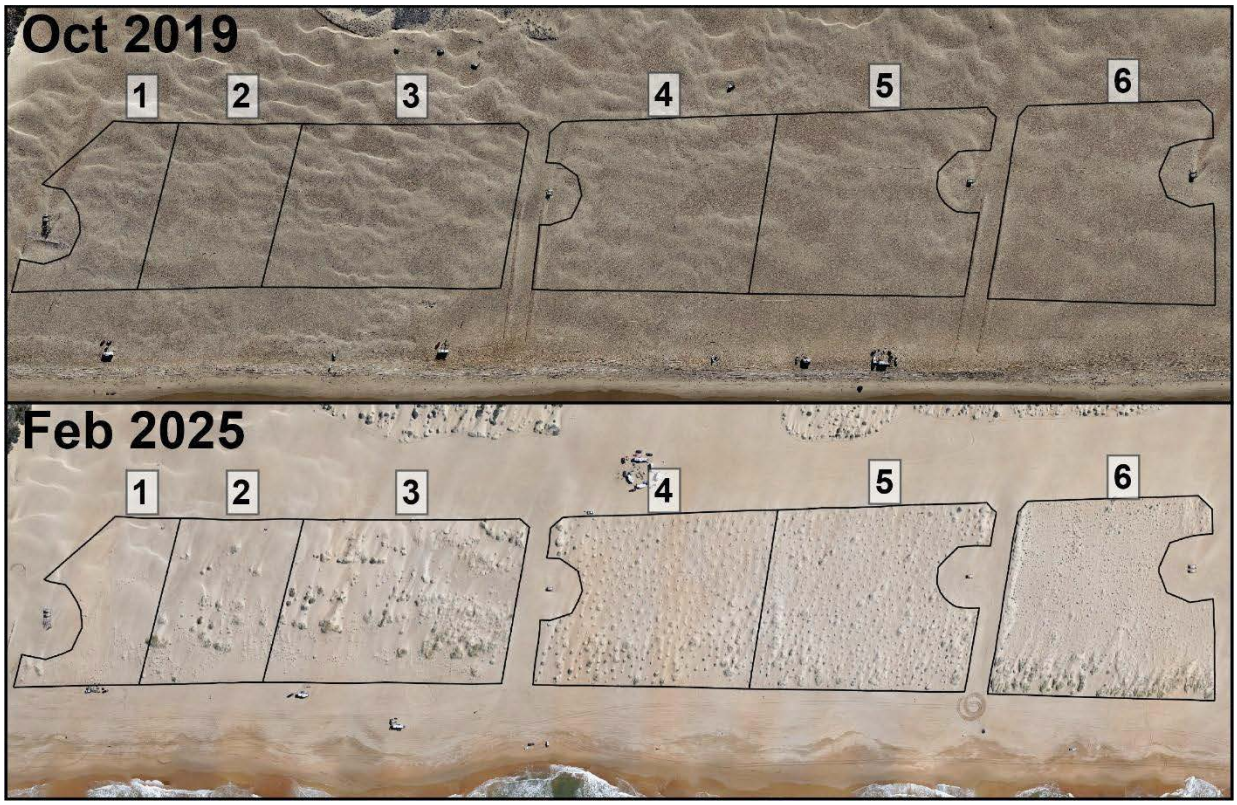
ATTACHMENT 06

UCSB 2024-2025 ODSVRA Foredune Restoration UAS Survey Report

- UCSB 2024-2025 ODSVRA Foredune Restoration UAS Monitoring Report (UCSB Report)
- SAG Review of UCSB Report "2024-2025 ODSVRA Foredune Restoration UAS Monitoring Report" (SAG Memo)

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2024-2025 ODSVRA
Foredune Restoration UAS Monitoring Report



Aerial image mosaics of the foredune restoration area in ODSVRA prior to implementation of restoration treatments in October 2019 (upper) and after 5 years of development in February 2025 (lower).

Prepared by: Zach Hilgendorf[1,2], Ian Walker[1], and Madison Heffentrager[1]

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June 2025

List of Acronyms:

California Department of Parks and Recreation – CDPR
Desert Research Institute – DRI
Digital Terrain Model – DTM
Foredune Restoration Area – FRA
Geomorphic Change Detection – GCD
Ground Sampling Distance – GSD
Light Detection and Ranging – LIDAR
Near Infrared – NIR
Normalized Difference Vegetation Index – NDVI
Oceano Dunes State Vehicular Recreation Area – ODSVRA
Off-Highway Vehicles – OHV
Particulate Matter – PM
Particulate Matter Reduction Plan - PMRP
Portable In-Situ Wind Erosion Laboratory – PI-SWERL
Post-Processing Kinematic - PPK
Red-Edge – RE
Red-Green-Blue Spectral Bands – RGB
San Luis Obispo Air Pollution Control District – SLO-APCD
Scientific Advisory Group – SAG
Structure-from-Motion – SfM
Stipulated Order of Abatement – SOA
Treatment Plot - TP
Uncrewed Aerial System – UAS
University of California Santa Barbara – UCSB

EXECUTIVE SUMMARY

The foredune restoration project was established in February 2020 as a nature-based solution to mitigate PM_{10} dust emissions from a highly emissive 48-acre site by promoting sand deposition and dune development. The foredune restoration area (FRA) consists of six treatment plots (TP), including (north-south): TP1) a control plot only textured by a sheepsfoot roller; TP2) sheepsfoot texture and broadcast native seeds; TP3) sheepsfoot texture and broadcast native plant and sterile rye grass seeds; TP4) low-density straw planting circles with nodes of juvenile native plants; TP5) high-density straw planting circles with nodes of juvenile native plants; TP6) complete straw cover with high density of juvenile plants.

An uncrewed aerial system (UAS) with high resolution cameras has been flown biannually (October and February) since Oct. 2019 to monitor and detect geomorphic and vegetation changes in the FRA and adjoining beach and back dune areas. To date, 10 flights have been conducted and resulting datasets include: georeferenced orthomosaics, plant cover maps, digital terrain maps (DTMs), topographic change maps, and sand volumetric change estimates. These datasets are used to examine quantities and patterns of sand erosion/deposition, dune development responses, and changes in vegetation across the treatment plots through time. These results are then used to assess the performance of the treatments based on indicators of dune development, sediment budget response, vegetation trends, and dust mitigation potential. This report provides results from 5 years of development through to February 2025.

Sand supply to the beach, which feeds aeolian transport into the FRA treatment plots to promote dune development, has been highly variable, as expected, due to seasonal to interannual changes in wave energy, beach erosion/rebuilding, and movement of rip current embayments. Generally, beach sediment budgets trended from positive from the pre-restoration baseline (Oct. 2019 to Feb. 2020) to negative by Feb. 2023, then back to positive values most recently (Feb. 2023 to Feb. 2025). Net changes over the observation period within the beach units indicate slight erosion in the northern two plots (TP1-2) and deposition in the southern four plots (TP3-6).

Despite notable fluctuations in beach sand supply, the treatment plots have maintained net depositional responses, albeit with some erosional intervals. Deviations include neutral (+/- 0.001 $m^3\ m^{-2}\ mo^{-1}$) to negative sediment budgets in Feb. to Oct. 2020 and Feb. 2023 through Feb. 2024. Meanwhile, net change of the TP1 control site remained neutral while the neighboring TP2 showed the lowest rates of accumulation related to notable sediment bypassing and longer-term declines in sand inputs from beach erosion. TP3 exhibited the second highest net positive sediment budget and significant dune development. TP4 and TP5 showed moderate amounts of sand accumulation (fourth and third highest, respectively), while TP6 accumulated the greatest net amount of sand, although most of this deposition was confined to the seaward edge of the plot and downwind of a drift fence along the transportation corridor to the north.

On average, plant cover has increased for all treatment plots since installation in Feb. 2020,

including slight recent gains (~1.66% cover) within the TP1 control site. To date, TP6, the most intensive treatment, showed the greatest net increase in plant cover (+11.13%), followed by TP3 (+6.86%), TP5 (+6.55%), TP4 (+5.56%), and TP2 (+5.04%). Peak observed historical cover at the FRA site and in the broader foredune zone of the OHV riding area, respectively, were about 3% and 6% in 1966[1]. Since Oct. 2023, a distinct decrease in plant cover occurred in most treatment plots with TP6 showing the largest declines (-7.70%) followed by TP5 (-3.50%), then TP3 (-3.40%). The cause of this decline is unclear, but the patterns are widespread across the FRA and could relate to unusually wet and stormy winters since 2022. Over this time, TP1 and TP2 maintained a gradual increase in plant cover, with establishment of smaller nebkha and juvenile plants along the seaward edges of the plots. Some species, namely *Abronia latifolia*, have shown rapid establishment and growth, and have played leading roles in dune development to date.

In terms of FRA treatment performance, following 5 full wind and plant growth seasons, the plots continue to evolve on different trajectories as a function of initial treatments and variability in sand supply, plant cover, and changing roughness. Relative rankings of treatment performance have not changed significantly since Oct. 2022, with TP3 as a top performer, followed by TP5, due to continued positive sediment budgets, greatest amounts of dune development and extension, maintenance of aeolian activity, continued increases in average plant cover, and greatest potential for reducing dust emissions. TP2 maintains the lowest performance due to modest amounts of accretion and dune development, low plant cover, and correspondingly low dust emissions control potential. The most intensive treatment (TP6) slid recently to second lowest performance due to continued declines in sediment budget, limited dune development, and marked declines in vegetation cover. Monitoring will continue as the treatments evolve to detect further responses indicative of success or concern for adaptive management and for longer-term sustainability of the FRA as a dust control mitigation site.

[1] Swet, N., Hilgendorf, Z., and Walker, I.J., 2022. UCSB Historical Vegetation Cover Change Analysis (1930-2020) within the Oceano Dunes SVRA. Report prepared for CDPR for the 2022 ARWP. 86 p.

1. Introduction

The purpose of the foredune restoration project is to help reduce dust emissions in the ODSVRA and downwind through the implementation of a nature-based foredune restoration area (FRA) on a formerly highly emissive site near the beach. To monitor and assess the performance of the FRA project, a team from UC Santa Barbara, in collaboration with CDPR, have conducted biannual UAS flights since Oct. 2019 (Figure 1). The UAS imagery datasets are used to create the following data products:

1. Twelve (12) visual (RGB) georeferenced aerial orthomosaic images of the FRA at ~1.5 cm resolution,
2. Ten (10) multispectral (RGB-RE-NIR-Pan) georeferenced orthomosaic images of the FRA at ~3.0-7.5 cm resolution collected concurrently with the RGB datasets since Oct. 2020,
3. Ten (10) NDVI orthomosaics used to assess vegetation cover in the FRA at ~3.0-7.5 cm resolution derived from the multispectral orthomosaic datasets
4. Ten (10) georeferenced, orthorectified maps of vegetation cover derived from RGB and NDVI imagery used to track changes in plant cover within the FRA,
5. Twelve (12) three-dimensional point clouds of surface topography within the FRA at a decimated resolution of 10 cm,
6. Twelve (12) three-dimensional digital elevation models (DTMs) of topography within the FRA at 10 cm pixel resolution,
7. Eleven (11) topographic change maps derived from statistically significant pixels of erosion and deposition between DTM intervals used to assess geomorphic and sediment volume changes.

Data collected during the UAS flights allows for high resolution, three-dimensional DTM surfaces to be constructed and compared to quantify sand volume changes and dune dynamics over time. Given the low-lying, prostrate nature of the vegetation, separation of plants from the underlying sand surface is difficult without introducing artifacts in the point cloud. Other data collected allow for examination of the growth of vegetation and the development of dune forms within the FRA.

This report briefly explains the methods used for data collection and processing, but focuses mainly on interpreting new results from 2024-2025 in the context of longer-term trends within the restoration treatments from the initial baseline survey of the FRA (Oct. 2019) through to Feb. 2025. These results span 5 full years of site development following treatment installations in Feb. 2020. As in previous reports, we also assess the performance of the restoration treatments at ODSVRA using 5 indicators, developed in consultation with SAG and CDPR, that track the geomorphic, sediment transport, vegetation characteristics and responses within the treatment plots (Walker et al. 2023)[2]. These indicators characterize the re-establishment of dynamic ecological and geomorphic conditions required to improve dune ecosystem form and function.

[2] Walker, I. J., Hilgendorf, Z., Gillies, J. A., Turner, C. M., Furtak-Cole, E., & Nikolich, G. (2023). Assessing performance of a “nature-based” foredune restoration project, Oceano Dunes, California, USA. Earth Surface Processes and Landforms, 48(1), 143-162.

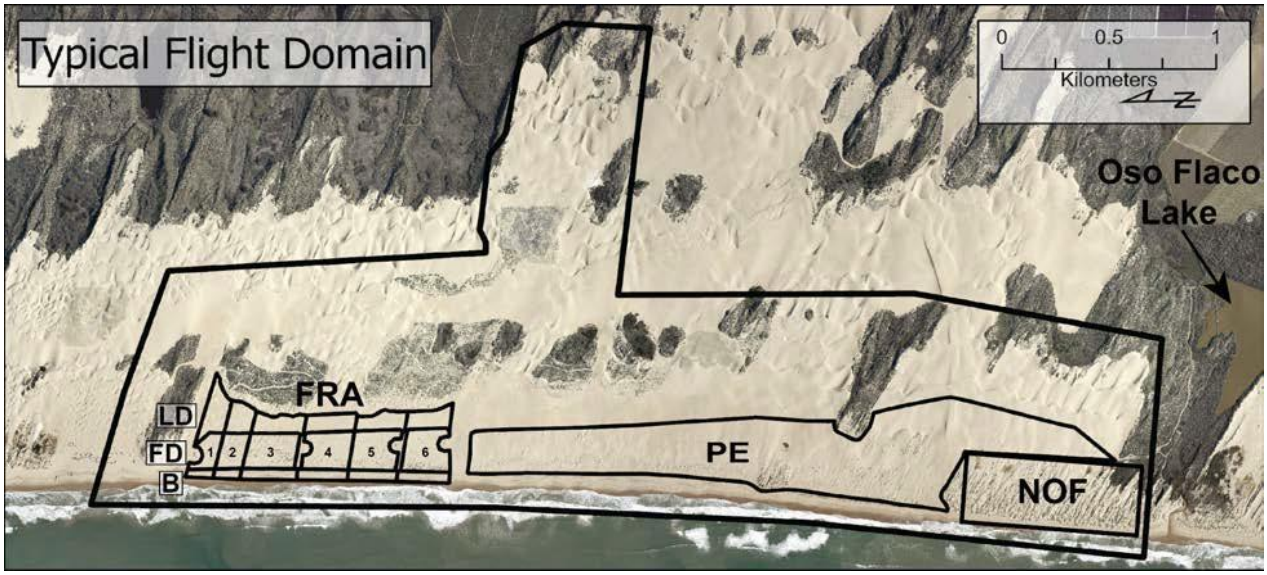


Figure 1. *Map showing the typical extent of the UAS surveys (North oriented to the left). The foredune restoration area (FRA) and foredune (FD) treatment plots (1-6) are shown with adjoining beach (B) and landward dune (LD) polygons used to delimit volumetric change calculations with the FRA. The Western Snowy Plover exclosure (PE, as of Feb. 2024) and North Oso Flaco (NOF) reference site are also shown. The underlying orthomosaic is from 27 Jan. 2023 (NOAA, 2024)[3].*

2. Methods

Full details on the methods used for this work are documented in prior reports by Hilgendorf et al. (2023[4], 2024[5]). Since October 2019, a fixed-wing, fully autonomous WingtraOne UAS platform has been flown biannually with surveys bracketing the nesting season of the Western Snowy Plover, typically in October and February. UAS imagery is processed using Structure-from-Motion (SfM) photogrammetry (Agisoft Metashape) to produce georeferenced orthomosaics, DTMs, and maps of vegetation cover produced using the Normalized Difference Vegetation Index (NDVI). These products are then used to monitor and characterize changes in sediment volumes, geomorphic responses, and vegetation cover within and beyond the restoration treatments (Figure 1). The UAS is typically flown at altitudes over 100 m above ground level and is equipped with on board, survey-grade GPS with post-processed (PPK) correction capabilities. During data collection, a GPS base station is operated in static collection mode and occupation datasets are used to refine UAS photo point locations to within millimeters of their real-world locations. Surveys are flown in full

[3] National Geodetic Survey, 2024: 2023 NOAA NGS Aerial Imagery for Situational Awareness: Central California, https://www.fisheries.noaa.gov/inport/item/69185.

[4] Hilgendorf, Z. Walker, I.J., Swet, N., & Heffentrager, M. (2023). UCSB 2022-2023 ODSVRA Foredune Restoration Survey Report. Research report to the Oceano Dunes Scientific Advisory Group (SAG) and the State of California Department of Parks and Recreation. 44 p.

[5] Hilgendorf, Z., Walker, I.J., Heffentrager, M. (2024). 2023-2024 ODSVRA Foredune Restoration UAS Monitoring Report. Technical Report to the Oceano Dunes Scientific Advisory Group (SAG) and the State of California Department of Parks and Recreation (CDPR). 37 p.

compliance with FAA regulations and as reviewed and approved by the University of California UC Unmanned Aircraft System Safety Program[6]. CDPR wildlife monitors are always present to ensure safe conditions for wildlife during the UAS flights.

To date, 12 UAS survey campaigns have been flown producing 12 visual (red, green, blue or RGB) datasets since Oct. 2019 and 10 multispectral datasets collected since Oct. 2020 (Table 1). Resulting high resolution (<2 cm) orthomosaic imagery is then converted in SfM software to three-dimensional point clouds of the underlying surfaces. Point clouds between campaigns are aligned to one another using static features in the landscape (e.g., structures, roads, etc.). Point clouds are then used to produce gridded (rasterized) DTMs. Raster surfaces are gridded to 0.1 m/pixel and assigned an elevation value by averaging all points within that 0.1 m^2 cell. Multispectral surveys are flown separately from the RGB flights.

Successive DTMs are imported into a GIS and the Geomorphic Change Detection (GCD) toolset, developed by Riverscapes Consortium, is used to detect locations of statistically significant elevation change and calculate associated volumes between collocated raster grid cells. The method applies a spatial statistical filter to remove surface changes that fall below a threshold uncertainty value with 95% confidence[7,8] based on a total uncertainty budget that includes the accuracy of the GPS station, the calculated uncertainty of the point cloud, and the root mean square error from the alignment of each point cloud with static features in the landscape. The uncertainty between two surveys is additive and pixels that exceed the minimum level of detection threshold (typically ~5 cm) are included. Significant pixels are used to create topographic (elevation) change maps for estimating volumetric changes and interpreting corresponding geomorphic changes. Results are usually partitioned into specified landscape units to monitor plot-based change through time, such as between the foredune restoration treatment plots themselves, as well as their adjoined beach and landward dune components (Figure 1).

Two multispectral sensors have been used to date: a Micasense RedEdge-MX (Oct. 2020 - Feb. 2022) and a Micasense RedEdge-P (Oct. 2022 to present). The RedEdge-MX has a 5-band sensor that captures visual (RGB), red edge (RE), and near-infrared (NIR) bands. This sensor was replaced with the RedEdge-P, which contains the same five bands and an additional panchromatic (Pan) band that is used to improve the resolution of the dataset from ~7 to ~3.5 cm/pix. From these bands, NDVI-derived vegetation maps are produced.

[6]https://www.ucop.edu/safety-and-loss-prevention/environmental/program-resources/unmanned-aircraft-systems-safety.html

[7] Wheaton, J. M., Brasington, J., Darby, S. E., & Sear, D. A. (2009). Accounting for uncertainty in DEMs from repeat topographic surveys: improved sediment budgets. Earth Surface Processes and Landforms, 35(2), 136-156. https://doi.org/10.1002/esp.1886.

[8] Hilgendorf, Z., Marvin, M. C., Turner, C. M., & Walker, I. J. (2021). Assessing Geomorphic Change in Restored Coastal Dune Ecosystems Using a Multi-Platform Aerial Approach. Remote Sensing, 13(3), 354. https://doi.org/10.3390/rs13030354.

Table 1. *Specifications for the RGB and multispectral UAS campaigns. Multispectral sensors were only used after installation of the vegetation treatments in Feb. 2020. GSD (ground sample distance) is the distance between the center of adjacent pixels and describes the cell size (pixel resolution) in centimeters. Total uncertainty values are the calculated vertical uncertainty for datasets used in DTM development and volumetric change detection mapping. As the multispectral datasets were not used for this purpose, no uncertainty value is shown.*

UAS Survey Campaign	Survey Date	Sensor Payload	Average Altitude (m)	GSD (cm/pix)	Total Uncertainty (m)
1. Baseline pre-restoration survey	1-2 Oct. 2019	Sony RX1RII	114	1.45	0.038
2. Initial treatment installations	10-11 Feb. 2020	Sony RX1RII	123	1.56	0.033
3. First post-treatment survey and growing season	13-15 Oct. 2020	Sony RX1RII	121	1.54	0.037
	16 Oct. 2020	Micasense RedEdge-MX	113	7.53	—
4. End of first year of geomorphic response and vegetation growth	17-18 Feb. 2021	Sony RX1RII	120	1.52	0.030
	18-21 Feb. 2021	Micasense RedEdge-MX	118	7.89	—
5. Second growing season	4-5 Oct. 2021	Sony RX1RII	121	1.54	0.025
	5-7 Oct. 2021	Micasense RedEdge-MX	119	7.82	—
6. End of second year of geomorphic response and vegetation growth	23-25 Feb. 2022	Sony RX1RII	112	1.42	0.043
	25-26 Feb. 2022	Micasense RedEdge-MX	116	7.71	—
7. Third growing season	17-18 Oct. 2022	Sony RX1RII	125	1.66	0.026
	19-21 Oct. 2022	Micasense RedEdge-P	111	3.67	—
8. End of third year of geomorphic response and vegetation growth	23 Feb. 2023	Sony RX1RII	121	1.59	0.034
	20-21 Feb. 2023	Micasense RedEdge-P	120	3.97	—
9. Fourth growing season	9 Oct. 2023	Sony RGB61	108	1.65	0.049
	10-13 Oct. 2023	Micasense RedEdge-P	135	4.42	—
10. End of fourth year of geomorphic response and vegetation growth	23 Feb. 2024	Sony RGB61	116	1.78	0.071
	21-23 Feb. 2024	Micasense RedEdge-P	133	4.38	—
10. Fifth growing season	29-30 Oct. 2024	Sony RGB61	107	1.65	0.047
	14-18 Oct. 2024	Micasense RedEdge-P	121	3.96	—
11. End of fifth year of geomorphic response and vegetation growth	20-21 Feb. 2025	Sony RGB61	125	1.89	0.030
	18-19 Feb. 2025	Micasense RedEdge-P	123	4.05	—

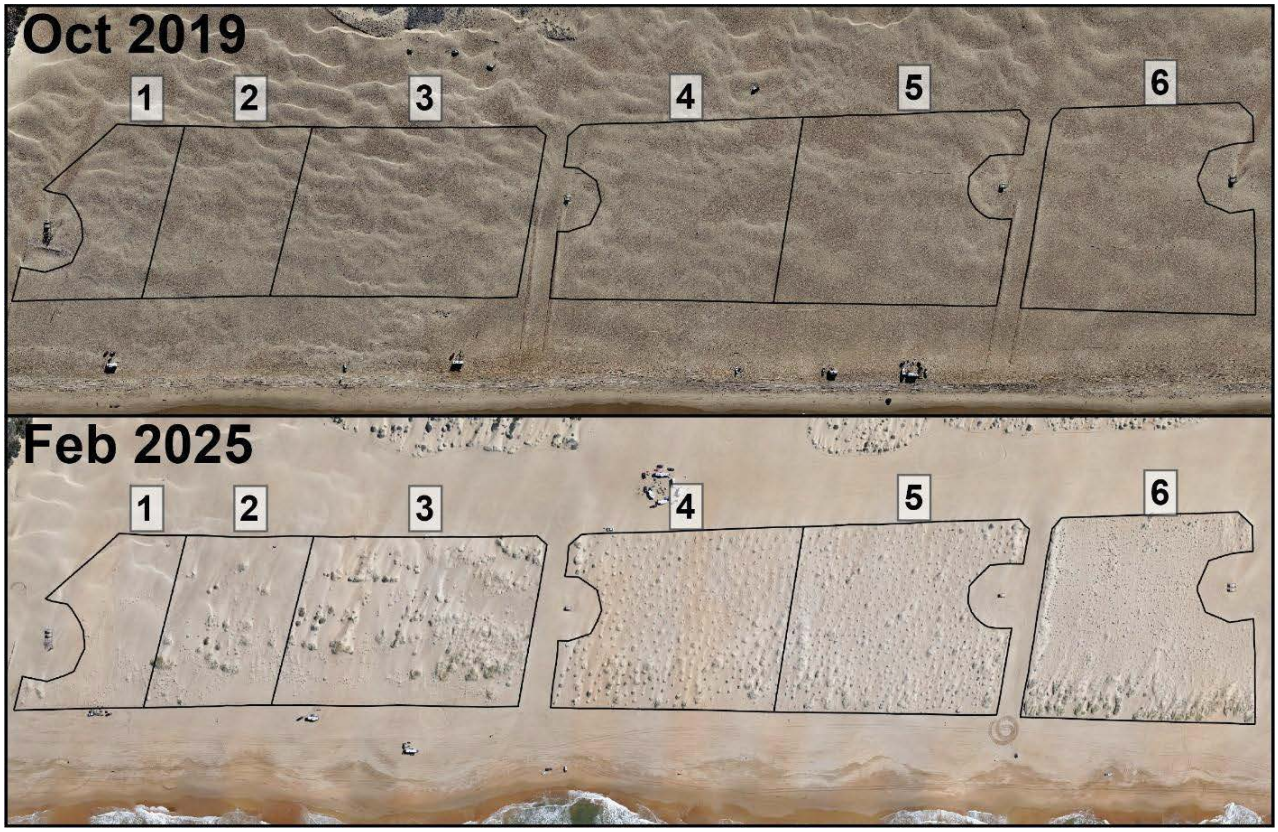


Figure 2. *Visible (RGB) orthophoto mosaics of the FRA from the initial baseline survey (Oct. 2019) prior to restoration treatment implementation in February 2020, and the latest (Feb. 2025) UAS survey. Numbers represent the treatment plot (TP) types: TP1) Sheepsfoot texturing (control site), TP2) native seeds, TP3) native seeds + sterile ryegrass seed, TP4) low density straw planting nodes, TP5) high density planting nodes, and TP6) broadcast straw, randomly planted seedlings, and broadcast seed. Notable aeolian activity, nebkha development, and streamlined shadow dune accretion is widespread in all treatments except within the control plot (TP1).*

3. Results

3.1 UAS visible (RGB) imagery and orthophoto mosaics

Figure 1 shows the typical extent of the UAS visual (RGB) orthophoto campaigns. Figure 2 and Appendix A show all biannual UAS RGB orthophoto mosaics of the FRA back to Oct. 2019. These images are used to interpret geomorphic responses within the treatment plots (TP), such as aeolian sand transport corridors (ripples), deflation surfaces (coarse lag deposits), and dune development. TP types are explained in the caption for Figure 2.

3.2 UAS multispectral imagery and plant cover estimation

To enhance the detection and monitoring of vegetation at the landscape scale in restoration treatment areas, multispectral imagery has been collected since Oct. 2020 (Figure 3). The initial

survey focused primarily on the seaward extent of the ODSVRA, including the FRA, seasonal plover exclosure, and established foredunes near Oso Flaco Lake. The Feb. 2021 survey covered a larger extent to match that of the RGB surveys and this coincident survey strategy has been followed since (Figure 1), with minor variations related to logistical and weather constraints. Multispectral sensors are calibrated pre- and post-flight with a calibration panel so that, while some orthomosaics in Figure 3 may appear to have variable contrast, individual pixels are properly scaled and the extracted indices are accurate.

NDVI values were calculated for all multispectral surveys to detect and map vegetation and its changes through time. Percent plant cover (normalized by total area of each treatment plot) has generally increased through time in all treatment plots (Figure 4, Table 2). TP6 shows the greatest plant cover change (from 2.5% in Oct. 2020 to 11.1% by Feb. 2025), followed by TP3 (2.7 to 6.9%), TP5 (1.7 to 6.6%), TP4 (0.9 to 5.6%), TP2 (0.4 to 5.0%) and TP1 (0.0 to 1.3%).

For context, plant cover observed in historical aerial imagery back to 1939 within the broader ODSVRA averaged approximately 25% in 1939 with a peak at 37% in 2012 and slight decline to 35% by 2020, before implementation of the FRA[9]. More recent imagery includes extensive backdune shrub and forest ecosystems, and other new restoration sites. Within the foredune zone of the OHV riding area, plant cover was low (2.6 %) in 1939, rose to a peak of 5.3 % in 1966, but steadily declined to ~1% from 1985 to 1998. These lower values reflect the influence of decades of vehicular, camping, and other recreation activities in the dunes prior to the earliest aerial photography. Within the FRA specifically, the maximum observed vegetation cover was 5.3% in 1939 then declined to negligible cover by 1985. Since then, plant cover in the FRA remained negligible until after implementation of the restoration treatments in 2020. In contrast, at the nearby South Oso Flaco reference site, plant cover was 26% in 1939, decreased to a low of 24% in 1949, increased to a peak of 66% in 2012, and remained >60% by 2020. At North Oso Flaco, foredune plant cover was extremely low (<1%) in the 1930s, but increased notably after 1985 to over 24% by 2012. Plant cover estimates in these reference sites partly reflect the influence of invasive species and more recent restoration efforts in these areas. Following restoration in the FRA, plant cover has increased to an average of 6.13% across all treatment plots by Feb. 2025 (Table 2), which remains below historic coverage ranges of the nearby reference sites at North and South Oso Flaco, but now exceeds the historic maximum cover of 1939 (5.3%), albeit in a variable patchwork distribution across 5 different restoration treatments.

Figure 4 shows general increasing trends in plant cover with notable seasonal declines (February), then increases (October) that bracket the plant growth season. Most treatments also showed a notable decline in plant cover in recent monitoring intervals (Oct. 2023 - Feb. 2025), however, TP1 and TP2 continue to show consistent increases over this time.

[9] Swet, N., Hilgendorf, Z., & Walker, IJ. (2022). UCSB Historical Vegetation Cover Change Analysis (1930-2020) within the Oceano Dunes SVRA. Technical report to the Oceano Dunes Scientific Advisory Group (SAG) and the State of California Parks and Recreation Department Off-Highway Vehicle Division. February 2022.

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254 ***Table 2.*** *Vegetation cover (%) in each treatment plot (TP1-6) as shown in Figure 4.*

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Survey Date	TP1	TP2	TP3	TP4	TP5	TP6
10-11 Feb. 2020	0.00	0.00	0.00	0.00	0.00	0.00
16 Oct. 2020	0.02	0.41	2.66	0.87	1.65	2.54
18-21 Feb. 2021	0.03	0.42	2.15	0.95	1.85	3.28
5-7 Oct. 2021	0.14	1.85	4.87	1.93	3.63	3.54
25-26 Feb. 2022	0.08	1.74	4.55	2.24	4.64	11.35
19-21 Oct. 2022	0.26	3.45	11.47	6.03	9.57	14.82
20-21 Feb. 2023	0.12	2.68	8.93	5.52	9.66	14.83
10-13 Oct. 2023	0.73	3.83	10.36	7.55	9.68	19.36
21-23 Feb. 2024	0.42	3.10	6.95	4.85	6.18	11.68
14-18 Oct. 2024	0.92	4.71	8.21	4.49	6.72	13.12
18-19 Feb. 2025	1.66	5.04	6.86	5.56	6.55	11.13

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Figure 3. *Multispectral false-color (G, B, NIR) UAS orthomosaics captured from a Micasense RedEdge-MX 5-band sensor (R, G, B, RE, NIR) in Oct. 2020 and a Micasense RedEdge-P 6-band sensor (R, G, B, Pan, RE, NIR) in Feb. 2025, used to map vegetation cover. Contrast differences are only visual and do not impact the indices calculated from the values of compared bands. Locations of the FRA treatment plots are outlined.*

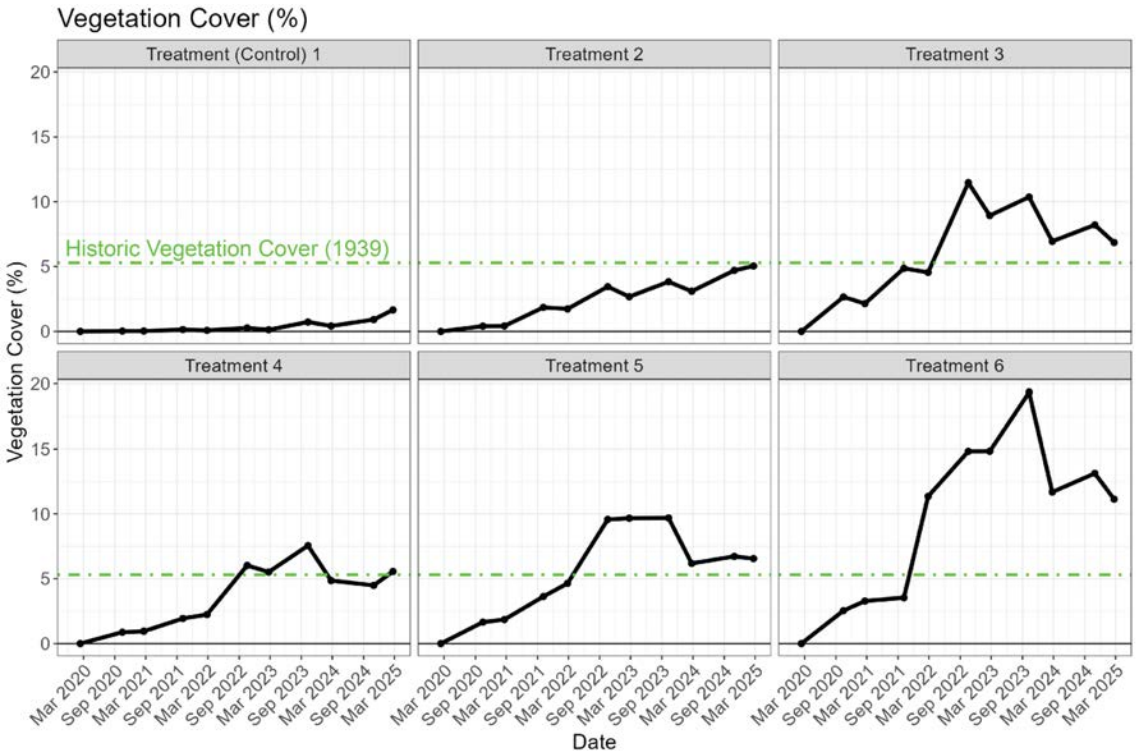


Figure 4. *Percent vegetation cover by treatment plot derived from the multispectral UAS surveys from Feb. 2020 (treatment implementation) through to Feb. 2025. Seasonal fluctuations are evident in most treatments due to declining cover before (Feb.) and increasing cover after (Oct.), reflecting the plant growth season. Green dash-dot line is the peak extent of historic vegetation cover in 1966 (5.3%) within the foredune zone of the broader OHV riding area in 1966 prior to establishment of the ODSVRA (Swet et al. 2022). Corresponding values shown in Table 2.*

3.3 Topographic Differencing and Volumetric Change Trends

The topographic difference maps (Figures 5 and 6) show areas and quantities of significant elevation change that are used to calculate volumes of sediment erosion or deposition between surveys in cubic meters (m^3) or normalized by area ($m^3\ m^{-2}$), which is effectively an average depth of change (m) over the entire treatment plot (or adjoining unit) areas. Data are also normalized by time (month) to allow comparison of changes across different observation intervals (i.e., ~8 months between the Feb. to Oct. interval and only ~4 months between the Oct. to Feb. interval). Values are presented in Table 3. The raster grid from which the volume estimates are determined remains fixed in position and size (0.10 m x 0.10 m) across all surveys. Pixels of statistically insignificant change, as determined by a two-tailed t-test at a 95% confidence interval in the GCD package (section 2), are not shown in the change detection maps and are not used to calculate sediment volumes.

Figures 5 and 6 show topographic difference maps (i.e., pixels of statistically significant elevation change) and Figure 7 shows a time series of normalized volumetric changes within the treatment plots and their adjoined geomorphic units from Oct. 2019 and Feb. 2025. Geomorphic units include each of the foredune treatment areas (FD), an adjoining beach area (B), and landward backdune

areas (LD) (Figure 1). The first interval (Oct. 2019 to Feb. 2020) provides baseline reference conditions prior to implementation of the restoration treatments.

One key control on the volumetric and geomorphic responses in the treatments is the amount of sand that enters the upwind beach from the nearshore, which effectively provides supply for aeolian delivery to the treatment plots. Beach units fronting the plots saw variable trends of positive (depositional) and negative (erosional) change in sediment volumes that relate to seasonal variations (e.g., winter storm erosion signals) and migration of rip current embayments. Generally, the beach units show a highly variable trend in sand volumes from positive values in the initial Oct. 2019 to Feb. 2020 baseline interval to distinctly negative values by Feb. 2023. More recently, the beach units fronting all treatment plots, except TP5, have shown positive trends since 2023 (Table 3). The northern 3 plots have experienced more pronounced erosive intervals compared to the southern 3 plots suggest a general trend of minor erosion in the northern beach units, transitioning towards a more depositional state in the southern units.

All foredune treatment plots exhibited net positive sediment volumes and, with some exceptions, most intervals showed positive sediment budgets (Figure 7, Table 3). Distinct negative (erosional) volumetric responses occurred in most plots except TP6 from Feb. to Oct. 2023, but shifted back to depositional conditions following Oct. 2023. The TP1 control site and TP2 (native seed) continue to show the lowest rates of accumulation, reflecting significant beach erosion and sediment bypassing due to limited vegetation establishment and nebkha dune development. TP3 (native seed + sterile ryegrass seed) shows the second highest net accumulation of sand and only recorded one erosional interval (Feb. 2023 to Oct. 2023). TP4 and TP5 (low and high density straw planting nodes, respectively) experienced comparatively moderate change, as the fourth and third (respectively) highest accumulating plots. TP6 (broadcast straw + plants + seeds) is the only plot that did not exhibit a negative change interval through time and recorded the greatest net deposition, although this is associated largely with accumulations from sand fences on the northern side and dune development on the seaward edge of the plot. Since Oct. 2022, all treatment plots have shown neutral to slightly positive trends in normalized sediment volumes.

The foredune treatment plots vary notably in their sedimentation responses to vegetation establishment and/or surface treatments. TP1 and TP2 were the least altered by treatment interventions and maintained similar change patterns across all intervals. Sand transport in these plots generated low-lying (0.4 to 0.6 m), slowly migrating semi-continuous transverse and barchanoid dune ridges and protodunes. Limited plant cover established in TP1 except for a few plants near the seaward edge of the plot, first observed in Oct. 2022. Some shadow dunes were present in the landward half of these plots, but these were not associated with vegetation (i.e., nebkha), rather with nodes of cemented sand and anthropogenic debris[10]. Following the winter

[10] Hilgendorf, Z. Walker, I.J., Swet, N., and Heffentrager, M. (2023). UCSB 2022-2023 ODSVRA Foredune Restoration Survey Report. Research report to the Oceano Dunes Scientific Advisory Group (SAG) and the State of California Department of Parks and Recreation. 44 p.

storm season of 2023-2024, vegetation wrack and propagules that washed into the plot gave rise to an increase in vegetation cover by Oct. 2024. TP2 exhibited a developing nebkha cluster in the center of the plot, but this had not expanded notably by Feb. 2025. TP1 and TP2 recorded the smallest net changes in sand volume over the monitoring period (Table 3).

TP3 has developed significant nebkha, predominantly with *Abronia latifolia*, and these dunes have begun to coalesce and form discontinuous ridges >2 m tall, which are the tallest dunes in the FRA. The latest two intervals showed positive volumetric changes within TP3, which has had among the greatest and most consistent positive sediment budget responses of the sites, the second largest depositional interval (Feb. to Oct. 2022, 0.122 m^3m^{-2}), and the second greatest net deposition (Oct. 2019 to Feb. 2023, 0.326 m^3m^{-2}) to date (Table 3). These responses occur despite a roughly 40% decline in plant cover from the peak value in Oct. 2022 (Table 2, Figure 4).

TP4 and TP5 experienced localized erosion between planting nodes during early intervals. Although some of these 'erosional streets' persist, nebkha are growing and slowly coalescing in both plots[14]. TP4 and TP5 experienced the fourth and third highest net deposition amounts, respectively, to date (Table 3). Nebkha dunes in TP5 are larger than in TP4 and closer in height to the larger dunes in TP3, with some dunes >1.5 m tall. In the most recent surveys, however, dunes in TP4 had grown notably, particularly along the seaward half of the plot. Nebkha coalescence was observed in both treatments along the seaward half of the plot by Oct. 2023.

TP6 had the most intensive treatment with the highest planting density and complete surface straw cover on installation. Although it maintains the highest plant coverage (Figure 4, Table 2), greatest depositional volumes, and highest net positive sediment budget to date (Table 3), the development of larger nebkha has followed a different pathway than plots TP3-5. A notable portion of the accretion in TP6 is associated with the sand fence on the northern border with the transportation corridor, which has promoted significant drift development in the treatment plot. This drift does not reflect the effectiveness of the treatment itself and was not removed from the volumetric calculations due to its varying shape and difficulty defining its boundaries. The same fence-drift pattern is also observed on the north fence line of TP4. Nebkha within the TP6 boundary, downwind of the sand fencing or inland from the seaward edge, have yet to exhibit significant development, while plant cover has also declined markedly by ~43% from the peak in Oct. 2023 (Table 2, Figure 4).

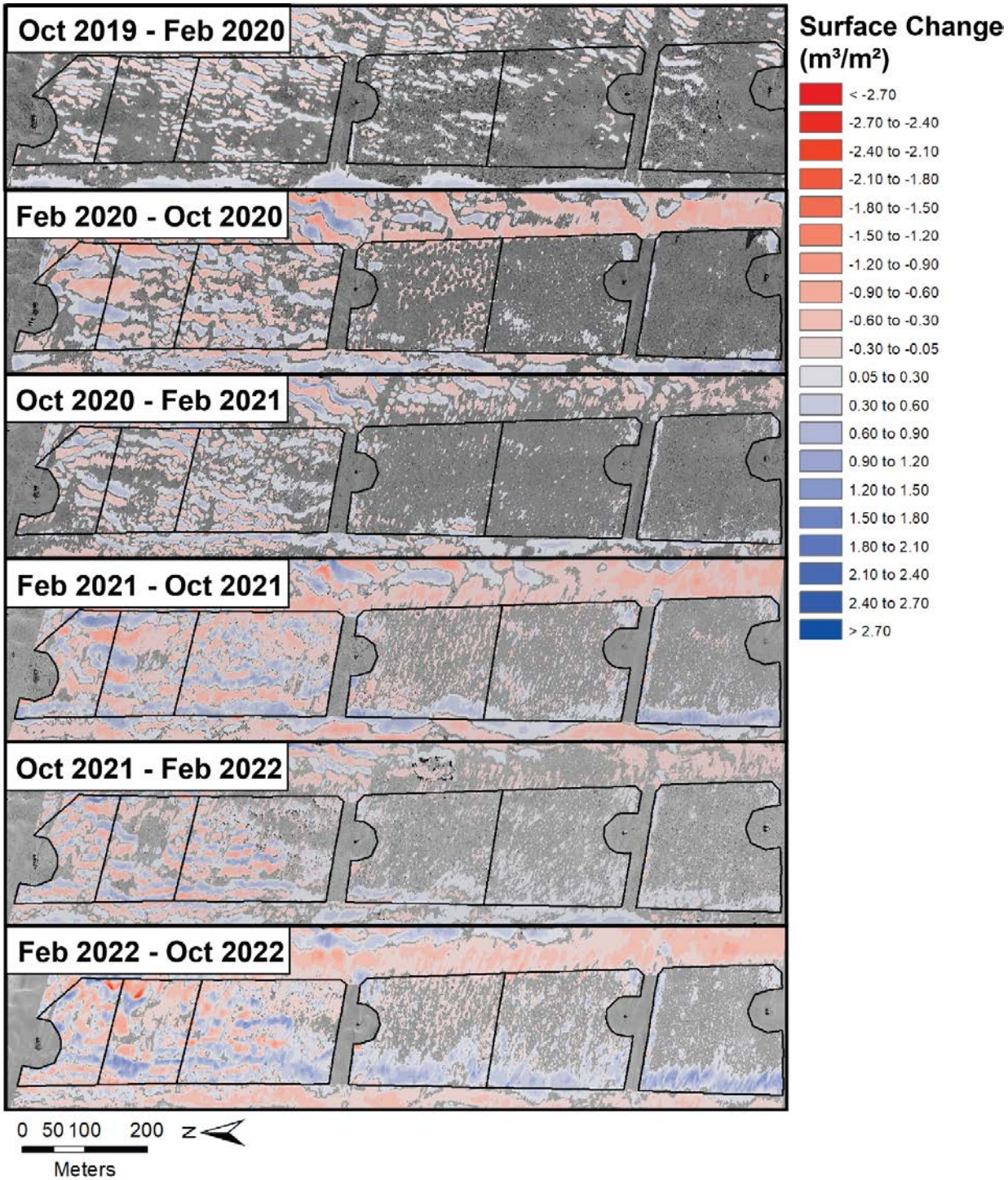


Figure 5. *Topographic change maps showing pixels of significant area-normalized volumetric changes (reds = erosion, blues = deposition) for survey intervals between Oct. 2019 and Oct. 2022 overlain on the UAS photomosaics for the second time step in each interval. Restoration treatment areas are outlined, from TP1 (control) on the left to TP6 on the right (see Figures 1 and 2). Intervening transportation corridors are not included in the analysis.*

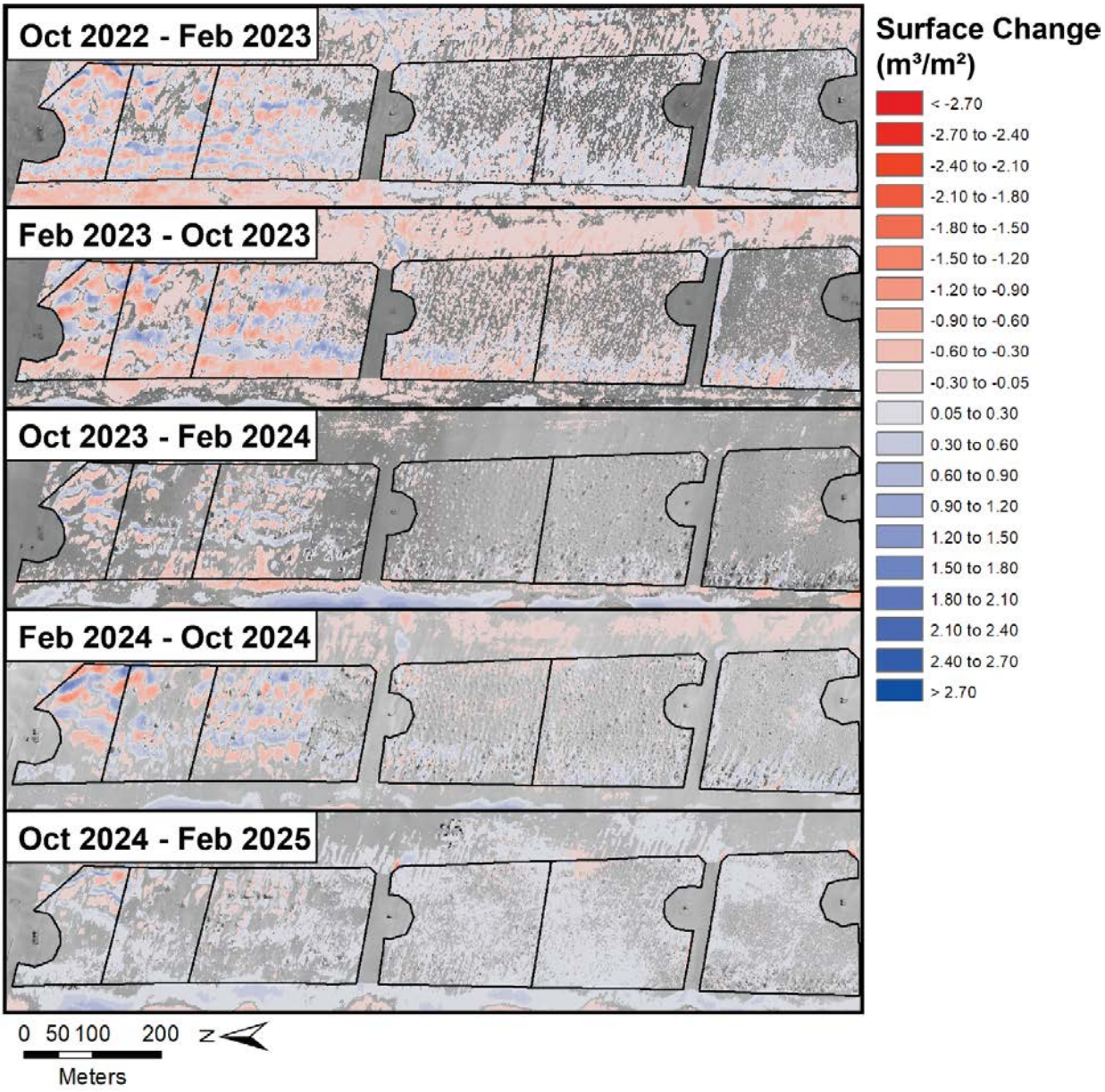


Figure 6. *Topographic change maps showing pixels of significant area-normalized volumetric changes (reds = erosion, blues = deposition) for survey intervals between Oct. 2022 and Feb. 2025 overlain on the UAS photomosaics for the second time step in each interval. Restoration treatment areas are outlined, from TP1 (control) on the left to TP6 on the right (see Figures 1 and 2). Intervening transportation corridors are not included in the analysis.*

Table 3. *Normalized surface volumetric changes for the beach (B), foredune treatment plots (FD), and landward dune (LD) zones. Blue text indicates sand accumulation, red text indicates erosion. Uncertainty values are provided in Table 1.*

Normalized Volumetric Change by Total Area ($m^3\ m^{-2}\ mo^{-1}$) x 100													
Tree	Geo	Oct	Feb	Oct	Feb	Oct	Feb	Oct	Feb	Oct	Feb	Oct	Net Ch
TP1 (control)	B	1.7	-0.2	-1.1	-0.5	1.5	-0.7	-9.0	0.6	1.6	0.1	4.8	*-0.1*
	FD	**0.1**	**0.1**	**0.4**	**0.9**	**0.8**	**0.4**	**-0.7**	**-1.6**	**0.0**	**0.4**	**1.0**	***0.1***
	LD	-0.1	0.2	0.6	-0.3	0.0	-0.1	0.2	0.0	-0.4	0.4	1.3	*0.1*
TP2	B	1.1	0.6	0.1	0.2	0.0	-0.5	-8.5	-0.6	0.1	1.5	3.3	*-0.1*
	FD	**0.1**	**-0.2**	**0.5**	**0.3**	**0.8**	**0.3**	**0.6**	**-0.6**	**0.0**	**0.3**	**0.8**	***0.2***
	LD	0.2	0.6	0.5	-0.2	-0.3	0.3	0.9	-0.1	0.1	-0.5	0.6	*0.1*
TP3	B	2.0	0.5	0.4	-0.5	1.6	-1.8	-6.6	0.6	3.6	1.4	2.5	*0.3*
	FD	**0.3**	**0.1**	**0.6**	**0.7**	**0.7**	**1.6**	**1.0**	**-0.5**	**0.0**	**0.4**	**0.3**	***0.5***
	LD	0.2	-0.5	0.7	-0.1	0.4	-0.9	0.4	-1.0	-0.1	-0.1	0.3	*-0.3*
TP4	B	3.6	1.2	-0.7	-0.3	1.1	-1.5	-1.2	0.6	4.5	1.5	1.3	*0.8*
	FD	**0.4**	**-0.2**	**0.2**	**0.4**	**0.4**	**1.2**	**0.8**	**-0.6**	**0.1**	**0.1**	**0.7**	***0.3***
	LD	0.1	-1.3	0.0	-1.4	0.0	-0.9	0.1	-1.2	0.0	-0.4	0.6	*-0.7*
TP5	B	3.4	-0.1	0.6	-0.2	1.4	-0.3	-2.0	0.6	3.0	1.1	-0.1	*0.7*
	FD	**0.2**	**0.1**	**0.1**	**0.3**	**0.3**	**1.1**	**0.8**	**-0.1**	**0.1**	**0.2**	**0.7**	***0.4***
	LD	-0.1	-1.8	0.1	-1.4	0.0	-2.2	-0.5	-1.7	-0.1	-0.5	0.7	*-1.1*
TP6	B	1.6	2.3	-1.4	-1.0	0.6	-0.9	-0.1	0.9	-2.0	2.3	2.2	*0.5*
	FD	**0.2**	**0.2**	**0.3**	**1.1**	**0.4**	**1.7**	**0.8**	**0.4**	**0.1**	**0.4**	**0.3**	***0.7***
	LD	-0.1	-2.1	-0.3	-2.2	-0.4	-2.9	-0.9	-1.8	0.0	-0.7	0.1	*-1.5*

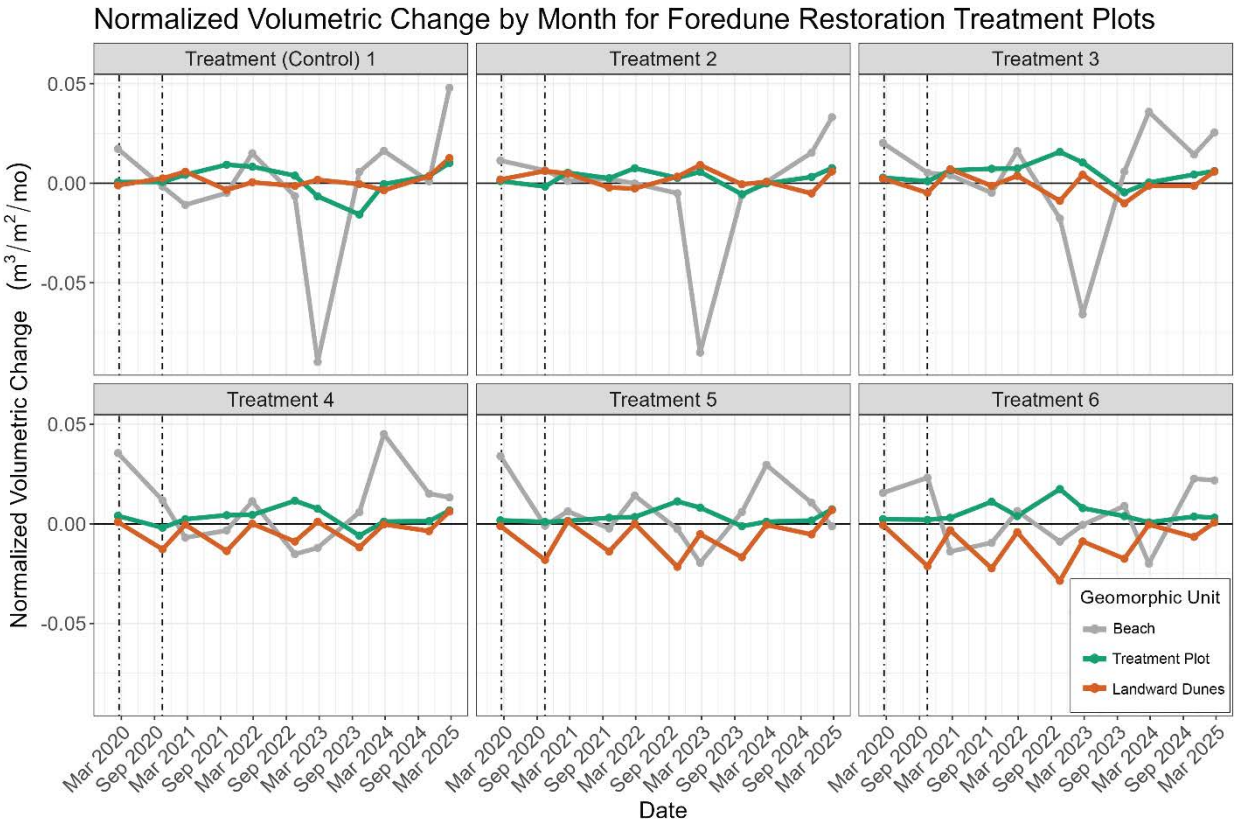


Figure 7. *Time series of normalized volumetric changes derived from successive survey intervals for each foredune restoration treatment plot (FD), adjacent beach (B), and landward dune (LD) units. Each point represents net results of volumetric change for the preceding interval (e.g., first point represents net change between Oct. 2019 and Feb. 2020, etc.). Dashed lines delimit the COVID-19 closure period (Mar. 2020 through Oct. 2020).*

4. Discussion

Most coastal dunes owe their form and function to the presence of vegetation. In turn, sand loving (psammophytic) plants require the conditions and disturbance processes offered by aeolian processes for their success[11,12]. These interactions are particularly important to recognize when designing and assessing foredune restoration projects. In addition, variability in sand inputs from the upwind beach, variations in other supply- and transport-limiting factors can also influence treatment responses and resulting dune evolution. At ODSVRA, sand volume and resulting geomorphic changes within the treatment plots show seasonal and interannual responses related to variations in factors that limit either the supply of sand to, or transport capacity of, aeolian

[11] Hesp, PA, and Martinez, M. (2007) Disturbance in coastal dune ecosystems. In: Johnson EA and Miyanishi K (eds.) Plant Disturbance Ecology: The Process and the Response, pp. 217–247. Elsevier.

[12] Wiedemann, A, and Pickart, A. (2007). Temperate Zone Coastal Dunes. Ch. 4 in Martinez, M. and Psuty, N. *Coastal Dunes: Ecology and Conservation. Ecological Studies 171*, 53-66. Elsevier.

transport, including: a) surface moisture, which acts as a supply-limiting factor that is highest in wetter winter months, b) the frequency of transporting winds, a transport-limiting factor that is highest in the April-June wind season, c) sand supply to the beach (and/or beach width), a supply-limiting factor that varies on seasonal to interannual scales, and d) the extent and type of treatment modifications, such as plant establishment and straw cover, which can act as both a supply- and/or transport-limiting factor on seasonal to interannual scales. Below, we interpret these interactions and responses within the FRA treatment plots with respect to sand volume and geomorphic changes, vegetation cover, and dune development. Following this, an assessment of performance of the treatments based on identified indicators is provided.

4.1 Geomorphic and Sand Volume Change Trends

Absolute volumes of sand inputs to the beach, foredune, and landward dune units at each treatment site over the 5-year monitoring period indicate relatively small changes in TP1 and TP2 in contrast to large changes in TP5 and TP6, which reflects an observed north-south gradient in sand supply to the beach as well as an increasing trend in wind strength. In addition, notable erosion is evident in the landward units behind TP3-6, which reflects lower sediment bypassing, an erosional wake effect that is not as pronounced in the more northern treatment plots, and the north-south gradient in increasing wind speeds. Seasonal to interannual variations are also evident at many locations, reflecting winter beach erosion and/or movement of rip cell embayments that reduce beach width, or spring/summer bar welding on to the upper beach and increased aeolian activity (see also erosion/deposition patterns and trends in Figures 5 to 7). Figure 7 also shows that, despite high variability in beach sand volumes and a general net erosional trend, the foredune treatment plots have maintained a net positive sediment budget response, indicative of continued accretion in developing vegetated dunes. Significant declines in beach sediment during the winter 2023 season (Oct. 2022 to Feb. 2023) were not mirrored in the adjoined foredune treatment plots, although most showed a continued or increasing negative trend in sand volume in the following interval (to Oct. 2023). The most recent Feb. 2024 to Feb. 2025 intervals showed consistent increased deposition between both the beach and foredune geomorphic units.

Changes in the landward dune units (LD) are variable given the lack of vegetation and continued influence of OHV traffic. Areas downwind of TP3-6 show seasonally alternating (peak-valley) trends in their sediment budgets, whereas areas downwind of TP1-2 do not show this trend. Though speculative, this could relate partly to the greater and seasonally varying influence of plant growth/roughness, sand accretion, and dune development within TP3-6 compared to TP1-2. For instance, this seasonal pattern is evident in the LD unit downwind of TP3, which alternated between positive budgets in fall/winter (Oct. to Feb.) and negative budgets during the wind and plant growth season (Feb. to Oct.) when more sediment accreted in the upwind treatment plot. The longer-term trend of this cycle is predominantly negative in the LD units behind TP4-6 (Table 3), which have

developed increasingly larger dunes and more extensive plant cover.

4.2 Vegetation Change and Dune Development

Since implementation, all restoration treatment plots (TP2-6) experienced an increase in plant cover (Figure 4). TP6 and TP3, respectively, had the fastest rates of vegetation establishment, while the TP1 control site and TP2 showed negligible to slow rates of plant cover to values that remain below the historical average. Most plots experienced a decrease in plant cover in the Oct. 2023 to Feb. 2024 interval, but had begun to increase over the last three survey intervals. Furthermore, the TP1 and TP2 plots showed greater increases in vegetation than in the previous two intervals. Overwash events in the preceding year deposited debris and some vegetation propagules within the seaward portions of the plots, allowing the establishment and expansion of vegetation and the initial development of some nebkha within TP1 (Figure 8), and notable increases in smaller vegetation along the seaward edge of the TP2 and TP3 plots.

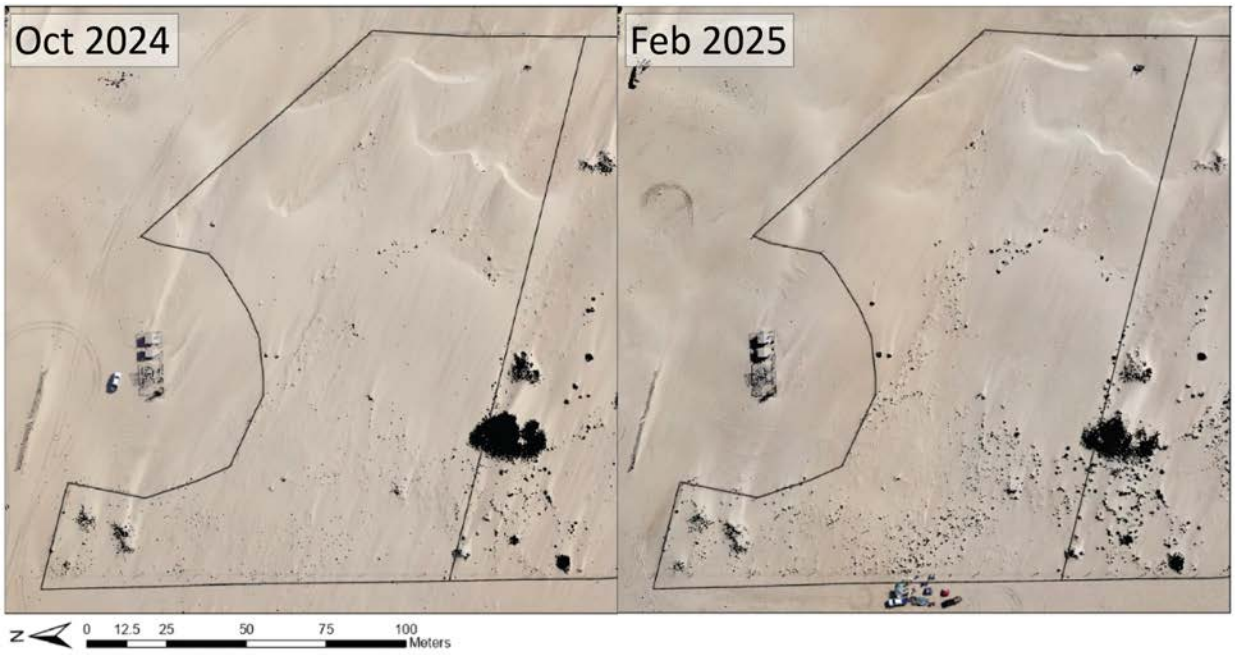


Figure 8. *Expansion of vegetation on the seaward margins (shoreline below bottom of image) of the control plot (TP1) and neighboring TP2 site between Oct. 2024 and Feb. 2025 in response to overwash deposits of debris and plant propagules during the preceding year. Vegetation pixels are shown in black, overlying the RGB orthomosaic image for each year.*

Dune development continues to differ distinctly across the treatment plots. At the TP1 control site, protodunes and transverse/barchanoid ridges continue to migrate through the plot, ranging in height from 0.3 m near the seaward edge to 1.3 m at the landward edge, with limited nebkha development near the seaward edge of the plot. Combined with a net neutral sediment budget, this

indicates appreciable sand bypassing through the control plot due to limited vegetation cover.

A similar pattern of migrating dune ridges was observed in TP2 and TP3, but with vegetated nebkha near the center of TP2 (>2 m high) and much larger (>3 m) coalesced nebkha ridges in TP3. These nebkha are formed predominantly with *Abronia latifolia*. Until Oct. 2023, TP2 and TP4 were the only sites with developed nebkha to show net erosion (volumetric loss) in response to wind erosion following installation. In TP4, this related to the development of erosional streets between the lower density straw planting circles.

Widespread nebkha development was observed in TP4-6. In TP4 and TP5 nebkha developed mostly on the planting circles and now reach heights > 2 m. TP5 has a greater number of larger nebkha distributed more broadly across the plot due to the closer spacing of the planting nodes, whereas nebkha in TP4 are generally confined to the seaward half of the plot. TP6 began as the roughest of all the plots (full straw cover, many randomly distributed plants), but only the seaward edge and northern fence line of the plot have shown appreciable dune development, while the size and development of nebkha in the central portion of the plot remains limited.

Feedbacks between dune roughness, secondary flow patterns, surface shear stress, and sand transport will continue to evolve and influence dune development[13]. While beyond the scope of this report, ongoing work comparing wind data from the meteorological stations at the eastern edge of the plots, nebkha development, and geomorphic change suggests that the more geomorphically developed TP3, TP5, and TP6 sites have the greatest impact on the wind fields. Variations in roughness patterns between these plots has resulted in notably different dune development pathways (Figure 9). TP5 has formed elongated nebkha chains with some coalescence, partly in response to the initial (random) arrangement of the straw planting circles. TP3 has developed laterally coalesced nebkha ridges at multiple locations to form some of the largest dunes within the FRA. Additional observations in TP2 and TP6 confirm two distinct developmental pathways. First, nebkha in TP2 and TP6 tend to 'clump' (wind-normal coalescence) and widen to produce discontinuous flow-transverse nebkha ridges. This lateral extension of nebkha is key to the development of a shore-parallel foredune ridge and the discontinuous morphology of foredune ridges in central and southern California is the typical form, given the controls of regional climate and native dune plant communities. Second, nebkha in TP4 and TP5 primarily exhibit 'chaining' (wind-aligned extension) that connects downwind nebkha via shadow dune extension. This pattern is partly driven by initial positioning of the planting circles and intervening erosional streets, but this type of organization (long streamlined nebkha ridges with erosional deflation troughs) is also observed in the North Oso Flaco reference site (Figure 1).

[13] Walker, I.J., Hesp, P. and Smyth, T. (2022). Airflow dynamics over unvegetated and vegetated dunes. Chapter 7.16 in Aeolian and Desert Geomorphology in Shroder, J. F. (Ed.) and Lancaster, N. (Section Ed). *Treatise on geomorphology*, *7*(2), pp.415-453. London, United Kingdom: Elsevier.

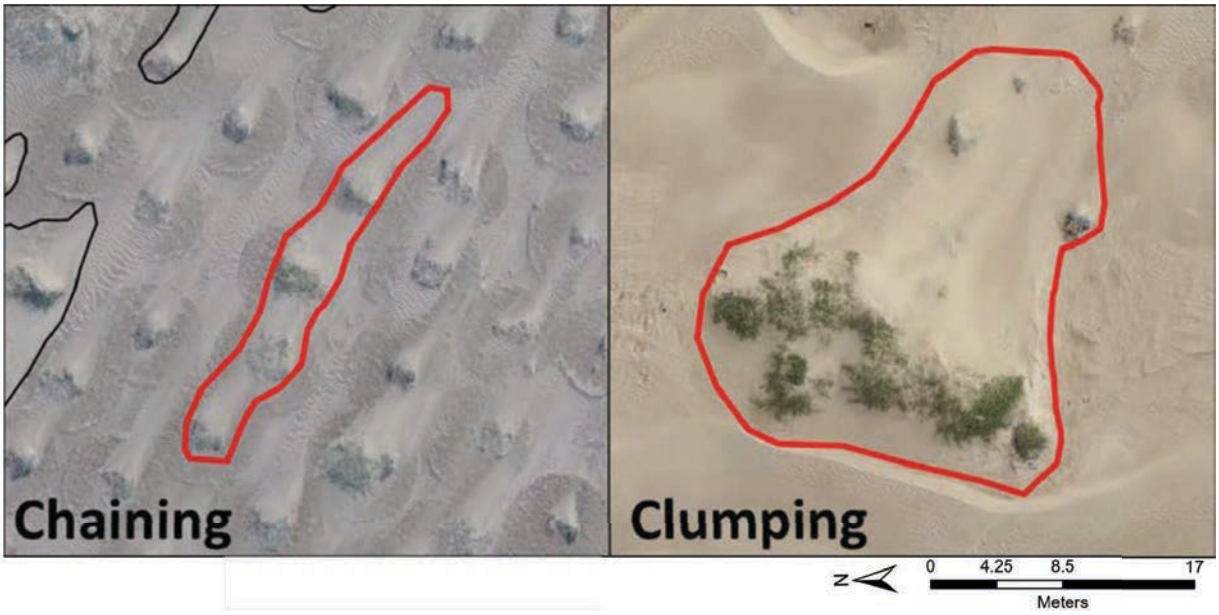


Figure 9. *Examples of two distinct dune evolution responses emerging in the treatment plots. Nebkha chaining (left, from TP5) involves wind-aligned extension of nebkha and shadow dunes to form long, linear ridges that do not exhibit substantial wind-normal coalescence with proximal nebkha. Nebkha clumping (right, from TP3) refers to lateral coalescence of nebkha that produces discontinuous wind-normal dune ridges with some wind-aligned shadow dune extension that facilitates wider nebkha organization with a broader tail.*

4.3 Performance Assessment of Restoration Treatments

The foredune restoration project at ODSVRA was designed to re-establish a foredune ecosystem with dust emissions mitigation benefits using a 'nature-based' approach with an assortment of treatment types of increasing levels of intervention. As the project is subject to adaptive management by CDPR, it is important to recurrently evaluate the relative performance of the treatments for forming self-sustaining dunes and reducing dust emissions. In response, we developed, in consultation with SAG and APCD, a series of indicators of performance that would be monitored and assessed each year. The outcome is a cumulative score whereby lower total values indicate higher overall performance. Indicators and relative performance assessment evaluation (Figure 10) are discussed below and explained further in Walker et al. (2023)[1].

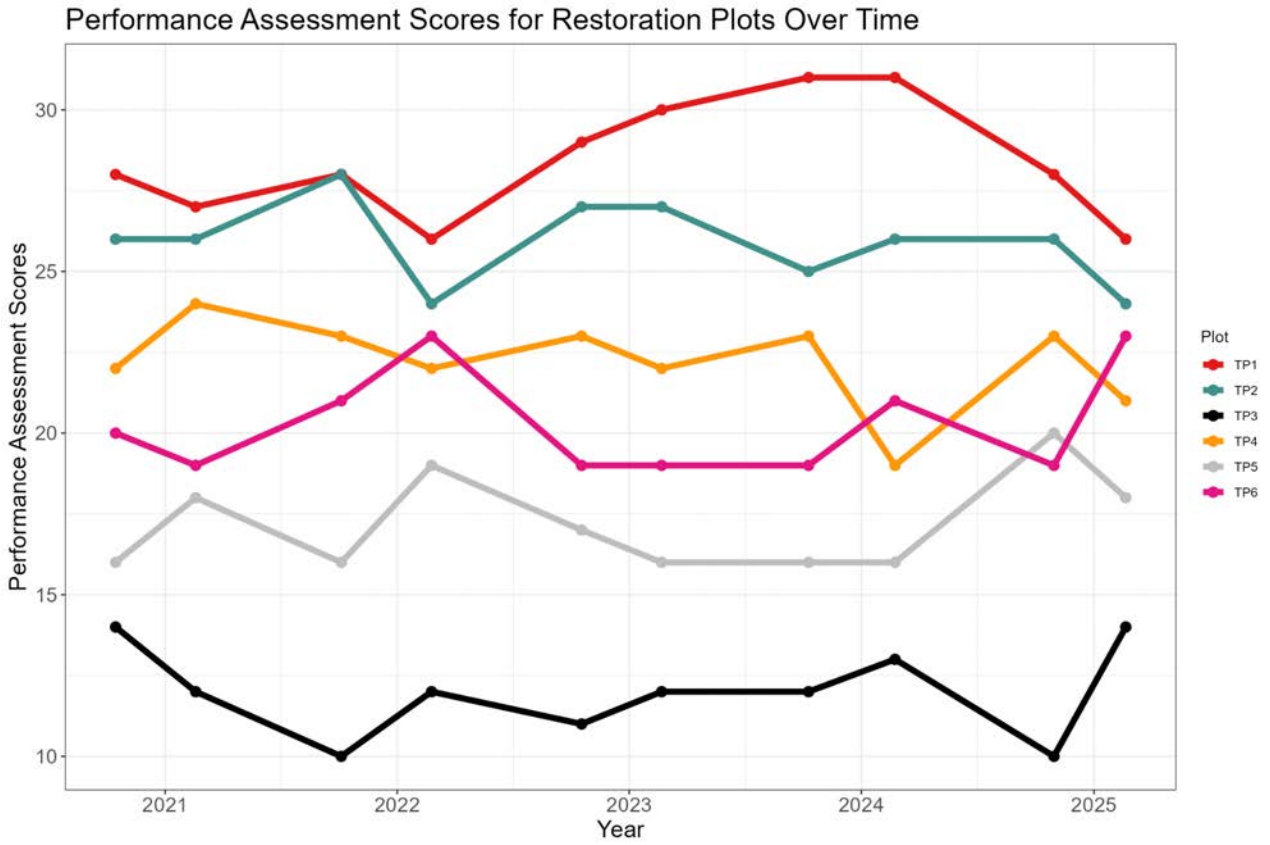


Figure 10. *Performance assessment trends of restoration treatment plots since installation in Feb. 2020. Performance scores are derived based on relatively ranked values (1 = best, 6 = poorest) across 5 different indicators, including: 1) positive sediment budget, 2) aeolian activity, 3) plant cover, 4) dune development, and 5) dust emissions mitigation potential. Lower cumulative scores indicate more effective performance. See text and Walker et al. (2023) for further description.*

Figure 10 shows the trajectories of cumulative treatment plot performance since installation in Feb. 2020. Overall, TP3 has maintained the highest performance ranking (lowest scores) since installation, followed by TP5. TP1 and TP2 maintain the poorest and second poorest performance, respectively, whereas TP4 and TP6 have alternated three times for third and fourth ranks. The recent switch in rank for TP4 over TP6 relates to a general south-to-north trend in increasing sediment deposition. Specific summaries for each of the assessment criteria are as follows:

1. All foredune treatment plots continue to show net positive sediment budgets. The last two intervals have continued with mostly positive budgets and net changes remain positive across all plots and greater than that of the TP1 control plot. TP6 exhibits the highest net positive change, followed by TP3, yet most of the response in TP6 relates to sand fence accretion along the northern margin that is not related to the treatment itself, and development of nebkha along the seaward edge.

2. Aeolian processes remain active in all treatments shown by rippled sand transport corridors, continued dune development, coalescence and migration, and persistence of erosional deflation surfaces with coarse lag deposits on all sites. Some interdune erosional responses are expected during early stages of dune development (e.g., erosional corridors between developing nebkha) and do not necessarily reflect poor performance. Maintenance of aeolian processes is required to provide needed ecological disturbance required for plant growth and dune development.

3. A net positive plant cover trend exists for all treatment plots since installation. Increases in the TP1 control site were negligible until recently. Despite net increases, appreciable declines in plant cover have occurred in all treatments since Oct. 2023. This was most pronounced in TP6, with smaller declines in TP3-TP5, and little change in TP2. Vegetation cover has generally stabilized at this level in TP3-6, with incremental increases in both TP1-2. On average, plant cover across the FRA (excluding TP1) is 7.03% with a current maximum of 11.68% in TP6 and a minimum of 3.10% in TP2. Some species, mainly *Abronia latifolia*, have shown rapid establishment and growth, promoting appreciable dune development. Recent changes in the trajectory of plant community development reinforce that more time is required to assess broader foredune ecosystem re-establishment and sustainability.

4. Dune development continues in all treatment plots. The largest (>2 m) nebkha developed in TP3 and TP5, smaller (1.0-1.5 m) nebkha in TP2 and TP4, and multiple smaller nebkha in TP6. This past year (2024-2025) also saw increased development of nebkha along the seaward edge of most treatment plots, particularly small, early-stage nebkha in the seaward edges of TP1-3. Two distinct patterns of dune evolution have emerged - nebkha clumping (with lateral extension) and chaining (with downwind elongation) - both of which are important indicators of the foredune development at the site. As dune evolution continues, continued accretion, geomorphic and ecological diversity, and dust mitigation benefits are expected.

5. Potential for treatments to reduce dust emissions is increasing as indicated by qualitative observations of increasing dune development, net increases in sediment accretion, and vegetation cover. Collectively, these observations suggest that the FRA, and other exclosed areas experiencing dune development and increasing plant cover (e.g., the Western Snowy Plover exclosure) have lower dust emissivity than neighboring open riding areas. More quantitative assessment of FRA treatments on flow dynamics and shear stress patterns is recommended to better identify related aerodynamic processes within, and dust emissions mitigation benefits downwind of the restoration treatments, as demonstrated by initial results[14].

[14] Furtak-Cole, E., Gillies, J.A., Hilgendorf, Z., Walker, I.J., & Nikolich, G. (2022). Simulation of flow & shear stress distribution on the Oceano Dunes, implications for saltation and dust emissions. Environmental Fluid Mechanics, 22(6), 1399-1420.

5. Summary and Conclusions

To monitor and assess the performance of the foredune restoration dust mitigation project at the ODSVRA, biannual uncrewed aerial system (UAS) surveys of the FRA have been conducted from Oct. 2019 through to Feb. 2025. Results presented in this report provide interpretations of 5 years of geomorphic and plant community development at the FRA.

Prior to implementation of the restoration treatments in Feb. 2020, there was negligible vegetation at the site and geomorphology was primarily driven by: i) aeolian processes moving sand landward by saltation and low transverse dune migration, and ii) the impacts of vehicle activity and camping. From the baseline surveys (Oct. 2019 to Feb. 2020), supply to the beach was variable, but net positive and deposition within the FRA generally was low to negligible over the barren sand surfaces. Following restoration, sand accretion, plant growth, and resulting dune development has continued steadily, yet differently, within the treatment plots. Some sites (TP2-TP6) now feature larger nebkha dunes (>2 m in TP3, TP5) and appreciable vegetation cover (~3-12%). During this past year (2024-2025), notable deposition was recorded in the beach and treatment plot units, while the landward plots exhibited among the highest observed deposition across the study period in the Oct. 2024 to Feb. 2025 interval.

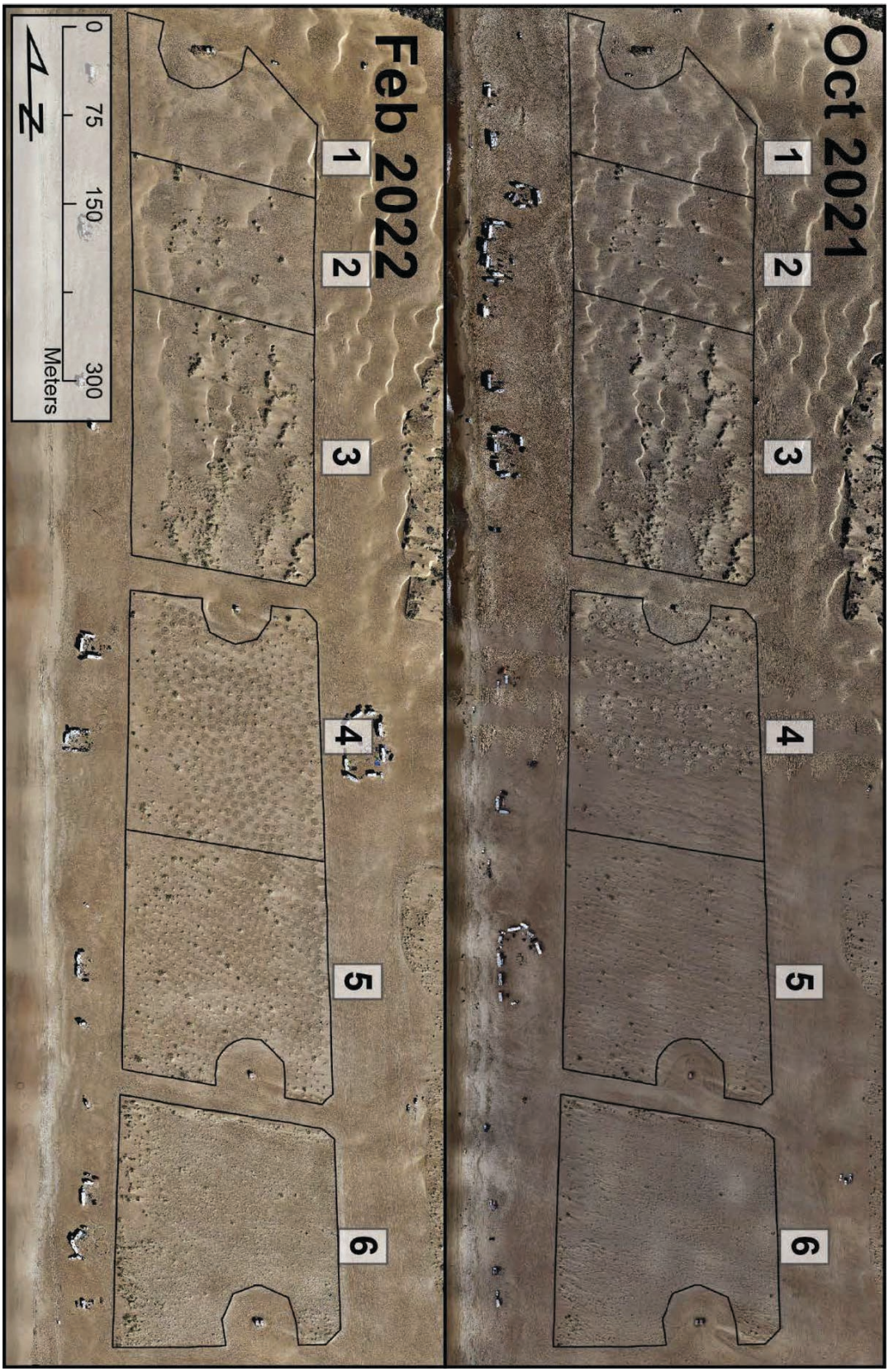
The restoration plots continue to evolve on different trajectories as a function of the initial treatments and variability in other controlling factors such as sand supply to the beach, plant cover, and roughness effects. The relative rankings of treatment site performance remain somewhat clustered, with TP1 (control) and TP2 consistently performing poorly, TP4, TP5, and TP6 alternating ranks periodically, and TP3 consistently maintaining the highest performance since installation. In this most recent interval, TP5 regained second best performance while the most intensive treatment, TP6, slid to fourth place below TP4 due to continued declines in sediment budget, limited dune development, and marked declines in vegetation cover. Next to the TP1 control plot, which received no vegetation treatment, TP2 maintains the lowest performance due to modest amounts of accretion and dune development, low rates of plant cover increase, and correspondingly lower relative dust emissions reduction potential. Monitoring will continue as the treatments evolve to detect further responses indicative of success or concern for adaptive management and for longer-term sustainability of the FRA as a dust control mitigation site.

Appendix A: Biannual RGB orthomosaics of the FRA from Oct. 2019 to Feb. 2025.

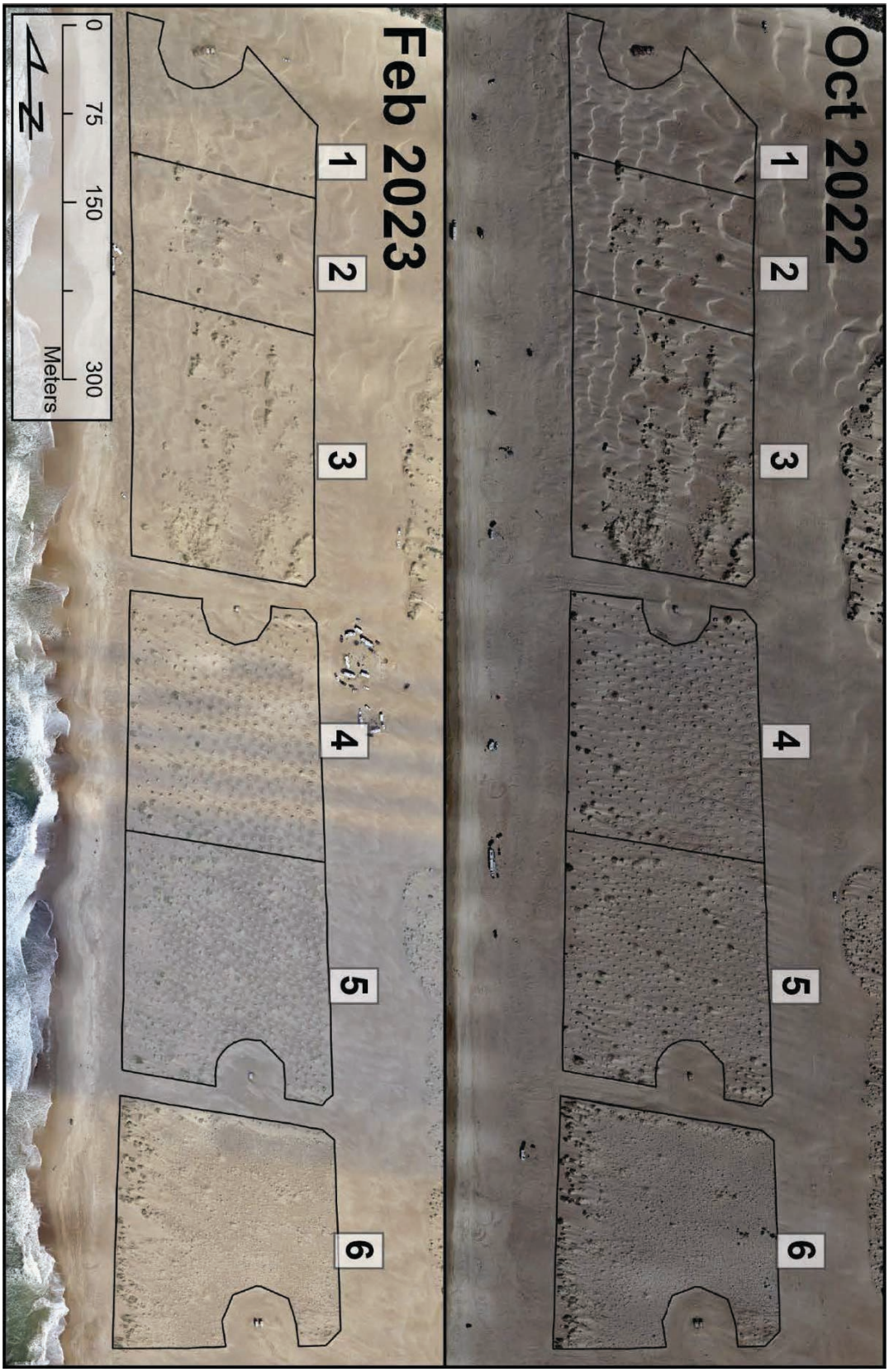




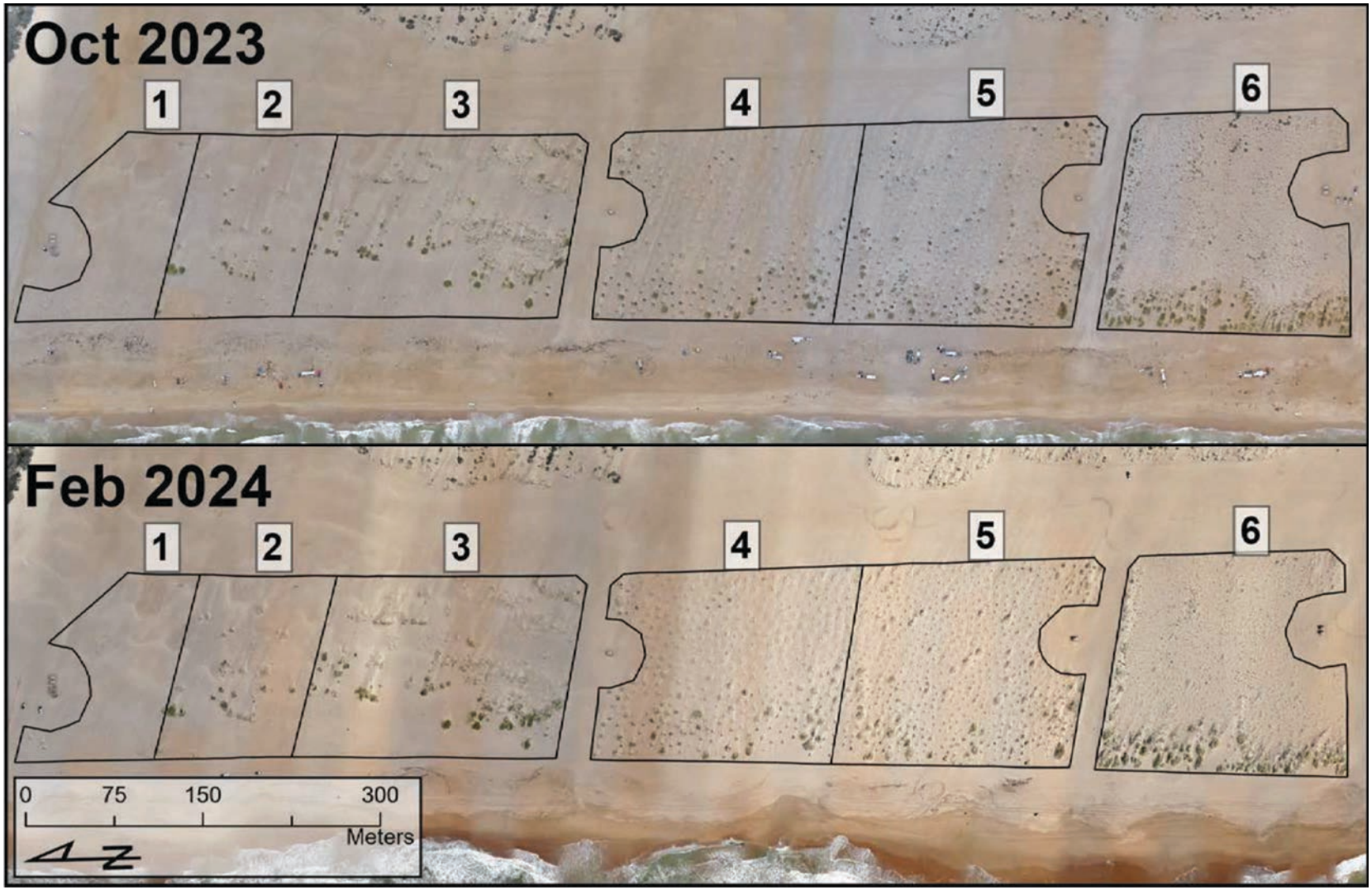
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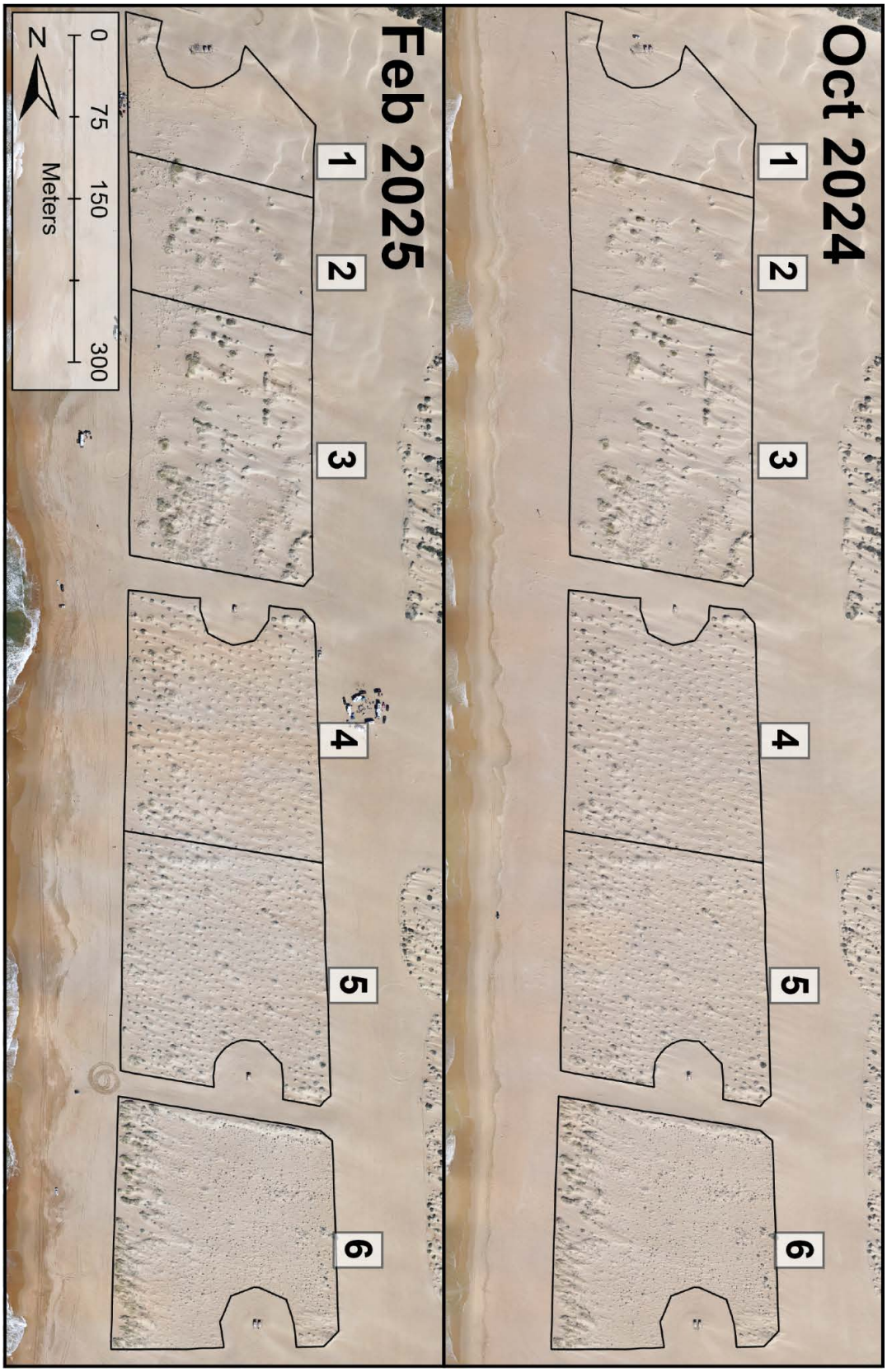
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582
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June 26, 2025

Memo: SAG Review of UCSB Report - "2024-2025 ODSVRA Foredune Restoration UAS Monitoring Report"

From: Scientific Advisory Group[1]

To: Jon O'Brien, California Department of Parks and Recreation

Cc: Ronnie Glick, California Department of Parks and Recreation

The Scientific Advisory Group (SAG) received a copy of the University of California, Santa Barbara (UCSB) report *"2024-2025 ODSVRA Foredune Restoration UAS Monitoring Report"* on June 10, 2025. SAG members have had the opportunity to review the document and this memo provides feedback on the UCSB report. Line item comments and editorial suggestions have been inserted into a PDF copy of the report forwarded with this memo.

The UCSB report delivers a comprehensive analysis of the nature-based foredune restoration area project at the Oceano Dunes State Vehicle Recreation Area. It documents advanced data collection methods and incorporates photographs, graphs, and tables to clarify findings. The study organizes its analysis around three primary metrics: vegetation cover, geomorphic changes, and volumetric alterations. In tracking changes against a pre-restoration baseline, the report offers crucial insights into foredune dynamics and the effectiveness of restoration efforts. SAG notes that the report is well-written and provides a clear overview of the dynamic evolution of the restoration area in terms of morphology and vegetation cover.

SAG recommends future discussion regarding the evaluation methods, specifically the need to reconsider the ranking system and performance metrics. The metric for dust emission potential, which is derived qualitatively from sediment storage, vegetation cover, and roughness, risks double counting treatment effectiveness, as a high rank on the individual metrics automatically inflates the dust emission score. Additionally, once the treatment area reaches a steady state, current metrics may fail to differentiate performance. Updating the assessment criteria before the 2026 ARWP could provide more precise evaluations. SAG recommends revisiting and refining the performance criteria to ensure they remain relevant and accurately reflect long-term changes.

Respectfully,

The Scientific Advisory Group

Bernard Bauer (Chair), Jack Gillies, Jenny Hand, Leah Mathews

[1] SAG member Dr. Ian Walker recused himself from SAG review of this document due to potential conflict of interest.

Summary of Comments on Foredune restoration area UAS report-2024-25-DRAFT-6-9-25.docx - Google Docs

Page: 1

Author: SAG Date: 6/23/25, 12:46:00 PM

Generally a nice report that is well written and clear in its messaging. Follows format of previous UAS reports and adds data from two flights in late 2024 and early 2025. Improved over last year's report.

Page: 3

Author: SAG Date: 6/23/25, 12:46:16 PM

I'm thinking about this statement in the context of what is described starting on line 582. It seems a bit unsupported because only qualitative evidence has been provided (as stated), and recent DRI PI-SWERL is mentioned, but no definitive data to substantiate.

Author: ian Subject: Sticky Note Date: 6/26/25, 6:35:14 PM

Agreed. This is the main reason why I've been pushing CDPR to let us continue the CFD work. This way we would have a more quantitative and less relative metric based on surface shear stress area below threshold within and/or downwind of the plots, for example. Requires further SAG discussion and request of CDPR to give us the go ahead re: CFD work. A preliminary study of the FRA treatments was conducted back in 2022, sent to a journal, rejected (wrong venue), and has not been resubmitted, partly due to DRI staffing issue.

Author: SAG Date: 6/23/25, 12:46:29 PM

Over what time period? And does this literally mean that an average over all plots?

Author: ian Subject: Sticky Note Date: 6/26/25, 6:36:06 PM

since installation, time-averaged and for each of the plots. text clarified.

Page: 5

Author: SAG Date: 6/23/25, 12:46:40 PM
Define UAS here.

Author: ian Subject: Sticky Note Date: 6/26/25, 6:37:22 PM
fixed

Page: 9

Author: SAG Date: 6/23/25, 12:46:50 PM

Is this paragraph necessary? It speaks to flights that cover areas outside the FRA, and therefore doesn't inform this report directly. In fact, it makes the reader believe that there might be some comparative analysis forthcoming (i.e., FRA vs PE or adjacent areas), but that never appears. Perhaps this would be the substance of another report (in the future?)

Author: ian Subject: Sticky Note Date: 6/26/25, 6:38:18 PM

agreed. paragraph removed.

Page: 13

Author: SAG Date: 6/23/25, 12:47:00 PM
Just wondering what value the regression lines add. Clearly we would not expect an increasing trend that extends far into the future, so why use a linear regression? I think we can expect all the curves to level off when some sort of equilibrium is achieved. In other words, linear regression is misleading (and of course, no statistics are presented, so what's the point?)

Author: ian Subject: Sticky Note Date: 6/26/25, 6:39:29 PM
agreed. linear trendlines to be removed.

Author: SAG Date: 6/23/25, 12:47:10 PM
The figure says 1939 and earlier (line 279) 1939 was 3.3%, not 5.3%. Note that this same comment was made in last year's report.

Author: ian Subject: Sticky Note Date: 6/26/25, 6:41:40 PM
Note that the original 3.3% value was an error. The value is 5.3% and has been fixed

Author: SAG Date: 6/23/25, 12:47:17 PM
Need to modify this as the Figures show maps but the Table shows numeric data.

Author: ian Subject: Sticky Note Date: 6/27/25, 7:22:42 PM
adjusted wording

Page: 14

Author: SAG Date: 6/23/25, 12:47:29 PM

I read these three sentences several times, but had a difficult time digesting the message. Perhaps a figure would help, showing how beach volume changed through time. This might make Figure 7 a bit easier to look at because one of the traces would be removed and presented separately here. Clearly beach volume changes is a key driver of what happens in the treatment areas, so maybe it deserves to be highlighted on its own.

Author: ian Subject: Sticky Note Date: 6/27/25, 7:21:21 PM

Modified and simplified the text, which was confusing.

Page: 15

Author: SAG Date: 6/23/25, 12:47:56 PM
had

Author: ian Subject: Sticky Note Date: 6/27/25, 7:24:41 PM
fixed

Page: 20

Author: SAG Date: 6/23/25, 12:48:05 PM
change to: consistent increased deposition

Author: ian Subject: Sticky Note Date: 6/27/25, 7:26:16 PM
fixed

Author: SAG Date: 6/23/25, 12:48:15 PM
This is quite speculative and not backed up with any evidence. I'm not sure what the point is, but I recommend deleting this sentence.

If memory serves, there was a comment last year about the erosional trends in these areas downwind of the FRA, which suggested that the fence line may be disrupting the flow (and adding turbulence). This leads to erosion in the wake of the fence whereas one would typically expect accretion in the lee of large roughness elements. I suppose the reasons for the changes are not well understood, and maybe it is sufficient to simply report what happened (and not speculate as to the reasons why).

Author: ian Subject: Sticky Note Date: 6/27/25, 7:34:20 PM
Agreed. Text modified to remove some of this material and indicate some speculation on relationship to FRA treatments.

Author: SAG Date: 6/23/25, 12:48:35 PM

If possible, it would be useful to indicate the landward extent of overwash in Figure 8. Was the wrack line surveyed or is it visible in any of the imagery that was acquired after the winter storms?

Author: ian Subject: Sticky Note Date: 6/27/25, 7:35:24 PM

We did not survey this, but per Ronnie's account and what we saw in February surveys there was debris in the leading edge (maybe 10-20m) inland.

Page: 22

Author: SAG Date: 6/23/25, 12:48:43 PM
change preferred to typical.

Author: ian Subject: Sticky Note Date: 6/27/25, 7:36:09 PM
fixed

Page: 25

Author: SAG Date: 6/23/25, 12:48:54 PM

The PI-SWERL data for 2024 actually show that the FRA is slightly more emissive than it was in 2022, although not to any degree of statistical reliability. In other words, the data don't support the assertion that the potential to reduce dust emissions is increasing.

Wondering whether it might be interesting to disaggregate the PI-SWERL measurements according to treatment area (rather than to look at only the ensemble).

Author: ian Subject: Sticky Note Date: 6/27/25, 7:45:31 PM

This is a good point and one that we have not yet considered (using the piswerl data). Comparison between 2022 and 2024 would provide some indication (albeit from snapshots) of relative emissivity. I could ask CDPR/DRI for these data for next year's assessment, unless SAG would like to see it incorporated this year. Since we established these criteria, this one has been lagging... as above, CFD has been floated to help assess this and could be done annually. We just need to work out the DRI/UCSB staffing and prelim workflow data that Eden did.

Author: ian Subject: Sticky Note Date: 6/27/25, 7:49:53 PM

I removed reference to the piswerl data entirely as we did not have access to it partitioned to individual treatment plots. I could average the measurements for each time interval and incorproate that if SAG/CDPR would prefer. It begs the question, however, should we be doing piswerl in the FRA each year (or at least more frequently).

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Author: SAG Date: 6/23/25, 12:49:03 PM

I believe that it was recommended (last year) to rethink the ranking system and performance metrics. This should be done sometime this year before the 2026 ARWP. In particular, the metric associated with potential to reduce dust emissions is a qualitative judgement based on all the other metrics (i.e., sediment storage, veg cover, roughness), so any treatment that ranks highly in those metrics will automatically rank highly in dust emission potential. It is double counting in my mind.

The other point is that we should expect these treatment areas to equilibrate to some steady state, and not continue to change indefinitely in terms of vegetation cover, sand storage, and roughness enhancement. If all the treatment areas were to achieve steady state this year, then next year they would all rank equally using the current metrics. I don't have an easy suggestion, but there should be a conversation to sort this out.

Author: ian Subject: Sticky Note Date: 6/27/25, 8:01:34 PM

Agree on both points. This requires broader SAG discussion. See earlier points re: piswerl and CFD re: assessing efficacy for reducing dust emissivty.The furtak-cole et al. (2022) initial CFD proof of concept paper is now cited. Indeed, most indicators could plateau at some point (and perhaps veg cover is now?) with dune development which could reach a quasi equilubrium state as a function of sand supply, plant community, wind regime and site footprint conditions. Beyond performance tracking, however, these indicators (and respective metrics) are also in place to inform adaptive management. Another discussion to be had.
I've modified the wording here slighly as the ranking orders have swapped for 4, 5 and 6 (fig. 10).

ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 07

Summary of Vegetation Monitoring of Restoration Sites at ODSVRA

(State Parks' ARWP Work Product)

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Summary of Vegetation Monitoring of Restoration Sites at ODSVRA

Line Intercept Transect Sampling

Methods

Line Intercept method (Line intercept: % cover = distance a+b+c+d+e+f / total transect length, where a, b, c, etc. are the intercept lengths of vegetation canopy) was used to estimate percent cover of species within each project area.

For this assessment both the foredune restoration area and back dune project areas were sampled in the fall of 2024. Reference sites for the foredune were sampled during the fall in 2021 and again during the fall months of 2023 and 2024 to account for any potential changes caused by storm surges or other environmental changes.

For the back dune habitats, reference sites were selected in areas that had been closed to vehicular activity for at least 20 years and had not been subject to restoration plantings in the past. Within back dune habitats, early succession communities (early seral) and climax communities (late seral) can vary considerably in species composition and percent cover. For this reason, both early seral and late seral reference sites were sampled for comparison. The late seral reference transects were first sampled in 2021 and the early seral reference transects were first sampled in 2022. Follow-up surveys of the original transect lines occurred in both the early and late seral reference sites during the fall or 2024.

Within each foredune restoration treatment area and reference site, a total of four transects of 30 meters each were sampled (the same transect lines were surveyed from 2020-2024). Within each back dune project area and reference site, a total of three transects of 30 meters each were sampled. In 2024, the project areas that were surveyed included the 48-Acre Foredune, planted February 2020; Lagrille Hill South, planted January 2022; North Orion, planted in November 2021; and South Orion, planted November 2021.

Starting points for the transect lines were randomly selected using GIS software. Originally, three transect lines were randomly selected from the eight cardinal and intermediate directions (i.e., north, northeast, east, southeast, south, southwest, west, and northwest). In 2022, within the 48-acre foredune restoration area, a fourth transect line was added in each foredune treatment running in the direction of the prevailing northwest wind.

A measuring tape was run along the transect and secured with wooden stakes. It is not uncommon for the wooden stakes to become buried or unburied and dislodged by sand movement between sampling years. As a result, stakes that don't remain between years are re-established using a GPS unit, resulting in some variability in the transect beginning points between years (estimated to be less than 1 m based on the GPS unit accuracy). As the vegetation canopy intersected the line, the species was noted on the datasheet along with the beginning and ending measurements of the canopy under "Start" and "Stop." When the canopies of two different species overlapped, each species was documented separately as two different canopies. A closed canopy for a given species was assumed until gaps in vegetation exceeded the width of 5 cm. All dead woody vegetation was included separately and noted as "dead" unless it was clearly the result of seasonal dieback of a perennial plant that was still viable.

Once each 30-m transect was surveyed, a reconnaissance-level survey was conducted of the project area and any additional species observed were noted. In the reconnaissance-level survey, the entire

foredune restoration area was searched for additional species by walking in belt transects of no more than 50 feet between surveyors.

Results

48-acre Foredune Project

In 2024, after the fifth growing season for the 48-acre foredune project, the treatment type with the highest vegetation cover was TP 6 – Parks' Classic, with 15.0% mean vegetation cover (see Table 1). The treatment type with the second highest mean vegetation cover was TP 3 – Native Seed and Grain Seed, with 14.0% mean vegetation cover. Three of the six different treatment types showed an increase in mean vegetation cover compared to last year's (2023) transect sampling results: TP 1 – Control, TP 2 – Native Seed and TP 3 – Native Seed and Grain Seed. TP 4 – Low-Density Nodes, TP 5 – High-Density Nodes, and TP 6 – Parks' Classic all showed decreases in mean vegetation cover compared to last year's (2023) transect sampling results. None of the treatment areas met the mean cover of the reference site which showed a mean percent cover of 18.35% (see Table 1 and Figure 1).

The treatment areas with the highest native species richness were TP 5 – High-Density Nodes and TP 6 – Parks' Classic both with nine (9) native species present followed closely by TP 4 – Low-Density Nodes with eight (8) native species present. These were each just slightly below the native species richness of the reference site (ten native species; see Table 1). In 2023, there were four (4) native species that were only present within the storm surge wrack on the western side of the 48-acre foredune, including, marsh jaumea (*Jaumea carnosa*), saltgrass (*Distichlis spicata*), dune rush (*Juncus lescurii*) and California bulrush (*Schoenoplectus californicus*). None on these species were observed in 2024, which was expected since they are not typically found in pioneer foredune habitats. Excluding the wetland species that were only observed in the storm surge wrack, two of the six different treatment types showed an increase in total species richness compared to last year's (2023) transect sampling results, including TP 4 – Low-Density Nodes and TP 5 – High-Density Nodes. TP 2 – Native Seed showed a decrease in total species richness while TP 1 – Control, TP 3 – Native Seed and Grain Seed and TP 6 – Parks' Classic showed no change in total species richness.

Back Dune Projects

Each of the backdune project areas that were surveyed showed healthy levels of vegetation cover, ranging from 20.0% to 48.5% (see Table 2 and Figure 2). None of the project sites that were sampled met or exceeded the percent cover of the reference sites (67.2% for early seral and 78.5% for late seral) but they did show substantial levels of cover and are anticipated to increase over time as plantings continue to grow. Of the 22 native species present within the early seral and late seral reference sites, the backdune projects had between 10 and 16 of them and a total richness (including non-native species) of between 15 and 23 species. The dominant species within the early seral reference site, dune bush lupine (*Lupinus chamissonis*), was also the dominant within all surveyed backdune projects with cover measurements of 17.4%, 22.4%, and 42.7% compared to 25.3% in the early seral reference site. Percent cover and richness are both anticipated to increase and approach the cover of the reference sites within the upcoming growing seasons.

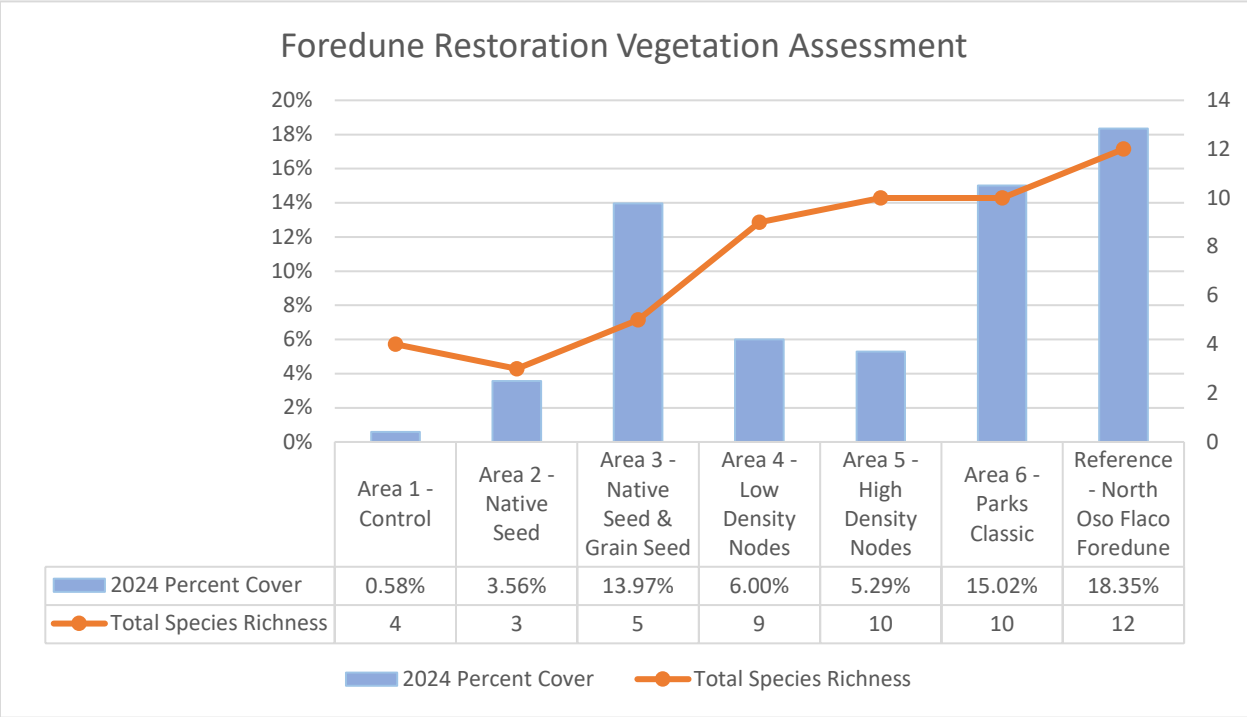


Figure 1. Vegetation composition in 48 Acre Foredune project areas compared to reference site. Four 30-meter transects were sampled in each of the foredune areas and reference site.

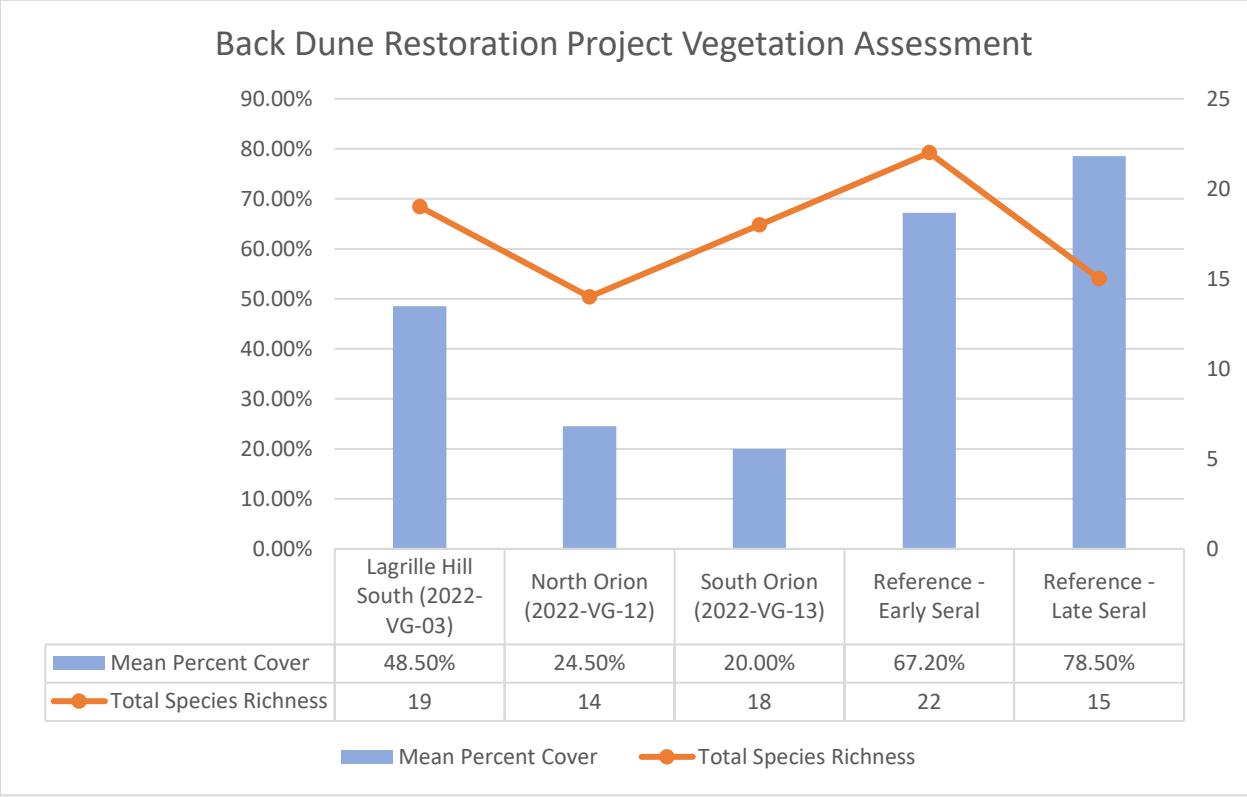


Figure 2. Vegetation composition in back dune project areas compared to reference sites. Three 30-meter transects were sampled in each of the back dune areas and reference sites.

Table 1. Table of results from the 48 Acre Foredune Restoration Project line intercept transect sampling.

Foredune Restoration Project Vegetation Assessment (Sept/Oct 2024)							
	Area 1 Control	**Area 2 Native Seed**	**Area 3 Native Seed & Grain Seed**	**Area 4 Low Density Nodes**	**Area 5 High Density Nodes**	**Area 6 Parks Classic**	**Reference North Oso Flaco Foredune (Oct 2024)**
Age of Planting (years)	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**	**-**
Total Species Richness	**4**	**3**	**5**	**9**	**10**	**10**	**12**
Transect 1	1.3%	13.8%	1.7%	6.7%	10.9%	9.9%	1.7%
Transect 2	0.0%	0.0%	26.5%	14.2%	2.7%	12.8%	45.0%
Transect 3	0.0%	0.0%	6.7%	3.1%	0.0%	31.3%	21.2%
Transect 4	1.0%	0.5%	20.9%	0.0%	7.6%	6.1%	5.4%
Mean Percent Cover	**0.58%**	**3.56%**	**13.97%**	**6.00%**	**5.29%**	**15.02%**	**18.35%**
Species	**Mean Percent Cover**						
Abronia latifolia	-	-	P	P	0.45%	P	P
Abronia maritima	P	2.93%	7.79%	0.74%	1.58%	2.68%	8.1%
Ambrosia chamissonis	0.02%	1.15%	6.33%	3.68%	2.96%	9.60%	6.5%
Atriplex leucopylla	P	-	-	2.13%	0.34%	P	-
**Cakile maritima*	0.57%	0.13%	P	0.03%	0.10%	0.05%	2.8%
Calestegia soldanella	-	-	-	-	-	-	1.0%
Camissoniopsis cheiranthifolia	-	-	-	P	P	0.58%	0.26%
**Carpobrotus chilensis*	-	-	-	-	-	-	1.1%
Ericameria ericoides	-	-	-	-	-	-	P
Erigeron blochmaniae	-	-	-	-	-	-	P
Eriogonum parvifolium	-	-	-	-	-	P	P
Eriophyllum staechadifolium	-	-	-	P	P	0.67%	-
Fragaria chiloensis						P	
Malicothrix incana	-	-	-	P	P	P	0.10%
Monardella undulata ssp. crispa				P	P		
Phacelia ramosissima			P				
Senecio blochmaniae	-	-	-	-	P	-	P
Dead Vegetation	-	-	-	-	0.03%	1.62%	-
*Non-native species; P=Present within Project Area but not on transect line							

Table 2. Table of results from the back dune restoration project line intercept transect sampling.

Back Dune Restoration Project Vegetation Assessment (Oct 2024)					
*Non-native species P=Present within project area	**Lagrille Hill South (2022-VG-03)**	**North Orion (2022-VG-12)**	**South Orion (2022-VG-13)**	**Reference - Early Seral (Oct 2024)**	**Reference - Late Seral (Oct 2024)**
Age of Planting (years)	**3**	**3**	**3**	**-**	**-**
Species Richness	**23**	**17**	**15**	**17**	**16**
Transect 1	**58.1%**	**52.7%**	**23.5%**	**60.0%**	**77.2%**
Transect 2	**40.1%**	**20.1%**	**22.7%**	**54.0%**	**82.4%**
Transect 3	**47.2%**	**0.6%**	**13.7%**	**87.8%**	**75.7%**
Mean Percent Cover	**48.5%**	**24.5%**	**20.0%**	**67.2%**	**78.5%**
Species					
Abronia umbellata	-	0.09%	P	-	-
Achillea millefolium	0.56%	1.09%	0.06%	2.2%	0.4%
Acmispon glaber	P	P	-	P	2.4%
Astragalus nuttallii	0.18%	-	-	-	-
Baccharis pilularis	P	-	-	0.6%	P
Camissoniopsis cheiranthifolia	0.19%	0.01%	0.16%	-	-
Castilleja affinis	P	-	-	P	-
Chenopodium californicum	-	-	-	-	1.2%
Cirsium occidentale	P	-	-	P	-
**Conicosia pugioniformis*	-	P	-	1.0%	0.01%
Corethrogyne filaginifolia	P	0.02%	0.69%	P	6.8%
Cryptantha clevelandii	-	-	-	-	3.8%
Dudleya lanceolata	P	-	-	-	0.17%
Eriastrum densifolium	P	P	0.02%	-	-
Ericameria ericoides	0.22%	P	P	27.3%	59.5%
Erigeron blochmaniae	0.24%	P	P	3.0%	-
Eriogonum parvifolium	0.04%	P	0.60%	-	0.24%
Eriophyllum staechadifolium	0.71%	P	0.74%	-	-
Erysimum suffrutescens	P	P	0.01%	0.5%	0.14%
Horkelia cuneata	P	P	P	-	-
Lupinus chamissonis	42.66%	22.42%	17.44%	25.3%	P
Malacothrix incana	0.01%	-	-	-	-
Monardella undulata crispa	2.46%	0.31%	0.47%	P	-
Phacelia ramosissima	1.61%	0.77%	P	0.6%	-
Populus trichocarpa	P	-	-	-	-
Pseudognaphalium biolettii	-	-	-	P	-
Pseudognaphalium californicum	-	-	-	-	0.03%
Pseudognaphalium ramosissimum	-	-	-	p	0.4%
Rubus urisinus	-	-	-	-	P
Salix lasiolepis	0.32%	-	-	P	-
Senecio blochmaniae	0.30%	P	P	0.6%	0.06%
Dead woody vegetation	0.82%	0.07%	-	9.5%	16.7%

Comparison of Line Intercept Transect Sampling Method and Results from Independent Studies

State Parks methods were designed to monitor the establishment of vegetation cover and species richness within specific project areas. Two recent and independent reports also evaluated vegetation cover within the ODSVRA using aerial imagery to analyze total vegetation cover, each using different imagery sources. Both studies were used to cross-reference the State Parks results. These reports include:

UCSB Historical Vegetation Cover Change Analysis (1930-2020) within the Oceano Dunes SVRA" (N. Swet, Z. Hilgendorf, I. Walker, December 28, 2021). Published as Attachment 07-04 in the 2022 ARWP

Hilgendorf, Z., Turner, C, Walker, I.J. UCSB-ASU 2020-2021 ODSVRA Foredune Restoration UAS Survey Report. 37p. Produced for CDPR-ODSVRA and published as Attachment 8 in the 2021 ARWP.

The methods used by Hilgendorf et al., 2021 were continued in subsequent seasons and the results from those surveys are included in Table 3.

The historical aerial imagery analysis of the NOF foredune (Swet et al., 2021) showed vegetation cover of 24.4% in 2012 and 19.1% in 2020, corroborating State Parks' transect results for the NOF Foredune reference site showing 23.0% in 2021, 16.9% in 2023 and 18.35% in 2024 (see Table 1). The reference transect lines showed a high degree of variability in cover ranging from 1.7% to 45.0% cover in 2024 which shows that vegetation within foredune habitats is highly clustered making it difficult to analyze change over time and determine target cover classes. Furthermore, the results from Swet et al., 2021 and the State Parks' transects corroborate that foredunes systems show a natural fluctuation in vegetation over relatively short periods of time.

A comparison of the Foredune Restoration Area vegetation coverage results from line-intercept and UAS surveys can be seen in Table 3 and Figure 3. It is noted the two studies had differing ways of defining vegetation cover and therefore variation in the results is expected. State Parks transect monitoring measured canopy cover, ignoring small gaps between leaves or stems (greater than [>] 5 cm), and included all parts of the vegetation canopy, not only the leaf cover, but also the woody stems, seasonally dormant plants, and dead woody vegetation. The UAS surveys used five-band multispectral imagery acquired from UAS surveys and NDVI method to determine vegetation cover. This is noteworthy because with NDVI method seasonal variations in cover are expected as seasonal changes in the leaf cover occur (i.e., NDVI does not tend to consider live woody stems or dormant vegetation that does not have photosynthesizing leaves). This could account for the reduction in cover from October to February, followed by an increase in the following October. Furthermore, the State Parks transect lines run along the contours of the ground, measuring surface cover (i.e. three-dimensional surface) while the UAS surveys measure aerial cover (i.e. two-dimensional surface) and the more the topographical variability on the ground increases the more the difference between the two survey methods may be apparent.

Additionally, variability in the results of the State Parks transect method is expected due to small sample size (four transects) and resetting of starting and stopping points with a handheld GPS unit when marker stakes are buried or dislodged.

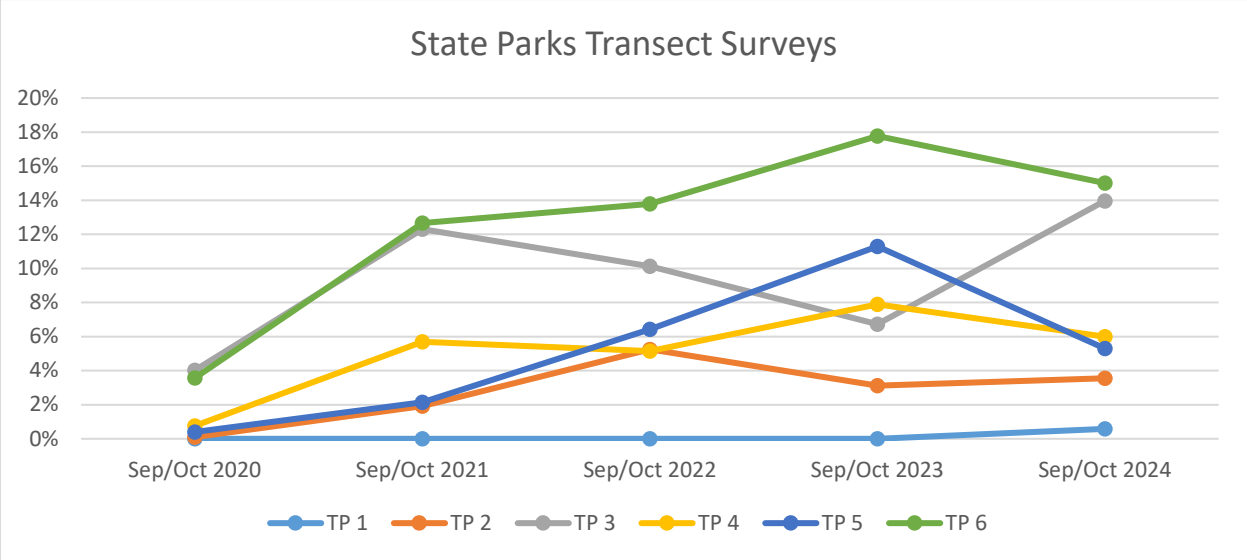
When comparing results from the State Parks transects and UAS surveys in 2024, both methods generally showed similar vegetation cover within the same treatment plots and followed a similar trend in areas where cover increased, decreased or showed little change. For TP 1 – Control and TP 2 – Native Seed, vegetation cover has increased gradually but consistently from 2020 through 2024 (one exception

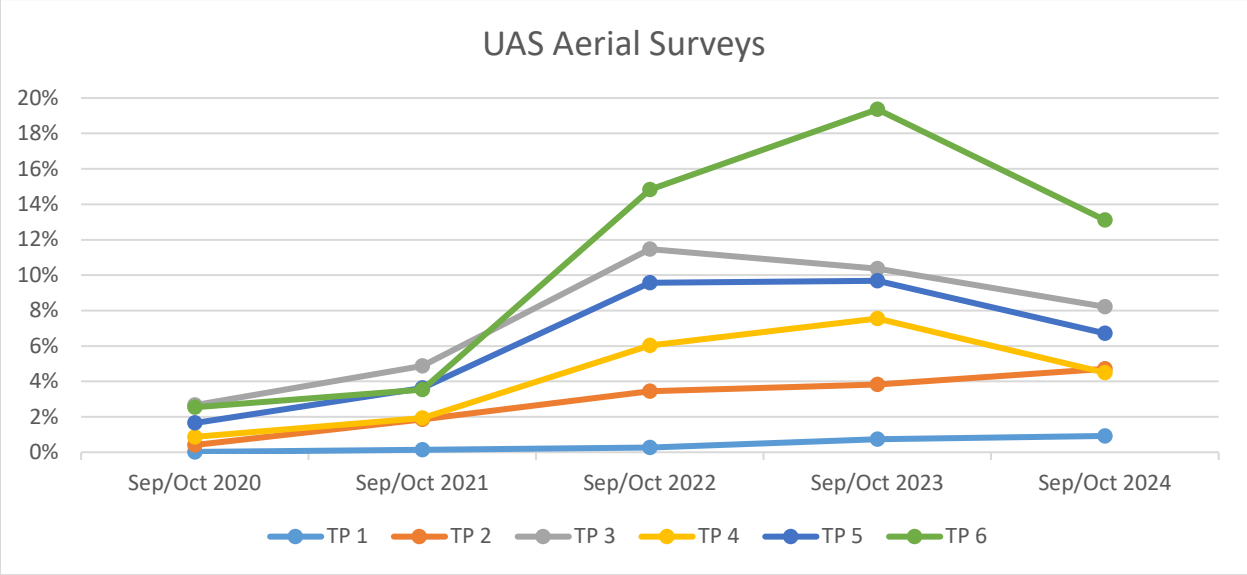
is the 2023 State Parks survey showed a decrease in cover in TP 2 – Native Seed). Within TP 4 – Low Density Nodes, TP 5 – High Density Nodes and TP 6 – Parks Classic, vegetation cover generally increased for the first three years and then either a leveled off or decreased during the subsequent two years. TP 3 – Native Seed and Grain Seed is the exception showing a continued decline in the UAS surveys from 2022 to 2025 while State Parks transects showed an initial decline from 2021 to 2023 and a rebound in 2024 to its highest cover measurement to date. All four State Parks transects within this treatment plot showed an increase in cover from 2023 to 2024 which indicates consistent expansion of vegetation along the transect lines within this treatment plot. Given that the UAS survey did not show this increase, it may not be representative of the entire treatment plot. Possible explanations in the discrepancy could be a result of the differences in sampling methodology or due to sampling error. One possible explanation related to differences in sampling methodology could be the presence of non-photosynthetic material (i.e. leafless stems or woody material) that would have been measured in the State Parks transect sampling but may not have been accounted for on the UAS survey. Another possible explanation is that the State Parks transect end points shifted as dune topography changed. Given the small sample size, these shifts could result in significant variation in cover between years, even if it is not representative of the treatment plot as a whole.

When comparing photographs of the transect lines between years, it is evident that measured change in vegetation cover is highly influenced by the change in sand accumulation and dune topography (see Figures 4 through 21). It appears that from 2022 to 2024, areas with vegetation loss could be attributed to fragmentation of surface leaf cover due to burial. It also appears that there was some leaf yellowing along the transect lines in 2024 that is not as apparent in 2022 or 2023. This yellowing could be a result of seasonal stress, and though it would result in reduced leaf cover, it does not appear to result in plant loss. Even though both the UAS surveys and the State Parks transects both show some decrease in vegetation cover, it appears that sufficient cover of native vegetation is persisting and continuing to accumulate sand and increase the size of the nebka throughout the treatment plots. As the nebka height grows over time, the slope lengths increase, resulting in a larger ground surface area. If the nebka develop faster than the vegetation expands this would result a measured percent cover decrease even though the vegetation surface cover may not have been lost. It appears from the photographs that this effect may be occurring, at least within certain areas of the treatment plots. The photographs show the nebka slopes steepening over time and vegetation migrating to the top of the nebka but not necessarily down the slope. This may be a natural effect of nebka build up resulting in a temporary decrease in vegetation cover and it is possible that as the nebka begin to consolidate, the measured vegetation percent cover may begin to increase again.

Table 3. Vegetation cover comparison between State Parks Transect Monitoring and the UAS Surveys.

48 Acre Foredune	**Area 1**	**Area 2**	**Area 3**	**Area 4**	**Area 5**	**Area 6**
February 2020						
UAS Survey	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
September/October 2020						
State Parks Transects	0.00%	0.10%	4.02%	0.76%	0.40%	3.57%
UAS Survey	0.02%	0.41%	2.66%	0.87%	1.65%	2.54%
February 2021						
UAS Survey	0.03%	0.42%	2.15%	0.95%	1.85%	3.28%
September/October 2021						
State Parks Transects	0.00%	1.91%	12.31%	5.69%	2.14%	12.66%
UAS Survey	0.14%	1.85%	4.87%	1.93%	3.63%	3.54%
February 2022						
UAS Survey	0.08%	1.74%	4.55%	2.24%	4.64%	11.35%
September/October 2022						
State Parks Transects	0.00%	5.25%	10.13%	5.14%	6.43%	13.79%
UAS Survey	0.26%	3.45%	11.47%	6.03%	9.57%	14.82%
February 2023						
UAS Survey	0.12%	2.68%	8.93%	5.52%	9.66%	14.83%
September/October 2023						
State Parks Transects	0.00%	3.12	6.73%	7.89%	11.29%	17.77%
UAS Survey	0.73%	3.83%	10.36%	7.55%	9.68%	19.36%
February 2024						
UAS Survey	0.42%	3.10%	6.95%	4.85%	6.18%	11.68%
September/October 2024						
State Parks Transects	0.58%	3.56%	13.97%	6.00%	5.29%	15.02%
UAS Survey	0.92%	4.71%	8.21%	4.49%	6.72%	13.12%
February 2025						
UAS Survey	1.66%	5.04%	6.86%	5.56%	6.55%	11.13%





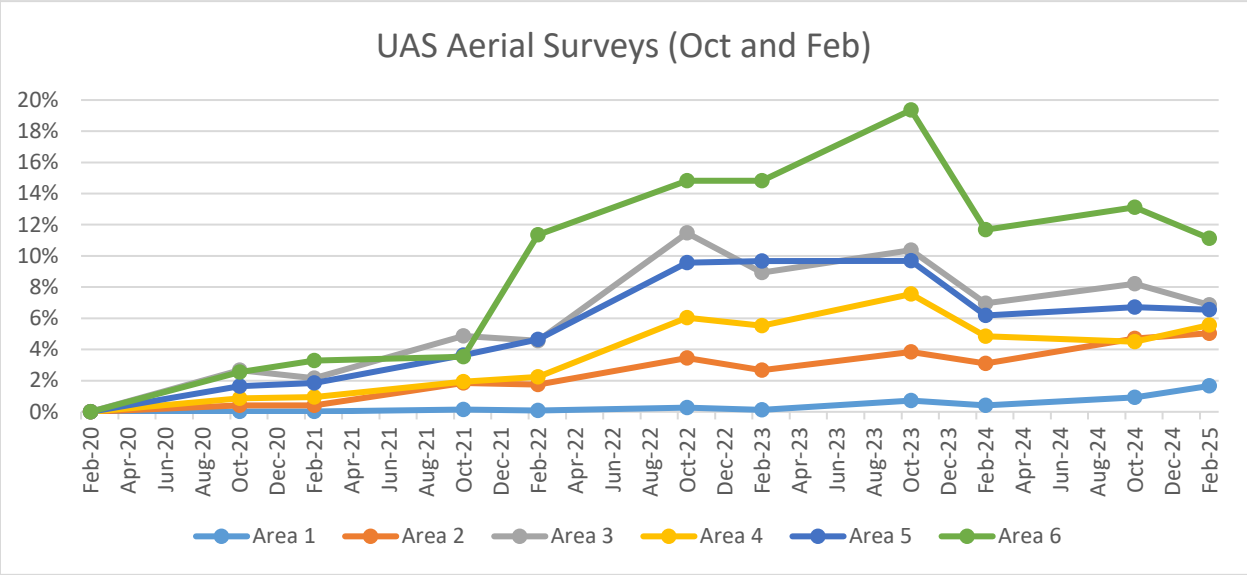


Figure 3. UAS Surveys Vegetation cover change over time including both Fall and Winter surveys.



Figure 4. TP1- Control, Transect #1 (start on left, stop on right) measured at 0.0% cover in Sep/Oct 2022.



Figure 5. TP1- Control, Transect #1 (start on left, stop on right) measured at 0.0% cover in Sep/Oct 2023.



Figure 6. TP1- Control, Transect #1 (start on left, stop on right) measured at 1.3% cover in Sep/Oct 2024.



Figure 7. TP2- Native Seed, Transect #2 (start on left, stop on right) measured at 21.0% cover in Sep/Oct 2022.



Figure 8. TP2- Native Seed, Transect #2 (start on left, stop on right) measured at 12.5% cover in Sep/Oct 2023.



Figure 9. TP2- Native Seed, Transect #2 (start on left, stop on right) measured at 13.8% cover in Sep/Oct 2024.



Figure 10. TP3- Native Seed and Sterile Grain Seed, Transect #2 (start on left, stop on right) measured at 24.8% cover in Sep/Oct 2022.



Figure 11. TP3- Native Seed and Sterile Grain Seed, Transect #2 (start on left, stop on right) measured at 12.6% cover in Sep/Oct 2023.



Figure 12. TP3- Native Seed and Sterile Grain Seed, Transect #2 (start on left, stop on right) measured at 26.5% cover in Sep/Oct 2024.



Figure 13. TP4- Low Density Nodes, Transect #2 (start on left, stop on right) measured at 8.6% cover in Sep/Oct 2022.



Figure 14. TP4- Low Density Nodes, Transect #2 (start on left, stop on right) measured at 21.6% cover in Sep/Oct 2023.



Figure 15. TP4- Low Density Nodes, Transect #2 (start on left, stop on right) measured at 14.2% cover in Sep/Oct 2024.



Figure 16. TP5- High Density Nodes, Transect #1 (start on left, stop on right) measured at 16.9% cover in Sep/Oct 2022.



Figure 17. TP5- High Density Nodes, Transect #1 (start on left, stop on right) measured at 30.5% cover in Sep/Oct 2023.



Figure 18. TP5- High Density Nodes, Transect #1 (start on left, stop on right) measured at 10.9% cover in Sep/Oct 2024.



Figure 19. TP6- Parks Classic, Transect #3 (start on left, stop on right) measured at 21.4% cover in Sep/Oct 2022.



Figure 20. TP6- Parks Classic, Transect #3 (start on left, stop on right) measured at 44.3% cover in Sep/Oct 2023.



Figure 21. TP6- Parks Classic, Transect #3 (start on left, stop on right) measured at 31.3% cover in Sep/Oct 2024.

Photo Point Monitoring

State Parks has conducted on-the-ground photo point monitoring of the 48-acre foredune project since 2020. Initial photo point monitoring occurred before the installation of the foredune in February 2020. Subsequent monitoring has occurred in May 2020, October 2020, and each subsequent October since 2020. Photo points are located on all four corners of each treatment area. For each photo point, two photos are taken, each with one of the treatment area boundary lines on the outer edge of the photo with the interior of the treatment area centered in the photo. There is also one photo point overlooking the entire 48-acre foredune project area. Select ground photo point monitoring examples are shown in Figure 22 through 33.

On-the-ground monitoring of backdune projects was conducted using the same methodology described for the 48-acre foredune project. Backdune ground photo monitoring was initiated in 2018 and is usually conducted in the summer and/or fall of each year. In 2024, ground photo monitoring was conducted in the fall only. Backdune photo points are positioned to capture changes within the general areas where backdune projects are located. The number of photos for each photo point and the number of photo points vary at each location to sufficiently capture each area. In total, 27 photo points were monitored in 2024. Select backdune ground photo point monitoring examples are shown in Figures 34 through 39.

In addition to on-the-ground monitoring, State Parks also conducted UAS photo point monitoring of the foredune project and backdune projects. The initial UAS imagery was captured in May 2020, with subsequent UAS imagery captured in December 2020 and every winter since. Two photo points were taken of each foredune treatment area (one from the east and one from the west for each area).

Also, backdune UAS photo points were initiated in December 2020, with subsequent imagery captured in December 2021 and every winter since, including February/March 2025. The number of photos for each photo point and the number of photo points vary at each location to sufficiently capture each area. Select UAS photo point monitoring examples are shown in Figures 40 through 49.



Figure 22. Photo point of 48 Acre Foredune Area 1 - Contol from west fenceline facing south. Photo taken on February 4, 2020.



Figure 23. Photo point of 48 Acre Foredune Area 1 - Control from west fenceline facing south. Photo taken on November 4, 2024.



Figure 24. Photo point of 48 Acre Foredune Area 2 – Native Seed prior to planting treatment from east fencline facing west. Photo taken on February 4, 2020.



Figure 25. Photo point of 48 Acre Foredune Area 2 – Native Seed 4.5 years after treatment from east fenceline facing west. Photo taken on November 4, 2024.



Figure 26. Photo point of 48 Acre Foredune Area 3 – Native Seed and Sterile Grain Seedprior to planting treatment from east fencelinefacing north. Photo taken on February 4, 2020.



Figure 27. Photo point of 48 Acre Foredune Area 3 – Native Seed and Sterile Grain Seed 4.5 years after treatment from east fenceline facing north. Photo taken on November 4, 2024.



Figure 28. Photo point of 48 Acre Foredune Area 4 – Low Density Nodeswithin the first season after planting treatment from east fencline facing west. Photo taken on May 19, 2020.



Figure 29. Photo point of 48 Acre Foredune Area 4 - Low Density Nodes4.5 years after treatment from easts fencline facing west. Photo taken on November 4, 2024.



Figure 30. Photo point of 48 Acre Foredune Area 5-High Density Nodes prior to planting treatment from west fencline facing north. Photo taken on February 4, 2020.



Figure 31. Photo point of 48 Acre Foredune Area 5-High Density Nodes 4.5 years after treatment from west fencline facing north. Photo taken on November 4, 2024.



Figure 32. Photo point of 48 Acre Foredune Area 6-Parks Classic prior to planting treatment from east fencline facing west. Photo taken on February 4, 2020.



Figure 33. Photo point of 48 Acre Foredune Area 6-Parks Classic 4.5 years after treatment from east fencline facing west. Photo taken on November 4, 2024.



Figure 34. Photo point of Tabletop Island prior to planting treatment, facing east. Photo taken on October 11, 2019.



Figure 35. Photo point of Tabletop Island after treatment, facing east. Photo taken on October 31, 2024.



Figure 36. Photo point of Area 1 prior to planting treatment, facing southwest. Photo taken on October 20, 2022.



Figure 37. Photo point of Area #1, 1.5 years after planting treatment, facing southwest. Photo taken on October 28, 2024.



Figure 38. Photo point of BBQ Flats prior to planting treatment, facing south. Photo taken on October 17, 2018.



Figure 39. Photo point of BBQ Flats, 5.5 years after planting treatment, facing south. Photo taken on November 4, 2024.



Figure 40. Drone photo point of 48 Acre Foredune Area 5-High Density Nodes, facing east. Image taken on May 8, 2020.



Figure 41. Drone photo point of 48 Acre Foredune Area 5-Native and Sterile Grain Seed, facing east. Image taken on February 18, 2025.



Figure 42. Drone photo point of 48 Acre Foredune Area 6-Parks Classic, facing east. Image taken on May 8, 2020.



Figure 43. Drone photo point of 48 Acre Foredune Area 6-Parks Classic, facing east. Image taken on February 18, 2025.



Figure 44. Drone photo point of Table Top restoration project area facing north. Image taken on February 5, 2022.



Figure 45. Drone photo point of Table Top restoration project area facing north. Image taken on February 18, 2025.



Figure 46. Drone photo point of Area 1 restoration project area facing northwest prior to planting. Image taken on March 6, 2022.



Figure 47. Drone photo point of Area 1 restoration project area facing northwest two years after planting. Image taken on March 19, 2025.



Figure 48. Drone photo point of Lagrille Hill restoration project area facing northwest taken immediately after planting. Image taken on March 6, 2022.



Figure 49. Drone photo point of Lagrille Hill restoration project area facing northwest three years after planting. Image taken on March 19, 2025.

ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 08

Increments of Progress Toward Air Quality Objectives, ODSVRA Dust Control 2024 Update

- Increments of Progress Toward Air Quality Objectives, ODSVRA Dust Control 2024 Update (DRI Document)
- SAG Review of Desert Research Institute (DRI) "Increments of Progress Toward Air Quality Objectives, ODSVRA Dust Control 2024 Update" (SAG Memo)

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Increments of Progress Towards Air Quality Objectives - ODSVRA Dust Controls, 2024 Update

J.A. Gillies, G. Nikolich, E. Furtak-Cole, Division of Atmospheric Science, Desert Research Institute

Dust controls including temporary wind fences and vegetation projects have been used within the Oceano Dunes State Vehicular Recreation Area (ODSVRA) to reduce the emissions of PM_{10} originating from the ODSVRA and to lower the regional PM_{10} burden on the Nipomo Mesa. Beginning in 2014 and continuing through 2023, a total of 412.5 acres of managed dust control areas have been established in the ODSVRA (State of California, Department of Parks and Recreation, 2024).

Here we demonstrate that the PM_{10} data measured at CDF and Mesa2 and the wind data measured 10 m above ground level (AGL) at the S1 tower show that PM_{10} measured at CDF and Mesa2 are lower now than prior to the establishment of dust controls and that this reduction in PM_{10} scales with the increase in acres of dust control upwind of these monitoring sites. In this report we update the ratio TPM_{10}:TWPD for CDF and Mesa2 and acres of dust control from Gillies et al. (2022a) with data from April to September, 2024.

Methods

The metric used to evaluate the production of PM_{10} from the ODSVRA is the ratio of the summation of the hourly PM_{10} (TPM_{10}, $\mu g\ m^{-3}$ [measured with a Beta Attenuation Monitor or BAM]) operated by the San Luis Obispo County Air Pollution Control District (SLOAPCD) and the summation of thresholded hourly wind power density ($W\ m^{-2}$) as measured at the S1 tower within the ODSVRA, for winds that are expected to cause saltation and dust emissions during the spring-summer period (April through September). Only valid, paired hourly values of PM_{10} ($\mu g\ m^{-3}$) and wind power density ($W\ m^{-2}$) are used for the summations.

Wind power density (WPD, $W\ m^{-2}$) is defined as (e.g., Kalmikov, 2017):

$$WPD = 0.5\ \rho_a\ u^3 \quad (1)$$

where ρ_a is air density ($kg\ m^{-3}$), and u ($m\ s^{-1}$) is wind speed at the measurement height above ground level (10 m AGL), a unit area of 1 m^2 is assumed in this application. For comparison among different locations and between different years, the height of measurement of wind speed and the lower limit of mean hourly wind speed for summation of Total Wind Power Density (TWPD) must be the same.

The following constraints were applied for the environmental data available:

1) A wind speed filter was applied based on screening for the conditions where it was most likely that the PM_{10} reaching CDF and Mesa2 was due to the generation of dust by saltation within the ODSVRA. Winds from 248° to 326° were used to ensure, conservatively, that the air flow that reached CDF and Mesa2 had most likely travelled from the ODSVRA.
2) Only wind speeds greater than a threshold value at which a visible trend between wind speed and increasing PM_{10} at the CDF and Mesa2 sites were determined from data that relates PM_{10} to wind speed measured at each of the sites.
3) Based on precipitation data from monitoring sites near the ODSVRA, the number of days where precipitation occurred prior to the hour of observation were identified. Observed data were removed from analysis if precipitation was observed less than 4 days prior (i.e., 3 days of drying with no precipitation).

To standardize the calculation of TWPD a lower limit of wind speed is chosen that corresponds with the lowest speed where the relation between increasing wind speed and simultaneous increase in PM_{10} is observed at a monitoring station. As for previous years, a wind speed of 3.5 m s^{-1} at 10 m above ground level (AGL) (WPD= 26 W m^{-2}) for CDF and Mesa2 defines the lowest value for the range over which PM_{10} is summed at these stations to calculate TPM_{10}. TWPD is the summation of the hourly mean wind speed measured at the S1 tower for the hours identified at CDF or Mesa2 that correspond to hourly mean wind speed ≥3.5 m s^{-1} (after screening for the wind direction and precipitation criteria).

The importance of using a consistent lower limit of mean hourly wind speed was demonstrated by Gillies et al. (2023) using the S1 tower wind and CDF PM_{10} hourly concentration data for the lower wind speed limits of 3.5 m s^{-1}, 4.0 m s^{-1}, and 4.5 m s^{-1} for each month, April through September 2024. As Gillies et al. (2023, their Fig. 1) showed, the strength of the relation between monthly TPM_{10} and monthly TWPD remained unchanged (R^2=0.99) for all three lower limit wind speeds but changing the lower limit of wind speed does change the slope and intercept values. A change in the lower limit of wind speed also changes the seasonal TPM_{10}:TWPD (i.e., the summation of all [filtered] hours for the period April-September), hence it is important to maintain consistency for the lower limit wind speed value for comparison purposes to evaluate temporal change in the ratio.

The choice of using the lower limit of wind speed at CDF of 3.5 m s^{-1} measured at 10 m AGL is that when this hourly wind speed is observed at CDF the wind speed at the S1 tower is likely above that needed for saltation and PM_{10} dust emissions to be occurring within the ODSVRA.

Results 2024

Based on the available multi-year data record, saltation and dust emissions occur within the ODSVRA when the S1 tower wind speed measured at 10 m AGL is approximately 8.5 m s^{-1}. Figure 1 shows the relation between hourly wind speed at 10 m AGL at CDF and at 10 m AGL at the S1 tower for April-September 2024. In 2024 the regression derived wind speed at CDF that corresponds to 8.5 m s^{-1} at S1 is 5.02 m s^{-1}. To be consistent over the years, however, the lower limit of hourly mean wind speed for summation is retained at 3.5 m s^{-1} as measured at CDF.

Total Wind Power Density, April-September 2011-2024

To place the wind conditions into context across the available S1 tower data record, 2011-2024, TWPD for the period April-September in each year was calculated (Fig. 2). For 2024, TWPD for the period April-September 2024 (TWPD=179572 W m^{-2}) is 10.7% lower than for the same period in 2023 (TWPD=20,1148 W m^{-2}). In the 14-year record from 2011 to 2024, 2019 had the lowest observed and 2022 the highest observed value of TWPD with the median TWPD for the period 2011-2024 being 20,5441 W m^{-2}.

Figure 3 shows the distribution of wind direction at S1 tower for 2023 and 2024 when applying the directional filter of 248°-326°. The distributions have the same median value of 280° for both years.

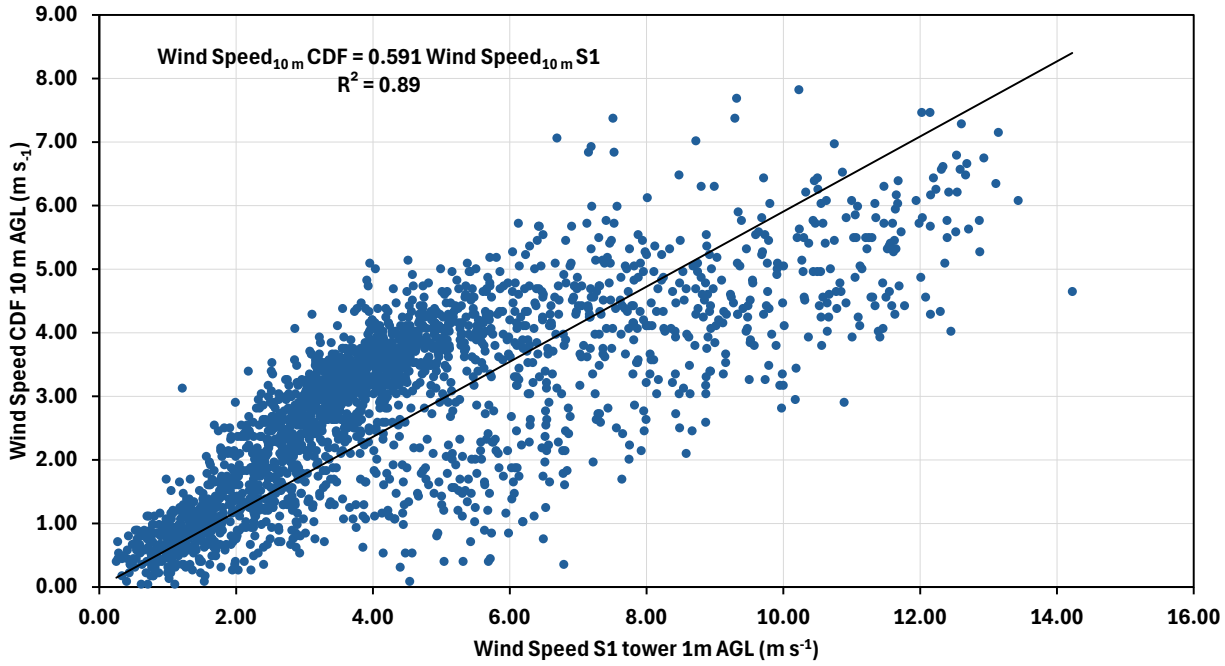


Figure 1. The correlation between mean hourly wind speed measured at 10 m AGL at CDF and S1 April through September 2024. Data filtered for the wind direction range 248°-326°.

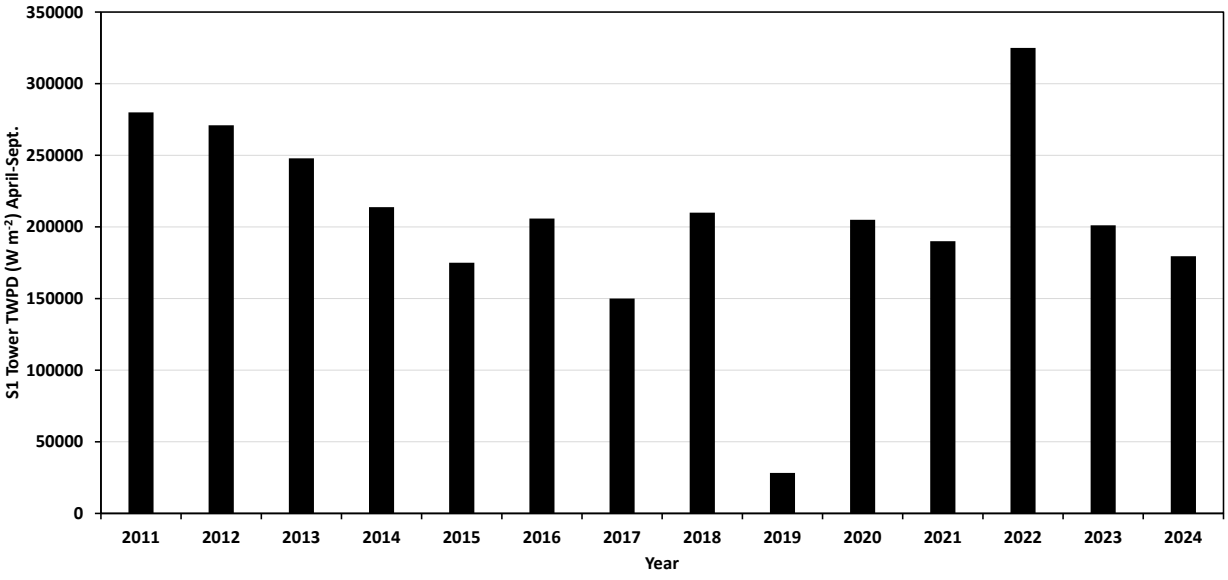


Figure 2. Total Wind Power Density (W m^{-2}) at the S1 tower for the period April-September 2011-2024. Data filtered for the wind direction range 248°-326°.

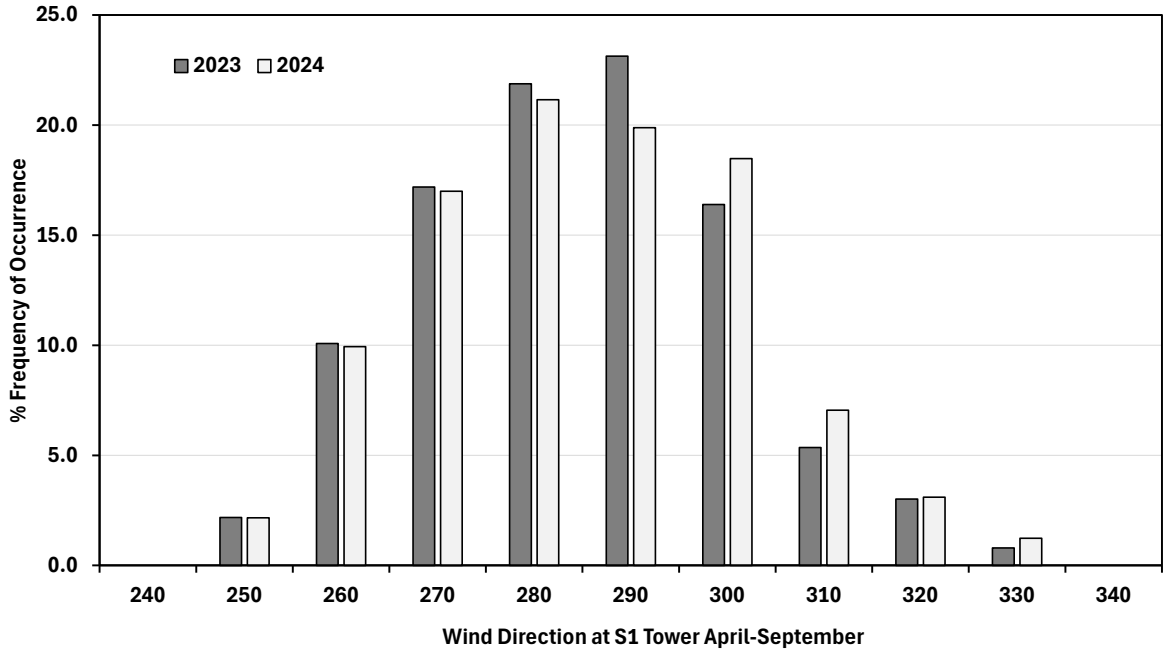


Figure 3. The distribution of wind direction at S1 tower for the period April-September 2023 and 2024, after applying the filtering criteria.

Total PM_{10} and Total WPD April-September 2024, CDF

As shown previously (Gillies et al., 2020, 2021, 2022a, 2023), TWPD measured at S1 correlates with total PM_{10} at CDF and Mesa2 (Gillies et al., 2020, 2021, 2022a, 2022b, 2023). This relation was also observed for the 2024 data (Fig. 4).

Based on the number of acres of dust control that have been established from 2013 (2 acres) through 2024 (330 acres) upwind of CDF, Fig. 5 shows that at CDF for the period April through September a downward trend in the TPM_{10}:TWPD ratio with increasing amounts of dust control acreage has been observed. Acres of dust control upwind of CDF are considered to lie within the directional range 270° to 325°, as centered on CDF. The datum for 2024 (TPM_{10}:TWPD=0.17) shows a very slight increase over 2023 (0.15). This may indicate that the ratio, representing the area upwind of CDF, has stabilized in the last three years and that the control measures in place have reached a static condition. The change in the TPM_{10}:TWPD ratio from 2023 (0.15) to 2024 (0.17), may also be reflective of natural variation in the dust emission system due to changing surface emissivity conditions as well as influences that are associated with the transport and dispersion of PM_{10} originating from different source areas within the ODSVRA. The ODSVRA dust emission system is complex with many non-linearities in the emission, transport, and dispersion of the PM_{10}, which contribute to its variability across space and through time. Attribution of the relative influence of these processes that result in year-to-year variability of the TPM_{10}:TWPD ratio is difficult to assess. For example, with respect to wind direction change between years, Fig. 6 shows the distribution of wind direction at CDF tower for 2023 and 2024 after applying the directional filter of 248°-326°. The median wind direction in this range in 2023 was 297° and 282° in 2024. This shift to more westerly winds in 2024 results in wind transporting PM_{10} from different areas

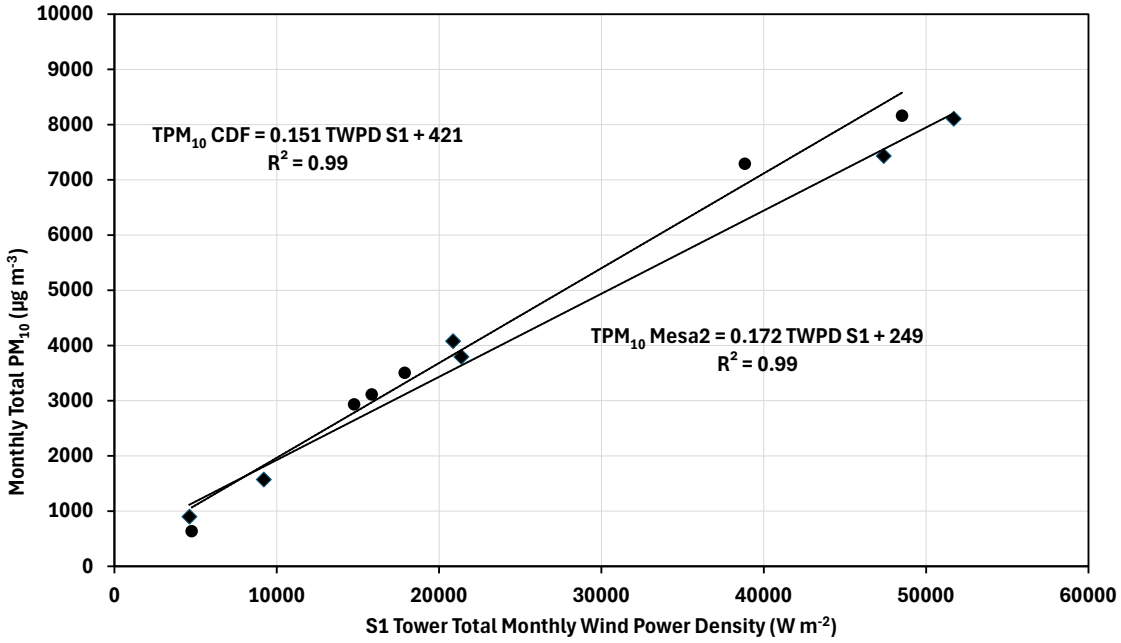


Figure 4. The relation between monthly Total PM_{10} and monthly Total Wind Power Density for all hours when the wind direction was from 248°-326° observed at CDF (diamonds) and Mesa2 (circles), wind speeds were ≥3.5 m s^{-1} (at CDF and Mesa2), and hours wherein there were <4 days since the last record of precipitation were removed.

within the ODSVRA reaching the CDF receptor site, within the defined directional filter range. An additional effect on the PM_{10} concentration at the CDF receptor is dispersion. As winds shift to a more westerly direction, the travel distance from the source areas to the receptor decreases, which will reduce the amount of dispersion. This could lead to higher concentrations of PM_{10} for similar wind conditions (i.e., speed and turbulence characteristics).

In Fig. 5, DRI reiterates from previous reporting (i.e., Gillies et al., 2022b, 2023) two years of data have not been included. In 2019 there were few hours where the winds exceeded the lower limit of wind speed to define the summation interval (i.e., ≥3.5 m s^{-1} at CDF and Mesa2), which due to the paucity of higher wind speeds leads to an unstable ratio condition. The TPM_{10}:TWPD ratio for 2020 was also not included in the least squares regression as during April-September of that year OHV activity in the Park was restricted due to COVID19.

Figure 7 shows the change in the TPM_{10}:TWPD ratio for CDF as a function of year. This provides a more generalized representation of the ratio as a function of the state of the surface conditions upwind of CDF for the April-September period across the 11 years of observation with the established filtering criteria applied in each year. The TPM_{10}:TWPD ratio has shown a steady decrease through time from 2013 through to 2023. The ratio increased in 2024, but it will take further years of data to determine whether there is an upward trend, indicating the Oceano Dunes are becoming more emissive, or whether the ratio will become stable, indicating that the dust emission system has stabilized with respect to the driving force of WPD producing similar levels of PM_{10} concentrations.

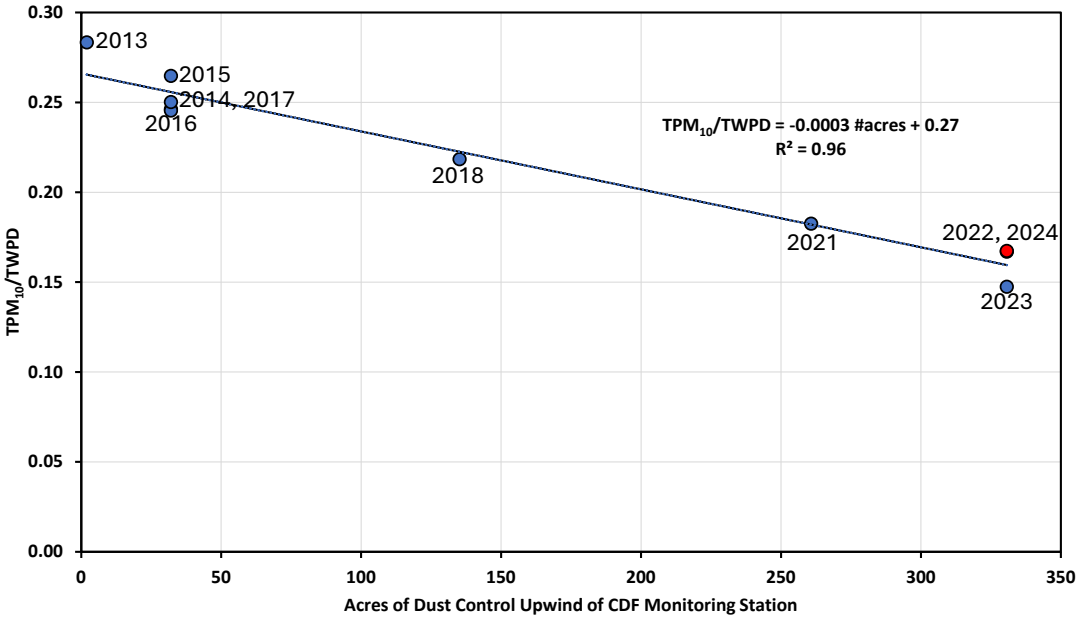


Figure 5. The relation between TPM_{10}:TWPD ratio value measured at CDF and the acres of dust control from 2013 through to 2024 placed upwind of CDF are accounted for in the directional range 270° to 325°. Data from 2019 and 2020 were excluded as discussed elsewhere. Note 2014 and 2017 data and 2022 and 2024 (red circle) data align on top of each other.

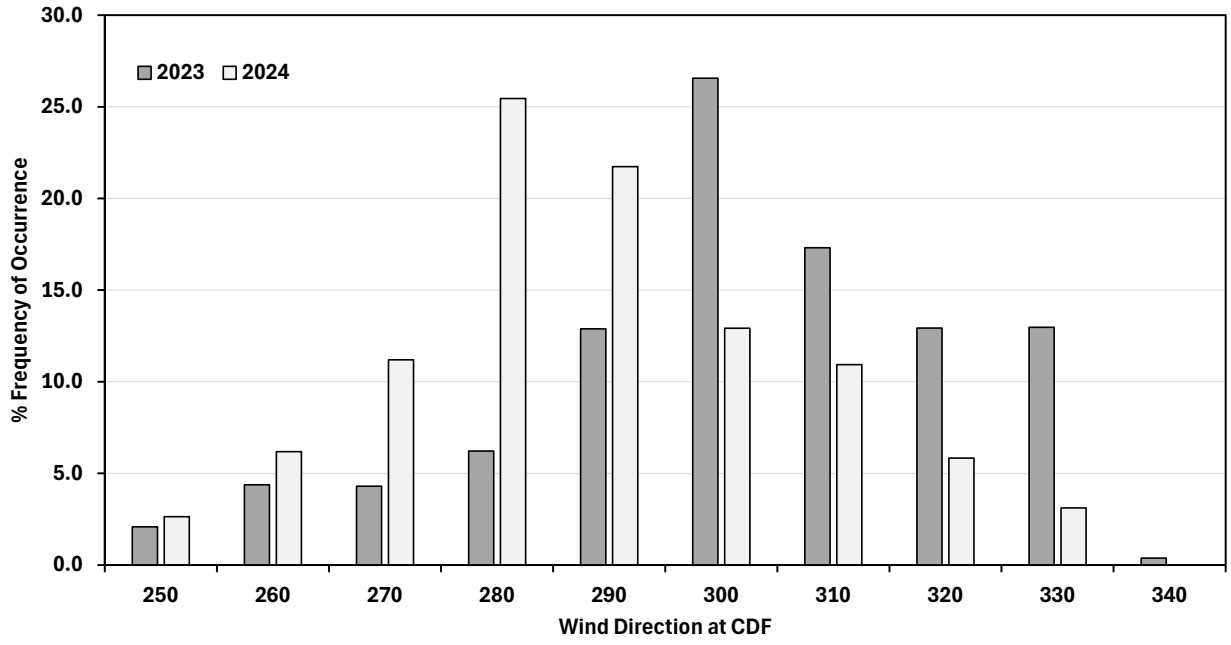


Figure 6. The distribution of wind direction at CDF for the period April-September 2023 and 2024, after applying the filtering criteria.

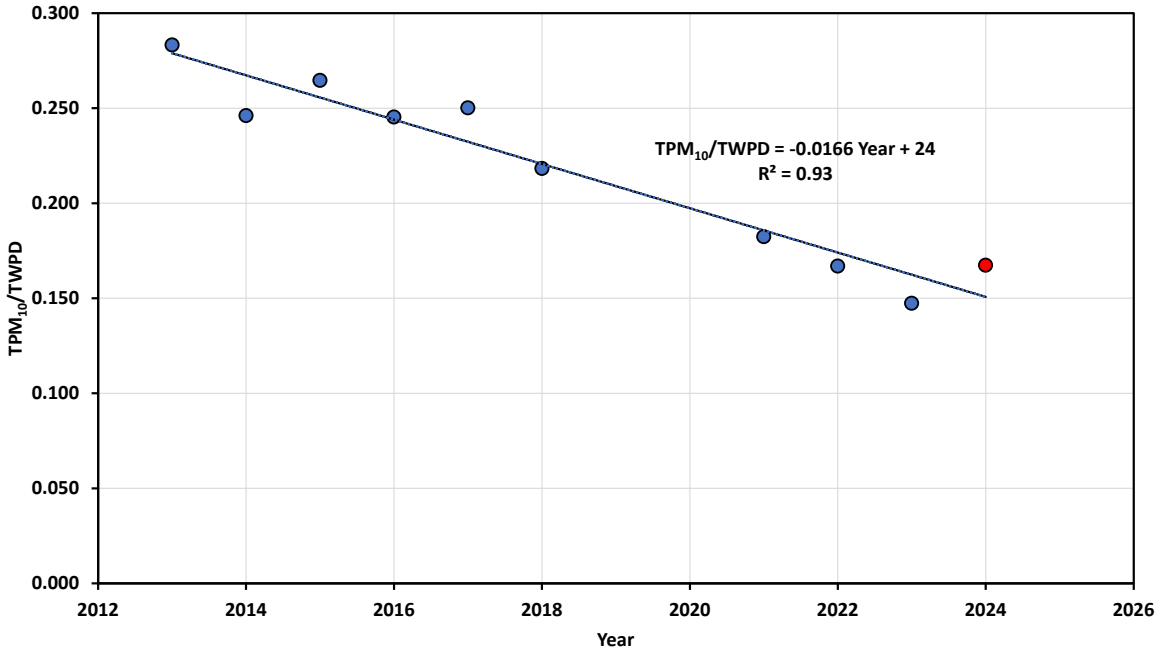


Figure 7. The relation between TPM_{10}:TWPD ratio value measured at CDF as a function of the year of observation with the wind speed, wind direction, and precipitation day filters applied. Data from 2019 and 2020 were excluded as discussed elsewhere.

Total PM_{10} and Total WPD April-September 2024, Mesa2

The ratio of TPM_{10}:TWPD for Mesa2 and S1 data for the period April through September for the years 2013-2024 as a function of acres of dust control upwind of Mesa2 is shown in Fig. 8. Acres of dust control upwind of Mesa2 are considered to lie within the directional range 270° to 305° as centered on Mesa2. This figure shows that a downward trend in the TPM_{10}:TWPD ratio is observed with increasing acres of dust control for the period 2018 (24.3 acres) – 2024 (168 acres). Prior to 2018, there was no clear trend in the TPM_{10}:TWPD ratio data as there were few acres of dust control upwind of the Mesa2 monitoring station.

Figure 8 indicates that a downward trend in the TPM_{10}:TWPD ratio through time for Mesa2 is supported with the inclusion of the 2024 datum. The value of 0.18 in 2024 does, however, indicate an increase from the previous two years. This may represent natural variation in the dust emission system as described above. There was also a shift in the wind direction in 2024 compared to 2023 (Fig. 9). The median wind direction in 2023 was 297° and 284° in 2024, similar to the shift in the distribution observed at CDF. This shift to more westerly winds could be sufficient to influence the TPM_{10}:TWPD ratio as the wind will be transporting PM_{10} from different zones from which the PM_{10} has been emitted and potentially the size, in terms of acres, of the area under dust management upwind of Mesa2. The wind direction data for 2023 and 2024, when further partitioned to represent a narrower direction defined by the frequency of occurrence representing ≥85% of the data in 2023 (280°-320°) and ≥78% of

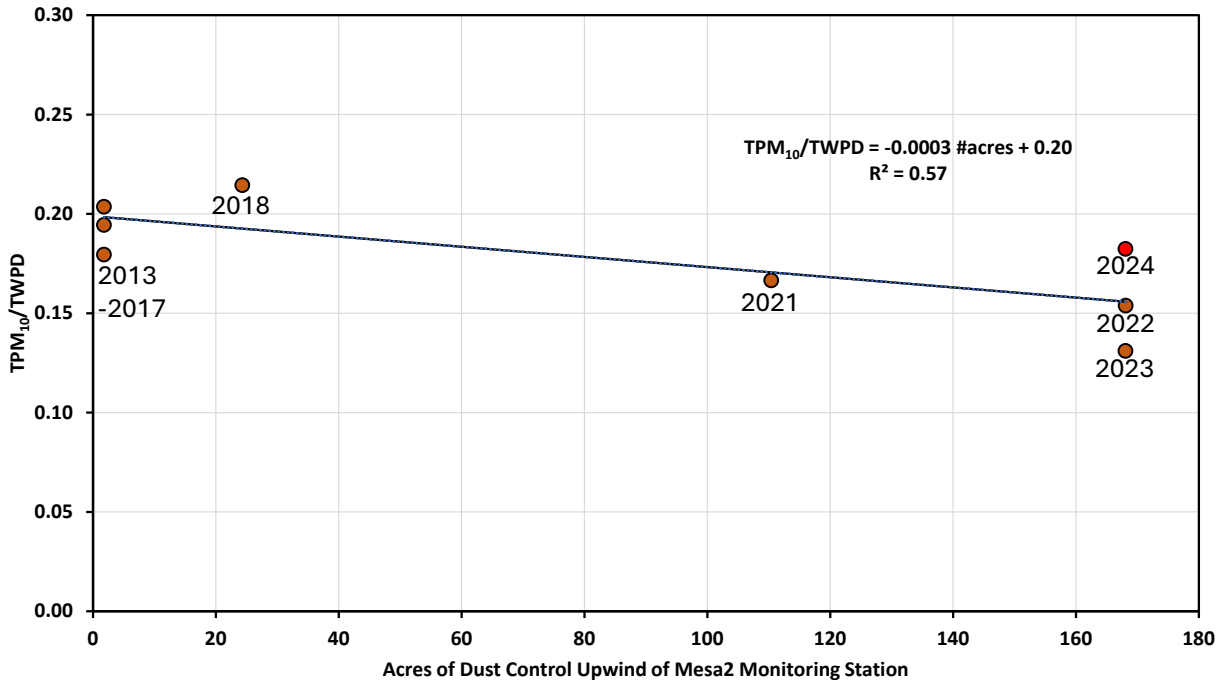


Figure 8. The relation between TPM_{10}:TWPD ratio value measured at Mesa2 and the acres of dust control from 2013 through to 2024 placed upwind of Mesa2 are accounted for in the directional range 270° to 305°. Data from 2019 and 2020 were excluded as discussed elsewhere. Note for the 2013-2017 data points some years are aligned on top of one another.

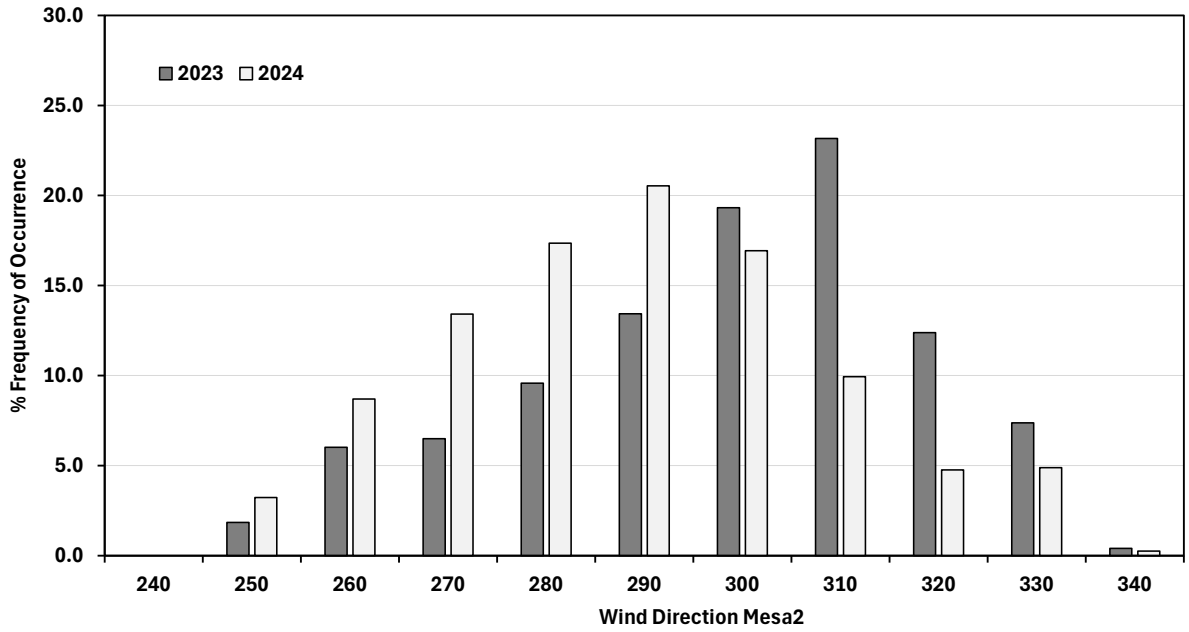


Figure 9. The distribution of wind direction at Mesa2 for the period April-September 2023 and 2024, after applying the filtering criteria.

the data in 2024 (270° to 305°) show that in 2024, the number of acres that are defined as being under dust management (i.e., active revegetation) within the defined directional range decreased by 55% compared with the acres defined as under dust management in 2023. The smaller amount of upwind acres of managed areas could, in part, explain the increase in the TPM_{10}:TWPD ratio in 2024. There was greater potential for dust generated from unmanaged areas in 2024 reaching Mesa2 than in 2023. The data for 2019 and 2020 were not included in the analysis as described above for the CDF site.

Discussions and Conclusions

This analysis has demonstrated that TWPD is a robust metric for explaining the relationship between wind-driven saltation and the accompanying emission of PM_{10} from the ODSVRA as measured at two key receptor sites, CDF and Mesa2. The TWPD and TPM_{10} measurement-based metric indicates that the PM_{10} originating from the ODSVRA has been reduced by approximately 43.3% at CDF using the 3-year (2022 - 2024) mean value of 0.16 (±0.01) for equivalent WPD conditions compared with the baseline year of 2013 (TPM_{10}:TWPD= 0.28). For Mesa2, the TWPD and TPM_{10} measurement-based metric indicates that the PM_{10} originating from the ODSVRA has been reduced by approximately 13.3% using the 3-year (2022 - 2024) mean value of 0.16 (±0.03) for equivalent WPD conditions compared with the baseline year of 2013 (TPM_{10}:TWPD= 0.18) when there were few acres of dust control upwind of the Mesa2 station.

Figures 5, 7, and 8 demonstrate that the TPM_{10}:TWPD ratio can be used to track the progress of the effect of dust controls on the dust emission system within the ODSVRA. It allows for quantification of the increments of progress as management efforts to limit dust emissions are further developed to meet the Stipulated Order of Abatement (SOA). It needs to be noted that the TPM_{10}:TWPD ratio indicates the production potential of PM_{10} as a function of WPD. An increase in WPD can result in more exceedances of the State or Federal standard even in the presence of increased amounts of dust controls because the PM_{10} is produced from the uncontrolled areas and it increases as a power function of wind speed, while the efficiency of the dust control does not. It should also be noted that the dust emission potential of the surfaces within the ODSVRA vary through time and across space and the wind climatology (wind speed and direction) in any given year is likely different compared to other years. This dynamism in the dust emission and wind climatology systems creates variability in the year to year TPM_{10}:TWPD metric. Without further modification or enhancement of the acres under dust control at the ODSVRA, there is every expectation that the value of this metric will oscillate around a mean value that is currently 0.16 for CDF and Mesa2 based on the last three years of data. Even if the acres of dust control remain essentially unchanged, variability in the TPM_{10}:TWPD metric can be expected due to the vagaries of wind climatology and shifts in emissivity strength across space driven, in part, by changing patterns of off highway vehicle (OHV) activity as a function of location and frequency of disturbance within the ODSVRA.

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Kalmikov, A. (2017). Wind power fundamentals. In *Wind Power Engineering,* ed. T.M. Letcher. Elsevier Science Publishing Co., Inc.

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May 8, 2025

Memo: SAG Review of DRI Report "Increments of Progress Towards Air Quality Objectives – ODSVRA Dust Controls 2024 Update" (12-24-2024 V2)

From: Scientific Advisory Group (SAG)[1]

To: Jon O'Brien, California Department of Parks and Recreation

Cc: Ronnie Glick, California Department of Parks and Recreation

The SAG recently received (via email on April 17, 2025) a copy of the Desert Research Institute (DRI) report (*Increments of Progress Towards Air Quality Objectives – ODSVRA Dust Controls 2024 Update*, dated December 24, 2024), and members have had the opportunity to review the document. This memo provides feedback on the DRI report.

As with the previous Increments of Progress (2022, 2023) reports, the primary message of this 2024 update is that the dust-mitigation efforts instituted by CDPR since 2013 continue to be effective in reducing PM_{10} concentrations at the CDF and Mesa2 monitoring stations. In particular, Figure 5 shows a downward trend in the ratio of TPM_{10}/TWPD as a function of increases in the total acreage under dust control measures (and therefore with time since 2013) at CDF. The most convincing aspect of this assessment is the fact that Total Wind Power Density (TWPD) has varied substantially from year-to-year, as shown in Figure 2 of the report, and yet the TPM_{10}:TWPD ratio continues to fluctuate around a mean low value since 2022. This speaks to the **overall effectiveness of the dust control measures undertaken in the past decade.**

The report is an update of last year's Increments of Progress (2023) document with new data from 2024 added to the analysis, but retaining the same document structure and narrative as before. The SAG has identified a large number of typographical errors and grammatical issues, which are detailed in a marked-up version of the original document that will be delivered under separate cover. **We encourage DRI to be more vigilant in preparing future versions of this document, with greater attention to detail and a thorough re-reading prior to submission.**

The SAG has one substantive area of concern, with respect to the discussion of the trends for Mesa2. Although the results for CDF are convincing as regards a decline in the TPM_{10}:TWPD ratio with increased acreage under dust control treatment, the results for Mesa2 are not nearly as compelling. Indeed, the ratio for 2024 for Mesa2 is approximately the same as it was for the period 2013-2017 when there were virtually no acres under treatment. The narrative makes it sound like Mesa2 is enjoying similar success as CDF, which it is not, and also posits that a shift in seasonal wind direction to more westerly approach angles is responsible for the increase in the ratio for 2024 from 2023. Although there is likely merit to this argument, from a statistical standpoint, the value for 2024 (or the mean from 2022-2024 = 0.16) is no different from that of

[1] Standard procedure for SAG review of DRI reports is for Dr. Jack Gillies to recuse himself from the discussions due to a potential conflict of interest. Despite being a SAG member in good standing, Dr. Gillies did not participate in this review in any manner nor was DRI consulted about any aspect of this review.

2013 (0.18) given the reported uncertainty range of +/- 0.03 (i.e.,0.13 to 0.19) quoted in the first paragraph of the Discussion & Conclusions section.

The TPM_{10}:TWPD metric remains a practical tool to evaluate the long-term impacts of dust-mitigation efforts in the ODSVRA, and overall, the SAG concludes that this report provides a useful update for how dust controls are affecting downwind air quality. However, the SAG questions whether the improvements in air quality at Mesa2 are, in fact, as evident as suggested in the report, and recommends further inquiry into the trends and the potential reasons for them.

The SAG believes that the report would be improved considerably after attending to the editorial issues identified in the marked-up copy of the report, as well as offering a more penetrating analysis of the situation at Mesa2 so as to more faithfully communicate the state of progress toward attaining the SOA objectives in 2024.

Respectfully,

The Scientific Advisory Group

Bernard Bauer (Chair), Jenny Hand, Leah Mathews, Ian Walker

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ODSVRA Dust Control Program Draft 2025 ARWP

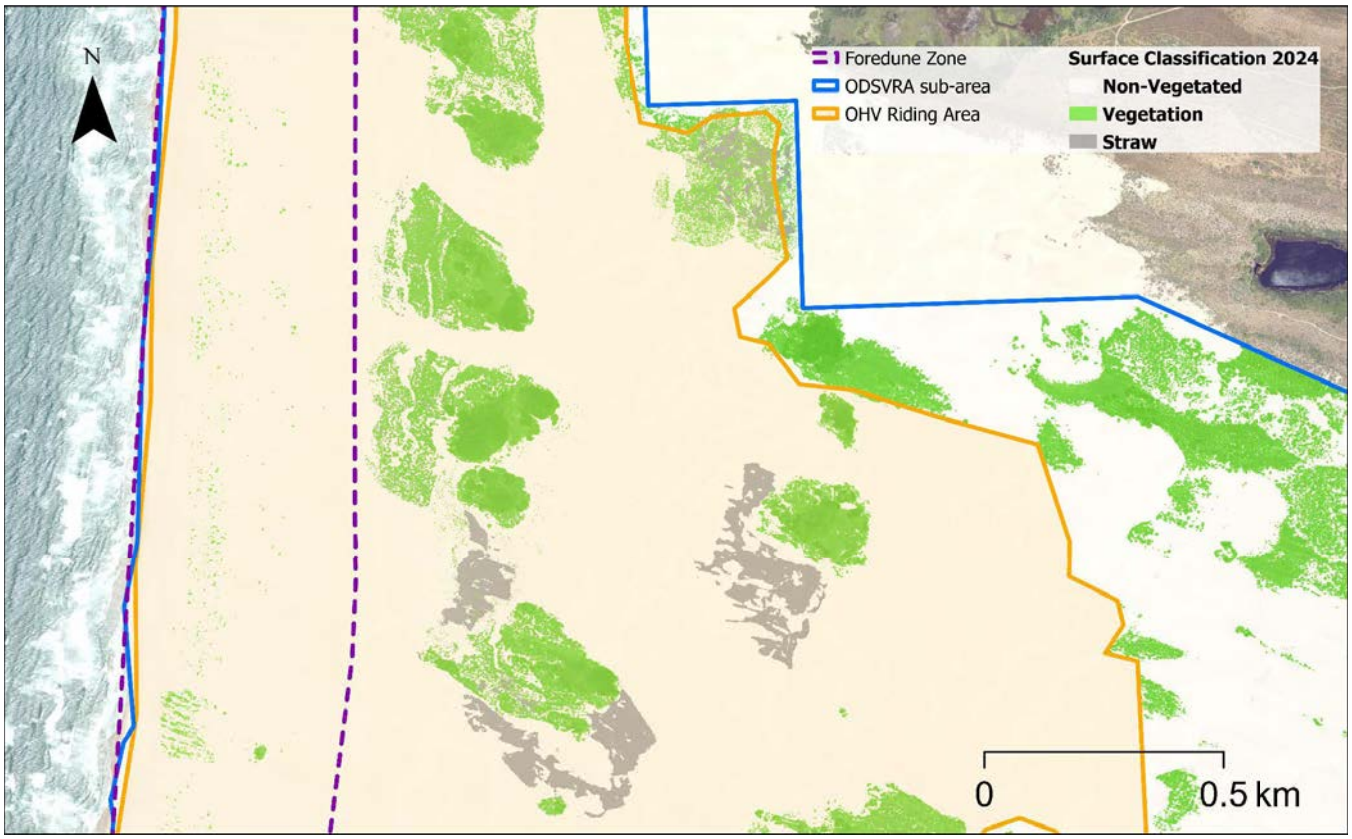
ATTACHMENT 09

Recent (2020-2024) Changes in Vegetation Cover within the Oceano Dunes SVRA

- Recent (2020-2024) Changes in Vegetation Cover within the Oceano Dunes SVRA (UCSB Document)
- SAG Review of UCSB "Recent 2020-2024 Changes in Vegetation Cover within the Oceano Dunes SVRA" (SAG Memo)

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Recent (2020-2024) Changes in Vegetation Cover within the Oceano Dunes SVRA



Map of vegetation and straw cover within a portion of the Off-Highway Vehicle Riding Area of ODSVRA derived from the recent 2024 NAIP aerial imagery.

Prepared by: Madison Heffentrager[1], Ian Walker[1,2], Zach Hilgendorf[1,3] , and Phoebe Mennis[1]

[1]Department of Geography, University of California Santa Barbara
[2]Member, Oceano Dunes Scientific Advisory Group (SAG)
[3]University of Wisconsin - Eau Claire

DRAFT June 2025

LIST OF ACRONYMS

Annual Report and Work Plan – ARWP
Barbecue – BBQ
State of California Department of Parks and Recreation – CDPR
Desert Research Institute – DRI
Foredune Restoration Area – FRA
Geographical Information System – GIS
Oceano Dunes State Vehicular Recreation Area – ODSVRA
National Agriculture Imagery Program – NAIP
Off-Highway Vehicles – OHV
Root Mean Square – RMS
Scientific Advisory Group – SAG
Stipulated Order of Abatement – SOA
State Vehicular Recreation Area – SVRA
Treatment Plot – TP

EXECUTIVE SUMMARY

This report provides an update to a previous historical vegetation cover (1930-2020) change assessment for ODSVRA prepared by Swet et al. (2022). The objective of the report is to map and quantify changes in vegetation cover from 2020-2024 to extend this previous analysis and help inform monitoring, modeling, and management of recent vegetation restoration efforts as dust emission mitigation strategies.

Aerial photography from 2024 was obtained from the National Agriculture Imagery Program (NAIP) to produce new, recent vegetation cover maps in the ODSVRA using the same GIS methods and analytical areas within ODSVRA as Swet et al. (2022), including: a selected zone of the the ODSVRA park boundary south of Arroyo Grande Creek (referred to as the ODSVRA sub-area), the OHV riding area, South Oso Flaco, North Oso Flaco, the foredune zone, and the foredune restoration area (FRA)(see Figure 1). These analytical areas were defined in consultation with CDPR and SAG for the initial analysis and are held the same here for consistency and direct comparison.

Straw cover is typically implemented as a temporary dust control measure and, in this report, was quantified and mapped separately from vegetation and sand surfaces for 2024, whereas the prior analysis classified straw as a non-vegetated surface. The 2024 vegetation cover estimates are appended to the historical results with emphasis on interpreting recent changes (post-2020) during a period of expansion of dust mitigation efforts by the CDPR using combined treatments with wind fencing, straw cover, and vegetation restoration.

Overall, in recent years both total vegetation cover (in backdune + foredune areas) and foredune plant cover increased in percent cover and rates of change in all analytical zones. By 2024, plant cover reached historic high values in all analytical areas compared to estimates dating back to the 1930s. Total vegetation cover for 2024 ranged from 0.81 km^2 (12.59% cover) in the OHV riding area, 1.59 km^2 (68.15%) in South Oso Flaco, to 6.66 km^2 (39%) in the larger ODSVRA sub-area. Plant cover in the foredune zone ranged from 0.06 km^2 (0.9%) in the OHV riding area to 0.7 km^2 (4.08%) in the broader ODSVRA sub-area. Foredune plant cover increased mainly in North and South Oso Flaco areas and minimally in the broader ODSVRA and OHV riding area. Generally, increases in plant cover since 2020 occurred near existing vegetation islands or straw stabilized sites, and most gains occurred in backdune areas. Vegetation losses were comparatively small and associated mostly with sand inundation on windward/western edges of restoration sites, inland dune migration over existing vegetation, and localized creek erosion in the foredune zone. The OHV riding area maintains the lowest total percent plant cover due to continued recreation activities. However, observations for this recent interval show a notable increase of 0.33 km^2 of new vegetation in the riding area mainly around existing vegetation islands and in the FRA. Recent efforts by CDPR have increased plant cover in the riding area to a historic high (12.59%), surpassing a previous peak in 1966 during a time of rapidly increasing OHV activity.

Widespread shifts from straw cover in 2020 to vegetation at restoration sites by 2024 suggests that straw placement continues to be effective at promoting vegetation establishment in this highly active dune landscape. Sand inundation and vegetation loss on the windward and lateral perimeters of these sites will require continued monitoring and adaptive management to maintain plant cover and hold restoration site footprints.

1. Introduction

Plant cover and detritus (e.g., straw, dead plants, woody debris) provide key surface roughness for developing and maintaining dune ecosystem form and function (Hesp and Walker, 2022; Walker et al., 2022a). When wind flow interacts with vegetation, momentum is extracted from the flow, wind speeds slow down, and sand grains can be deposited if wind strength falls below the transport threshold, resulting in localized sediment deposition (e.g., Buckley, 1987; Wolfe and Nickling, 1993; Arens, 1996; Suter-Burri et al., 2013; Sherman and Ellis, 2022; Walker et al., 2022a). Wind flow over established dunes is further influenced by plant density, porosity, height, and rigidity (Buckley, 1987; Arens, 1996; Suter-Burri et al., 2013). The interaction of flow with plant roughness and the spatial arrangement of plants can, in turn, impact dune development and form (Keijsers et al., 2015; Walker et al., 2022b). In this way, plants act as an ecological engineer, and some have described it as a "soft-engineering" approach in other applications (e.g., Feagin et al., 2015; Griggs and Reguero, 2021).

Aeolian sand transport and related dust emissions can also be modified or influenced by other local factors, such as fetch distance for developing saltation (e.g., beach width), salt, biological crusts, moisture content, and slope (e.g., Arens, 1996; Bauer et al., 2009; Walker, 2020; Sherman and Ellis, 2022). Like plants, straw cover is an effective, albeit temporary, way to inhibit aeolian sand transport and dust emissions, as it functions as both a supply-limiting factor (i.e., modifying the availability of sand to aeolian transport) and transport-limiting factor (i.e., modulating the ability of wind to impart sufficient shear stress on a sand surface). Sand fences can also be used to reduce aeolian sand transport by acting as a transport-limiting factor that promotes localized deposition downwind of, or in between, fences (Li and Sherman, 2015). Various types of artificial roughness elements, including straw bales, artificial porous cubes, and wind fences, have been used by CDPR at the ODSVRA to reduce aeolian sand transport and dust emissions (Gillies and Lancaster, 2013; Gillies et al., 2017).

Since implementation of the SOA in 2018, CDPR has increased efforts to stabilize dune surfaces with straw cover and vegetation as a dust control measure in the ODSVRA in both backdune and foredune areas (Figure 1). In February 2020 a 48-acre Foredune Restoration Area (FRA) was implemented with 5 different treatment plots using combinations of straw, native dune seeds and plants, and a sterile rye grass seed. The initial responses and efficacy assessment for this site is described in Walker et al. (2022b) and progressive performance of the FRA is reported in each ARWP. Other backdune restoration sites were implemented in historical locations of dune scrub vegetation islands evident in early aerial photography (Swet et al., 2022). Often, wind fencing and/or straw cover are used as initial phases in vegetation re-establishment on bare sand surfaces to reduce sediment transport and provide stable areas for eventual planting.

The purpose of this study is to map and quantify recent changes in vegetation and straw cover within the ODSVRA from 2020 to 2024, following increased restoration and dust control efforts by CDPR. This study extends a prior assessment (Swet et al., 2022) of historical plant cover classified from aerial imagery dating back to the 1930s. This study focuses on vegetation changes in sub-regions within the ODSVRA, including: a selected zone of the ODSVRA park boundary south of Arroyo Grande Creek (referred to as the ODSVRA sub-area), the OHV riding area, South Oso Flaco, North Oso Flaco, the foredune zone, and the FRA (Figure 1). The ODSVRA sub-region is not the entire region of the ODSVRA

and Pismo Beach State Park managed by CDPR[1]. These sub-regions were defined in consultation with CDPR for the initial Swet et al. (2022) report and are held the same here for consistency. Main deliverables are an interpretation of recent changes in plant cover and an updated inventory of vegetated dust control sites for ongoing emissions modeling efforts by DRI to assess progress toward compliance with the air quality goals of the revised SOA.

[1] https://csparks.maps.arcgis.com/apps/webappviewer/index.html?id=f96a883ff4154455b23bdc119f4574a9



Figure 1: *Map of the ODSVRA showing zones used for the vegetation cover change analyses in this report. These zones are identical to those used in the longer-term historical vegetation change report by Swet et al. (2022). Underlying image source: NAIP 2024.*

2. Methods

Aerial imagery for 2024 was downloaded as a single frame image at 0.6 m resolution from the NAIP server[2]. The 2024 4-Band image was collected on 04/28/2024 with an 8 bit unsigned pixel depth, while the 2020 image was collected on 06/07/2020. The 2024 image was projected to be in NAD83(2011) UTM Zone 10N to match the coordinate system of the prior results. The image was clipped to be local to the boundary of the ODSVRA to reduce file size and processing time. A 2022 NAIP image exists, however, at the time of this report, the surface classification was unable to be performed due to computational limitations.

The 2024 image was georeferenced to the NAIP 2020 reference image using methods outlined by Swet et al. (2022)[3]. The NAIP imagery was roughly georeferenced on download so the steps in the linked ArcGIS workflow are only applicable when discussing the control point creation. Ten matching control points were selected between the 2020 and 2024 images in areas of immobile, distinct corners of concrete and buildings proximal to the boundary of the ODSVRA. The 2024 image was georeferenced to the control points using the spline method with a Total RMS Forward-Inverse Error of 0.000 m. The Forward-Inverse Error is a measure (in pixels) of how close the selected pixel location is to the control point after georeferencing between 2020 and 2024[4]. This accuracy measure is relative to the accuracy of the ten control points and does not suggest that the locational accuracy of the entire image outside of the control points is 0.000 m. To ensure the 2024 image was aligned properly to the 2020 image after georeferencing, roadways and building corners were visually compared using the Swipe Layer tool in ArcGIS Pro.

Classification of surface type was done in ArcGIS Pro v.3.2. by training a classification tool (Training Samples Manager, support vector machine) and verified through manual pixel reclassification. Forty samples for each class (vegetation, straw, and non vegetated) were selected across the study site to train the classifier. A representative selection of raster pixels in the imagery were used to train the classifier to identify the various surfaces. The classified raster surface was quality checked through visual inspection and pixels were reclassified as necessary using the Pixel Editor tool. Vegetation cover classifications and change calculations presented are subject to inaccuracies based on image quality, inconsistencies in lighting, and image resolution, and subsequent instances of pixels containing both vegetation and sand. The analysts conducted manual inspections of the classified raster layers to reduce the incidence of misclassifications, although some level of uncertainty is to be expected. For instance, straw cover pixels were detected in North and South Oso Flaco areas where, to our knowledge, straw was not distributed by CDPR. This likely reflects misclassification of dead or senesced vegetation, although resulting cover values (0.01%, Table 2) are well within the bounds of uncertainty for the method (roughly 2-3%).

[2] *https://nrcs.app.box.com/v/naip/folder/17936490251*

[3] *An updated link to the comparable georeferencing workflow is located here: https://learn.arcgis.com/en/projects/georeference-imagery-in-arcgis-pro/*

[4] *https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/overview-of-georeferencing.htm*

The results are parsed into analytical zones (regions) that match those of the previous historical vegetation cover assessment by Swet et al. (2022) (Figure 1), including: the ODSVRA sub-area[5], the OHV riding area, North Oso Flaco foredune area, and South Oso Flaco dunes. See Swet et al. (2022) for further reasoning behind the delineation of the boundaries of these analytical zones. Foredune and backdune vegetation cover within the analytical zones were also calculated as separate units, as applicable. Vegetation cover for the FRA was quantified for comparison to the other foredune units across the ODSVRA. Interpretation of vegetation cover changes within each of the restoration treatment plots in the FRA are provided in separate reports (e.g., Hilgendorf et al., 2024). All imagery, boundaries, and raster layers were in NAD83(2011) UTM Zone 10 N.

Areal (km^2 and acre) and percent cover of vegetation and straw cover were calculated for the 2024 image. Total analytical zone area was computed as the area within the polygon shapefile for each analytical zone (Table 1). The Extract by Mask tool in ArcGIS Pro was used to extract each rasterized surface classification within each analytical zone boundary. Total area of vegetation cover was calculated as the count of classified vegetation pixels multiplied by the resolution of the raster. Due to inherent differences in vector and raster data, the "non-vegetated" surface was calculated as the area of rasterized vegetation pixels (plus the area of straw, as applicable) subtracted from the total area of the polygon for each analytical zone. The existing 2020 vegetation cover calculations did not include straw classification and only reported "vegetated" and "non-vegetated" surfaces, which is an important distinction when interpreting the results presented in this updated report.

A change detection analysis between classified vegetation raster surfaces from 2020 and 2024 was also performed using the Raster Calculator tool in ArcGIS Pro. Change (positive or negative) in vegetation between the 2020 and 2024 rasters was calculated as a percent value and was mapped and plotted as rates of positive, negative, and net change over time (% yr^{-1}). Percent change per year was calculated as the number of pixels (either positive vegetation cover or negative vegetation cover) divided by the number of years (4), following the method used by Swet et al. (2022). It is acknowledged that normalized percent change per year does not capture the true interannual variability in plant growth that actually occurred between 2020 and 2024, but rather provides an average change condition over the interval. Historical positive, negative, and net change values reported by Swet et al. (2022) also show long term variability in vegetation cover per year between subsequent image years.

The method by which vegetation cover is calculated impacts the percent and areal cover of vegetation slightly. This is reflected in minor discrepancies between our estimates and those of Swet et al. (2022) for 2020 (roughly 2%), and between that study and CDPR's estimates, on the order of 3% (Swet et al., 2022). These discrepancies are similar and likely result from uncertainties related to the raster to polygon conversion used to calculate areas by Swet et al. (2022) and rounding errors. The 2020 dataset is not unique to this type of uncertainty. The historical datasets produced by Swet et al. (2022) for 1939 and 1978 also had uncertainties of 3% and 0.5%, respectively, compared to undocumented CDPR results (Swet et al., 2022).

[5]*Note: the ODSVRA sub-area in this report excludes the unanalyzed portion of the ODSVRA near Oso Flaco referenced by Swet et al. (2022). This exclusion results in a different polygon area of the ODSVRA sub-area and subsequently differences in vegetation cover percentage compared to the total area of the polygon.*

Table 1: *Area of each analytical zone and associated foredune zone. The FRA is also included for reference.*

Polygon Area	ODSVRA sub-area	OHV Riding Area	North Oso Flaco	South Oso Flaco	Foredune Restoration Area
Total Analytical Zone (km^2)	17.06	6.41	0.28	2.34	-
Foredune Zone (km^2)	3.89	1.95	0.28	0.44	0.19

3. Results

3.1. Total Vegetation Cover

Vegetation maps for 2020 and 2024 (Figures 2 and 3, respectively) show locations of classified plant cover and straw throughout ODSVRA. Overall, vegetation cover between 2020 and 2024 increased across the ODSVRA, while non-vegetated surfaces decreased accordingly (Table 2, Figure 4). Observed increases are largely the result of increased plant cover in backdune areas, with each zone experiencing ~3.4 to 4.9% increases. The North Oso Flaco site saw the greatest increase (~5%), but this site is small by comparison, so this reflects only +0.02 km^2 increase in plant cover. Increases in foredune vegetation elsewhere were <1% of the total areas in South Oso Flaco (+0.14 km^2), the OHV riding area (+0.29 km^2), and the larger ODSVRA sub-area (+0.64 km^2) (Table 2). In particular, recent restoration within the FRA and continued closure of the Western Snowy Plover nesting exclosure area have promoted favorable conditions for foredune plant community re-establishment since 2020. Specific changes and trends within these areas are covered in separate reports by UCSB in 2025 (Hilgendorf et al., 2025a, b).

The expansion of dust mitigation efforts by CDPR to 2022 has increased vegetation cover in the ODSVRA at large, and within each analytical zone, to levels that surpass historic values dating back to the earliest imagery of the 1930s (Figure 4). The ODSVRA sub-area reached ~39% cover (6.66 km^2), which exceeds the historic high value in 2012. The OHV riding area has lower vegetation cover, but recent efforts by CDPR have increased cover to 12.59% (0.81 km^2), mostly in backdune areas near existing vegetation islands, which now exceeds that in 1966 (12.36%, 0.79 km^2) during a time of rapidly increasing OHV activity (Swet et al., 2022). South Oso Flaco also reached a historic high for plant cover in 2024 (1.59 km^2 or 68.15%), which partly reflects the presence of invasive plants in this region. Plant cover at North Oso Flaco in 2024 is essentially equal to the peak in 2012 (24.38 vs. 24.41%, respectively) at roughly 0.07 km^2 (Figure 4, Table S1, Swet et al., 2022).

3.1.1. Straw Cover

Straw cover is often implemented by CDPR in advance of, or concurrent with, vegetation treatments to stabilize sand surfaces and protect seed/seedling establishment and growth. Swet et al. (2022) did not map straw cover separate from vegetation using the 2020 NAIP image, but rather included it as a non-vegetated surface, which was done to distinguish living plant cover from temporary straw cover (see their Figures 2 and 3). Here, straw cover was classified separately for 2024 and presented as both percent cover and areal cover for each analytical zone (Table 2). In the 2024 imagery, straw is most visible within

the OHV riding area (bright yellow pixel clusters in Figure 3), however, the majority of classified straw cover pixels (0.18 km^2) were identified in the non-riding area of ODSVRA (Table 2), which are not readily visible in Figure 3. It is also likely that some of the classified straw pixels include dead or senesced vegetation, despite the manual reclassification step in the methodology (Section 2). Refined classification for straw cover could be done in consultation with CDPR to cross-reference known straw placement sites, although the improvement to the calculations could be relatively small and within the existing uncertainty range.

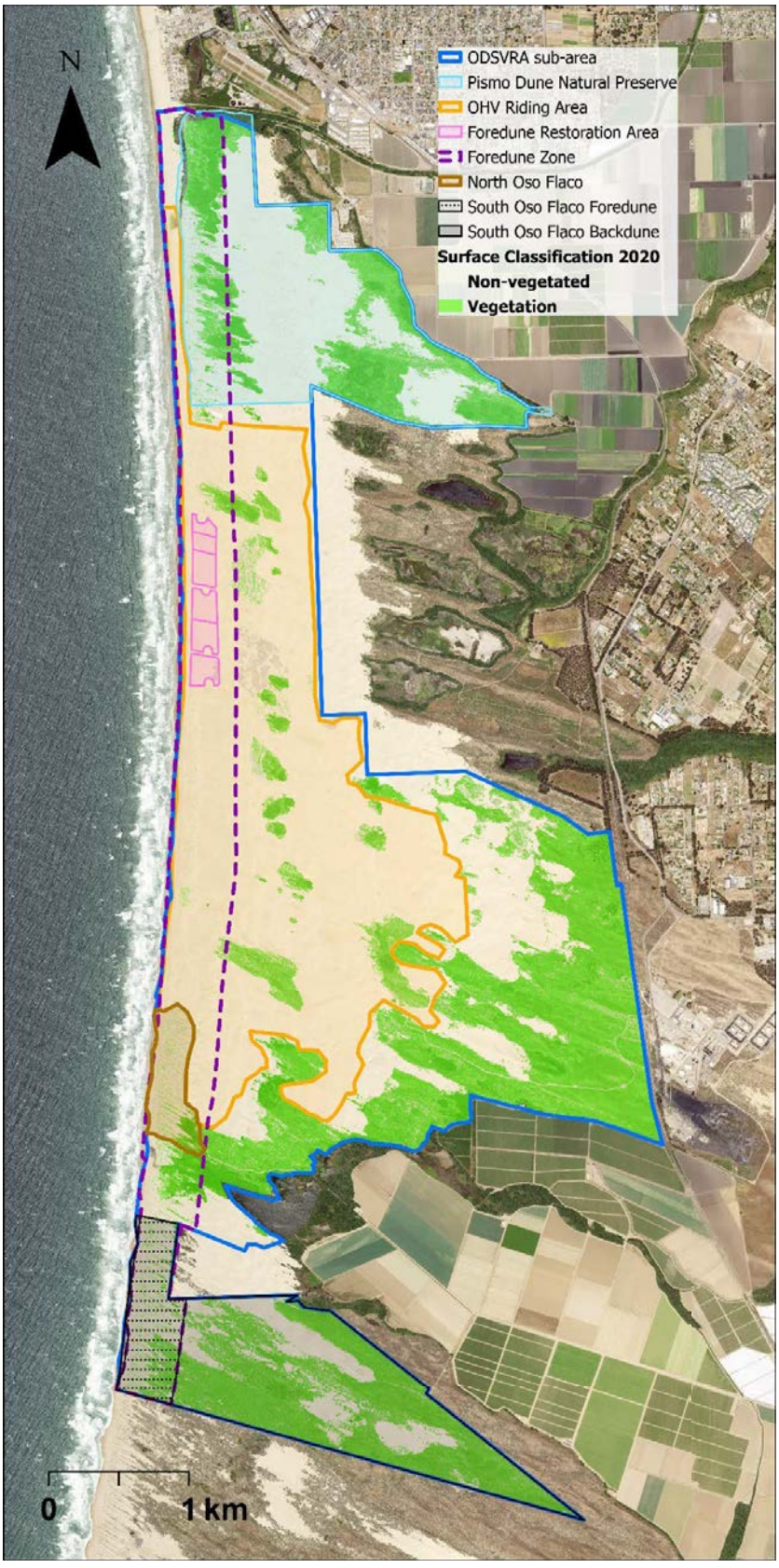


Figure 2: *Vegetation cover map in 2020, which does not identify straw cover (i.e., not classified as vegetation)(Swet et al., 2022). Underlying image is from NAIP 2020.*



Figure 3: *Vegetation cover (green) and straw cover (bright yellow) classified separately for 2024. Underlying image is from NAIP 2024.*

Table 2: *Calculated surface classification (land cover) values for vegetated, non-vegetated, and straw areas for the analytical zones in the ODSVRA sub-area, OHV riding area, South Oso Flaco, and North Oso Flaco. Foredune and backdune extents for each analytical zone were defined by the delineations shown in Figure 1, as defined by Swet et al. (2022). Percent cover values were reported relative to the total polygon area of each analytical zone. *calculations for 2020 were redone for the purposes of this report and vary slightly from the initial Swet et al. (2022) analysis as explained in the text. **2024 calculations classified straw cover separately from the non-vegetated surface cover. Straw was included as a non-vegetated surface in 2020 in the original analysis. This is an extension to Table 3 from Swet et al. (2022), see also Tables S2 and S3. Some rounding differences in acreages reported for 2020 exist due to the differences in the number of significant figures presented in the current report and in the Swet et al. (2022) report.*

		ODSVRA sub-area				OHV riding area				South Oso Flaco				North Oso Flaco		
		Vegetated		Non vegetated	Straw	Vegetated		Non vegetated	Straw	Vegetated		Non vegetated	Straw	Vegetated	Non vegetated	Straw
		Foredune	Backdune			Foredune	Backdune			Foredune	Backdune			Foredune		
2020	km^2	0.64	5.37	11.01		0.04	0.47	5.89		0.12	1.33	0.84		0.05	0.22	
	acres	158.15	1326.95	2720.62	-	9.88	116.14	1455.44	-	29.65	328.65	207.57	-	12.36	54.36	-
	%	3.74	31.58	64.68		0.67	7.40	91.93		5.27	58.05	36.68		19.05	80.95	
2020*	km^2	0.64	5.38	11.04		0.04	0.47	5.89		0.12	1.34	0.88		0.05	0.23	
	acres	158.15	1329.42	2728.03	-	9.88	116.14	1455.44	-	29.65	331.12	217.45	-	12.36	56.83	-
	%	3.74	31.54	64.72		0.68	7.39	91.93		5.16	57.15	37.69		18.88	81.12	
2024**	km^2	0.70	5.96	10.10	0.30	0.06	0.75	5.48	0.12	0.14	1.45	0.74	0.00	0.07	0.21	0.00
	acres	172.97	1472.74	2495.75	74.13	14.83	185.33	1354.13	29.65	34.59	358.30	182.86	0.04	17.30	51.89	0.01
	%	4.08	34.97	59.19	1.76	0.90	11.69	85.47	1.94	6.08	62.05	31.84	0.01	24.38	75.62	0.01

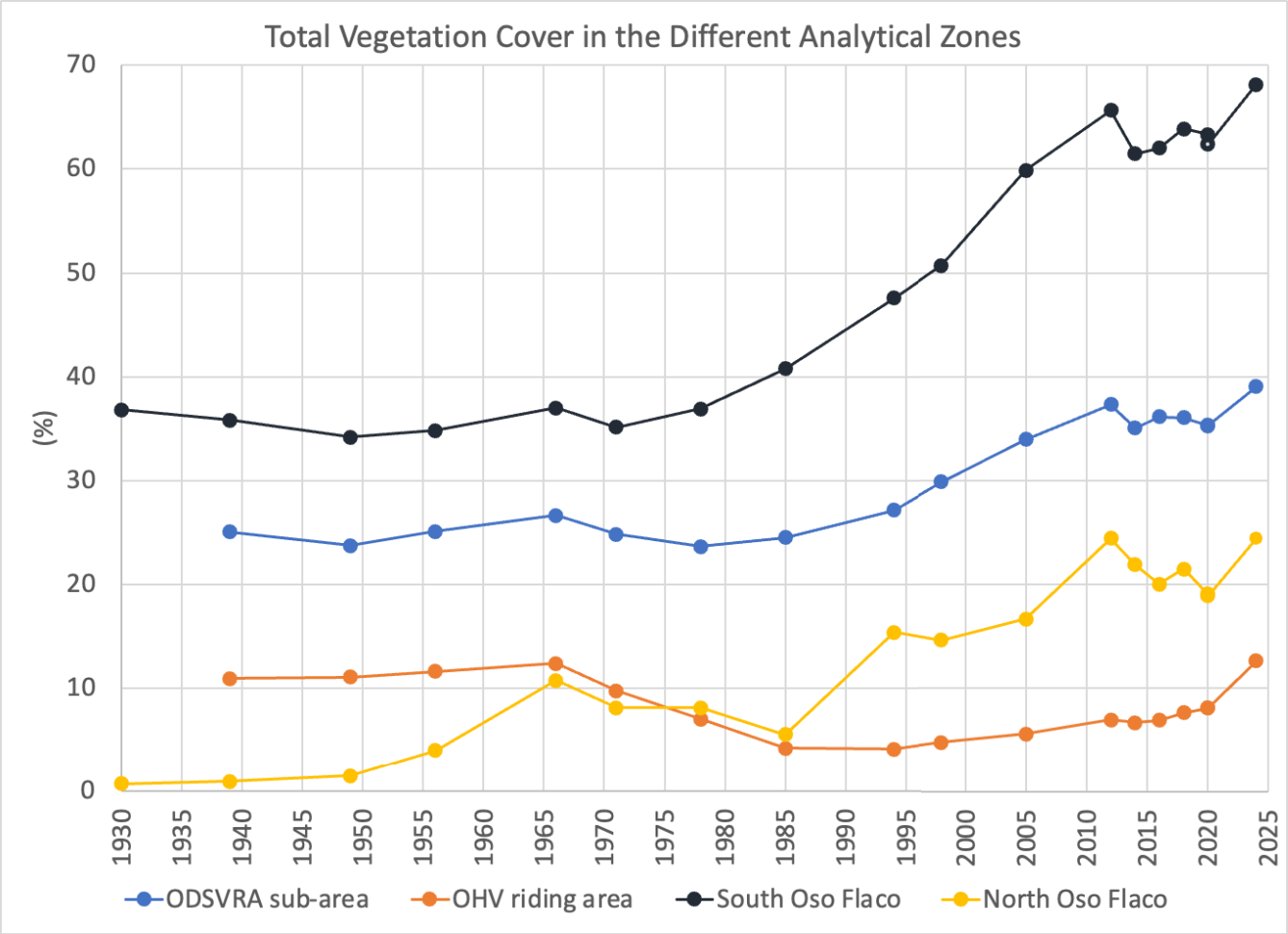


Figure 4: *Historical time series of total vegetation cover (foredune + backdune areas, Table 1) as a percentage (%) of the ODSVRA sub-area at large, the OHV riding area, South Oso Flaco area, and North Oso Flaco (foredune only). Historical data are from Swet et al. (2020) as in Table S1. Slightly differing results for 2020 presented in Table 1 are small for all but South Oso Flaco (see hollow circle symbol). Percent cover values are derived as a proportion of the respective areas of each analytical region. Updated version of Swet et al. (2022: Figure 4).*

3.2. Temporal Changes in Foredune Vegetation Cover

Generally, percent vegetation cover within the foredune zone of each of the analytical areas in the ODSVRA increased from 2020 to 2024 (Figure 5). In contrast to the trends for total vegetation cover for the broader analytical zones (Figure 4), which reached historic high coverage values by 2024, plant cover in the foredune zones has not reached historic highs, except at North Oso Flaco (Figure 5). Increases in foredune vegetation mainly occured in North and South Oso Flaco areas (5.49 and 4.92% increases since 2020, respectively), while increases within the broader ODSVRA area (1.5%) and the OHV riding area (0.7%) were much lower. Within the ODSVRA at large, foredune vegetation cover was higher in 2005 (0.07 km^2) and 2012 (0.08 km^2) compared to 2024 (0.06 km^2)(Figure 5). Although foredune vegetation in the OHV riding area has increased steadily since 1994, plant cover in 2024 (0.06 km^2) remains well below the historic high in 1966 (0.10 km^2). For comparison, vegetation cover trends for the FRA, which was an active riding area prior to implementation of the restoration treatments in February 2020, show

an increase from virtually no plant cover in 2020 (only 4.0 x 10^{-6} km^2) to 4.0 x 10^{-3} km^2 in 2024. This 2.17% increase now brings vegetation cover in the FRA above the historic high value of 2% at that specific site in 1949, which was just prior to notable increases in unsanctioned OHV activity within the Oceano Dunes. Further details on vegetation change dynamics in the FRA is provided in a separate report (Hilgendorf et al., 2025a).

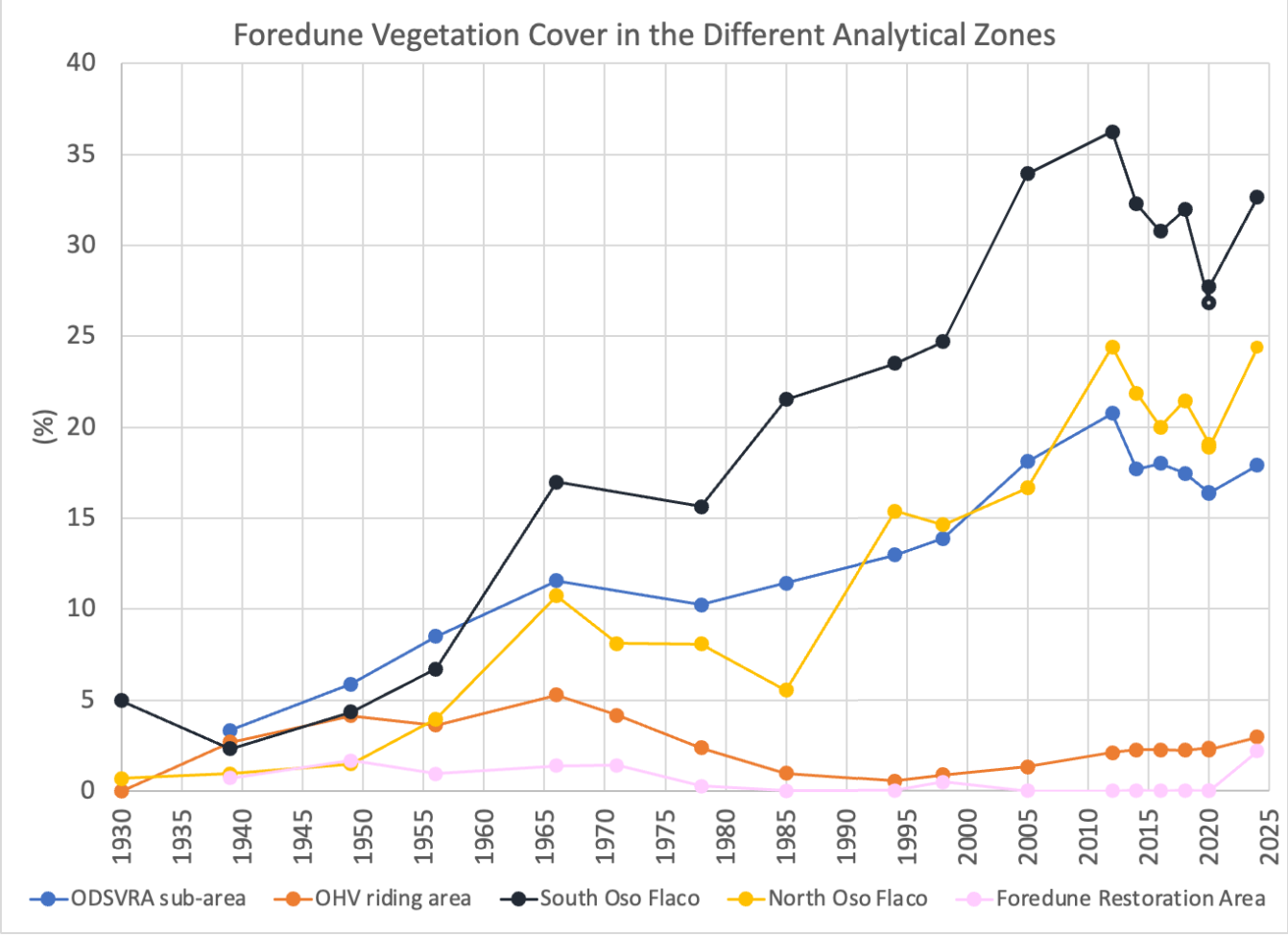


Figure 5: *Percent vegetation cover within the foredune zone of the ODSVRA sub-area, the OHV riding area, South Oso Flaco, and North Oso Flaco areas. Values are relative to the extent of the foredune zone within each analytical zone (Table 2, see Figure 1 for delineations). Historical values are from Swet et al. (2022)(see also Table S4). Vegetation cover within the FRA is shown for comparison, but reported in more detail by Hilgendorf et al. (2025a). The South Oso Flaco 2020 point calculated in this study (hollow circle point) is slightly lower than the value from Swet et al. (2022) as explained in the text.*

3.3. Spatial Patterns in Vegetation Cover Change between 2020 and 2024

The vegetation change detection map (Figure 6) shows that gains in plant cover by 2024 were largely associated with plant growth/expansion within existing restoration islands (e.g., BBQ Flats, Bigfoot, North Eucalyptus Tree, Eucalyptus Tree), along the western boundary at La Grille Hill, and on the windward/west side of Boyscout Camp. Vegetation losses were less extensive, more localized, and found mostly on windward/western edges of vegetation restoration islands, along the exposed sides of the

Pipeline site, on the downwind/eastern edges of migrating unvegetated transgressive dune lobes, and in other areas of invasive vegetation removal/restoration (e.g., Pavilion Hill, foredunes fronting the Pismo Dune Preserve north of the riding area, North and South Oso Flaco). Vegetation losses were also associated with creek migration and beach/bank erosion at Oso Flaco Creek and Arroyo Grande Creek near the south and north ends of the ODSVRA, respectively (Figure 6). New straw cover is evident in the southern area of Eucalyptus Tree and the 2024-VG01 site south of La Grille Hill. Given the early timing of the 2024 NAIP imagery (April 28, 2024), it is noted that this assessment does not capture any newer straw cover or plant growth responses since spring 2024. Locations of these efforts through July 2024 are documented by CDRP in the 2024 ARWP[6].

Swet et al. (2022: Figures 10-12) provided historical vegetation change maps and change rates for key intervals, including: 1939 to 1985 (leading up to establishment of ODSRVA in 1982), 1985 to 2012 (preceding the consent decree for Rule 1001 and related dust mitigation efforts), 2012 to 2020 (preceding the interval of analysis for this report). As far as recent changes following the SOA in 2018, and subsequent rates of change in plant cover (% yr^{-1}) with dust control measures implemented by CDPR, we compare our 2020 to 2024 results to those of the previous 2018 to 2020 interval from Swet et al. (2022). Figure 7 shows that both the ODSVRA sub-area and the OHV riding area maintained net positive vegetation cover and increasing rates of cover from 2018 to 2024. Meanwhile, both South and North Oso Flaco sites shifted from declining vegetation cover change rates from 2018 to 2020 to increasing plant cover change rates from 2020 to 2024 (Figure 7). Since 1930 there has been variability in net vegetation gain and loss rates in ODSVRA (Swet et al., 2022: Figure 6). However, around 2016, during early implementation of dust mitigation measures following Rule 1001 and the SOA in 2018, trends in these areas all showed declining vegetation cover rates, with net negative change at North and South Oso Flaco. Our results indicate a reversal of these negative change rates following recent (post-2020) vegetation restoration and dust mitigation efforts by CDPR.

4. Summary and Conclusions

Total vegetation cover (backdune + foredune zones) and foredune plant cover in each of the analytical zones within the ODSVRA have shown increases in percent cover and rates of change in recent years. By 2024, total percent vegetation cover reached historic high values in all analytical areas compared to estimates derived from historical aerial imagery dating back to the 1930s. Total vegetation cover ranged widely from 0.81 km^2 (12.59% cover) in the OHV riding area, 1.59 km^2 (68.15%) in South Oso Flaco, to 6.66 km^2 (39%) in the larger ODSVRA sub-area. Plant cover in the foredune zone ranged from 0.06 km^2 (0.9%) in the OHV riding area to 0.7 km^2 (4.08%) in the broader ODSVRA sub-area.

Generally, increases in vegetation cover from 2020 to 2024 was observed near the existing vegetation islands or formerly straw stabilized sites, and most gains occurred in backdune areas compared to foredune zones. Net vegetation losses were comparatively small and associated mostly with sand inundation on the windward/western edges of vegetation restoration sites, inland dune migration over existing vegetation, and localized creek erosion in the foredune zone.

[6] *See 2024 Oceano Dunes SVRA ARWP, Figure A01-01: Cumulative Dust Control as of 7/31/24.*

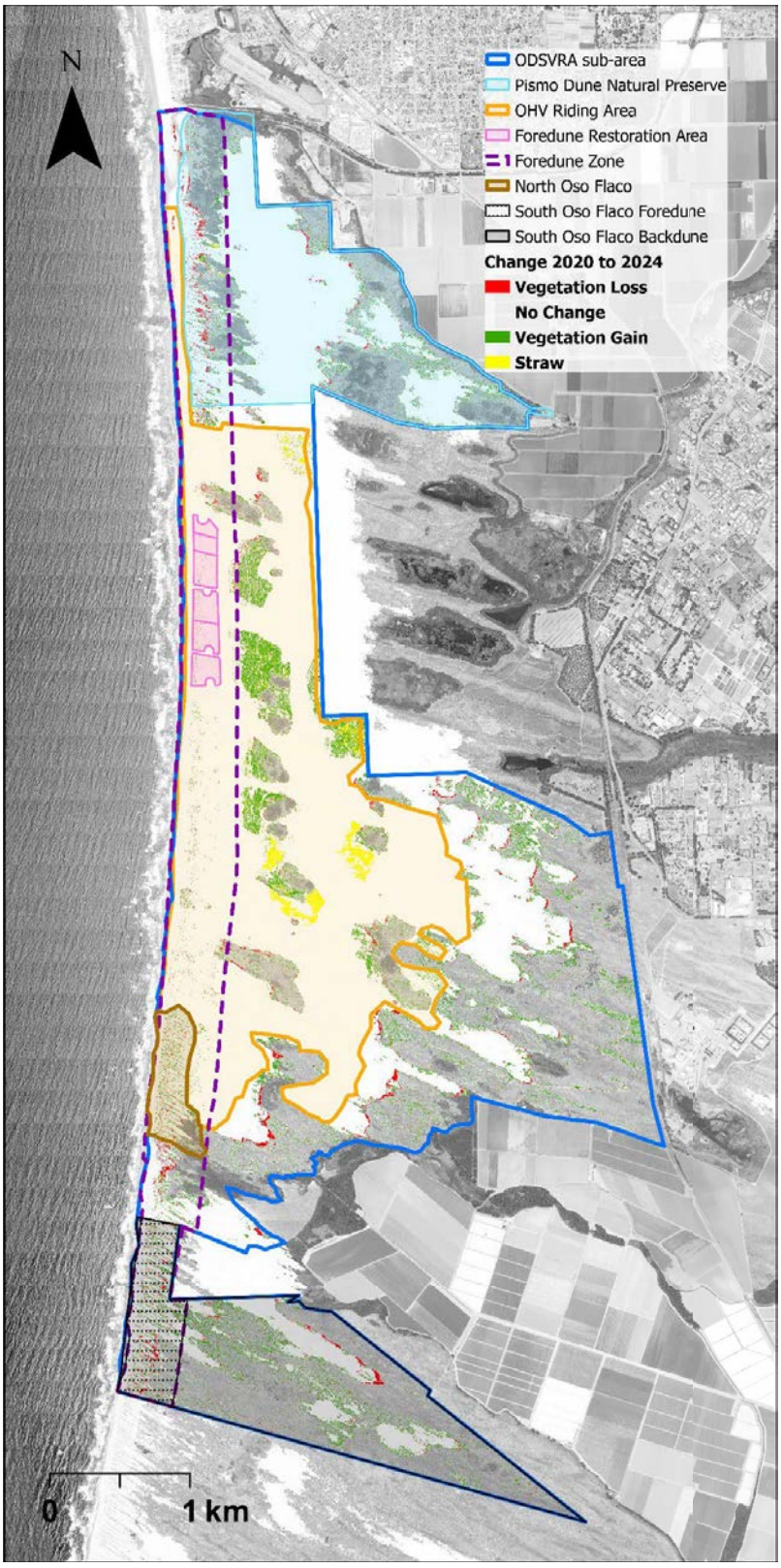


Figure 6: *Vegetation change map from 2020 to 2024. Red areas indicate vegetation loss and green locations show vegetation gain. Straw cover in 2024 is mapped in bright yellow. Underlying image is a greyscale of NAIP2024.*

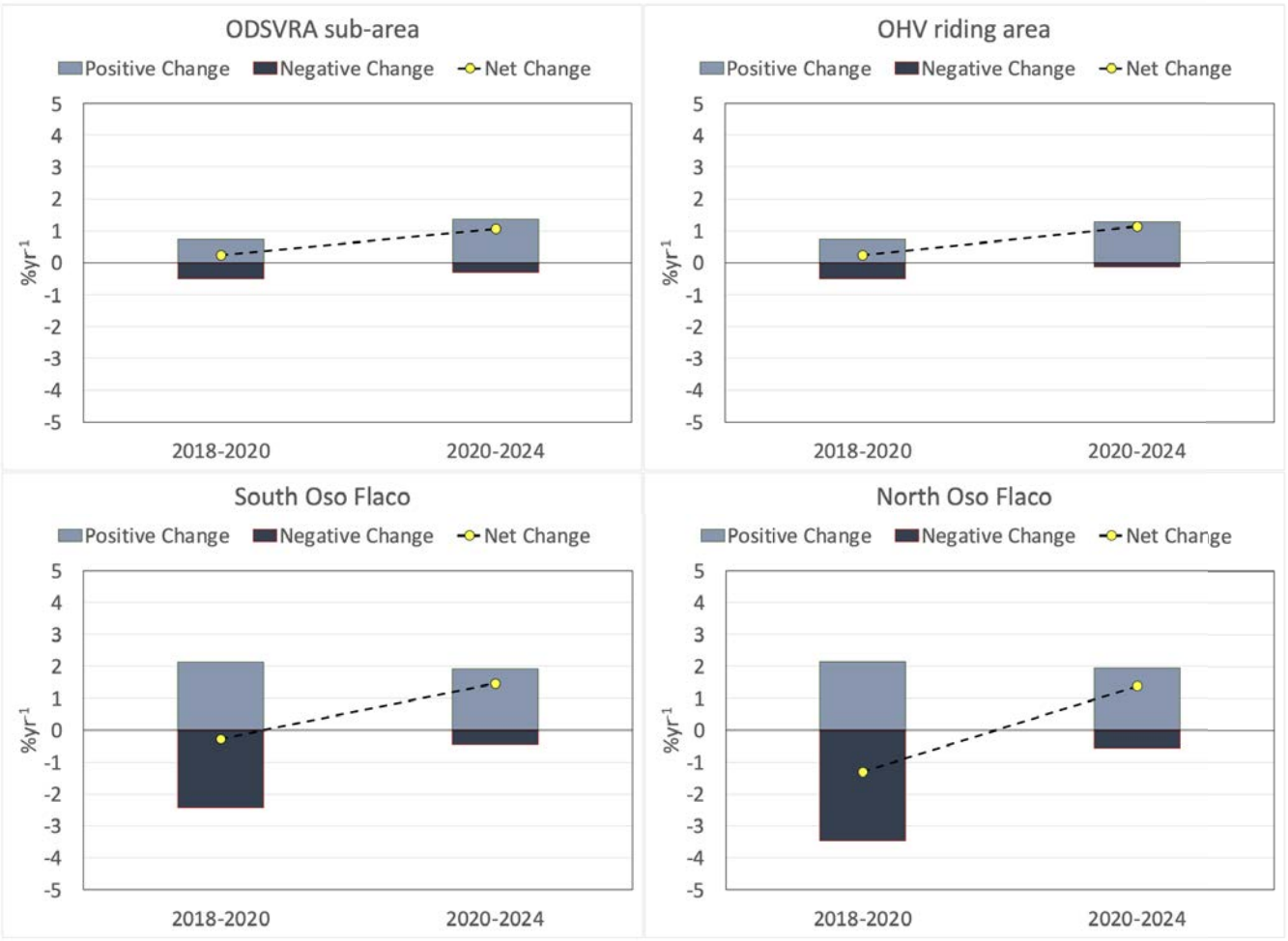


Figure 7: *Positive (green), negative (red), and net change (circles) in total vegetation cover from 2020-2024 (this study) and 2018-2020 (Swet et al., 2022: Figure 6)(see also Supplemental Table S5) expressed in % yr $^{-1}$ for each of the analytical zones relative to their total polygon area.*

The OHV riding area maintains the lowest total percent cover of vegetation in the ODSVRA due to continued recreation activities. However, vegetation cover maps for this recent interval show a notable increase of 0.33 km^2 of new vegetation in the riding area mainly around existing vegetation islands and in the FRA. These recent efforts by CDPR have increased plant cover in the riding area to a historic high (12.59%, 0.81 km^2), surpassing a previous peak in 1966 during a time of rapidly increasing OHV activity.

Widespread shifts from straw cover in 2020 to vegetation in restoration sites at BBQ Flats, Bigfoot, North Eucalyptus Tree, Eucalyptus Tree, La Grille Hill, and Boyscout Camp by 2024 suggests that straw placement continues to be effective at promoting vegetation establishment and restoration in this highly active dune landscape. Sand inundation and vegetation loss on the windward and lateral perimeters of these sites will require continued monitoring and adaptive management to maintain plant cover and hold restoration site footprints.

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6. Supplements

Surface classification results and associated calculations from 2020 and 2024 are provided. Some tabular data on historical vegetation percent cover in the total and foredune analytical areas are provided here but were originally calculated by Swet et al. (2022).

Table S1: *Total percent vegetation cover relative to the area of the polygon of the analytical zone (Table 1), including values from Swet et al. (2022). Asterisk (*) represents the 2020 values that were recalculated for this updated report.*

Total Vegetation Cover (%)					
Year	ODSVRA sub-area	OHV riding area	South Oso Flaco	North Oso Flaco	**Error**
1930	-	-	36.79	0.69	-
1939	25.05	10.92	35.80	0.95	3%
1949	23.75	11.07	34.16	1.49	-
1956	25.11	11.59	34.82	3.96	-
1966	26.63	12.36	37.00	10.72	-
1971	24.8	9.75	35.11	8.1	-
1978	23.66	7.02	36.92	8.09	0.5%
1985	24.49	4.21	40.76	5.54	-
1994	27.13	4.13	47.59	15.37	-
1998	29.85	4.74	50.71	14.62	-
2005	33.95	5.57	59.90	16.64	-
2012	37.31	6.91	65.66	24.41	-
2014	35.05	6.65	61.48	21.87	-
2016	36.15	6.89	62.02	20	-
2018	36.05	7.63	63.88	21.46	-
2020	35.32	8.07	63.32	19.05	3%
2020*	35.28	8.07	62.32	18.88	-
2024	39.05	12.59	68.15	24.38	-

Table S2: *Total vegetation cover classification results for 2020 and 2024 used to create Table 2. Values are relative to the total area of the polygon for each analytical zone as in Table 1.*

		ODSVRA sub-area	**OHV Riding Area**	**North Oso Flaco**	**South Oso Flaco**
Year	**Polygon Area (km^2)**	17.06	6.41	0.28	2.34
2020	Non-vegetated Area Relative to Polygon (km^2)	11.04	5.89	0.23	0.88
	Vegetated Area (km^2)	6.02	0.52	0.05	1.46
	Vegetation Area Relative to Polygon (%)	35.28	8.07	18.88	62.32
	Foredune Vegetation (km^2)	0.64	0.04	-	0.12
	Backdune Vegetation (km^2)	5.38	0.47	-	1.34
	Foredune Vegetation (%)	3.74	0.68	-	5.16
	Backdune Vegetation (%)	31.54	7.39	-	57.15
2024	Non-vegetated Area Relative to Polygon (km^2)	10.10	5.48	0.21	0.74
	Vegetated Area (km^2)	6.66	0.81	0.07	1.59
	Vegetation Area Relative to Polygon (%)	39.05	12.59	24.38	68.15
	Foredune Vegetation (km^2)	0.70	0.06	-	0.14
	Backdune Vegetation (km^2)	5.96	0.75	-	1.45
	Foredune Vegetation (%)	4.08	0.90	-	6.08
	Backdune Vegetation (%)	34.97	11.69	-	62.05
	Straw (km^2)	0.30	0.12	0.00	0.00
	Straw Area Relative to Polygon (%)	1.76	1.94	0.01	0.01
2024-2020	Difference in Vegetation Area (km^2)	0.64	0.29	0.02	0.14

Table S3: *Foredune vegetation cover classification results for 2020 and 2024 used to create Table 2. Values are relative to the total area of the foredune zone within each analytical zone polygon as in Table 1.*

		Foredune Zone (ODSVRA)	**Foredune OHV Riding Area**	**South Oso Flaco Foredune**	**Foredune Restoration Area**
Year	**Polygon Area (km^2)**	3.89	1.95	0.44	0.19
2020	Non-vegetated Area Relative to Polygon (km^2)	3.25	1.90	0.31	0.19
	Vegetated Area (km^2)	0.64	0.04	0.12	0.00
	Vegetation Area Relative to Polygon (%)	16.39	2.24	27.70	0.00
	Foredune Vegetation (km^2)	-	-	-	-
	Backdune Vegetation (km^2)	-	-	-	-
	Foredune Vegetation (%)	-	-	-	-
	Backdune Vegetation (%)	-	-	-	-
2024	Non-vegetated Area Relative to Polygon (km^2)	3.19	1.89	0.29	0.19
	Vegetated Area (km^2)	0.70	0.06	0.14	0.00
	Vegetation Area Relative to Polygon (%)	17.89	2.95	32.62	2.17
	Foredune Vegetation (km^2)	-	-	-	-
	Backdune Vegetation (km^2)	-	-	-	-

	Foredune Vegetation (%)	-	-	-	-
	Backdune Vegetation (%)	-	-	-	-
	Straw (km^2)	0.00	0.00	0.00	-
	Straw Area Relative to Polygon (%)	0.09	0.01	0.00	-
2024-2020	Difference in Vegetation Area (km^2)	0.06	0.01	0.02	-

Table S4: *Foredune vegetation cover relative to the foredune zone portion of the total analytical zone (Table 1), including values from Swet et al. (2022). Asterisk (*) represents the 2020 values that were recalculated for this updated report.*

Foredune Vegetation Cover (%)					
Year	**ODSVRA sub-area**	**OHV riding area**	**South Oso Flaco**	**North Oso Flaco**	**Foredune Restoration Area**
1930	-	-	4.96	0.69	-
1939	3.33	2.68	2.32	0.95	0.71
1949	5.88	4.13	4.34	1.49	1.67
1956	8.49	3.61	6.71	3.96	0.96
1966	11.56	5.27	16.99	10.72	1.38
1971	-	4.16	-	8.1	1.42
1978	10.24	2.38	15.63	8.09	0.28
1985	11.44	0.97	21.52	5.54	0.01
1994	12.97	0.54	23.51	15.37	0.01

1998	13.86	0.88	24.70	14.62	0.47
2005	18.1	1.3	33.92	16.64	0
2012	20.76	2.09	36.24	24.41	0
2014	17.69	2.24	32.27	21.87	0.01
2016	17.99	2.24	30.76	20	0
2018	17.46	2.21	31.95	21.46	0.01
2020	16.36	2.35	26.83	19.05	0.00
2020*	16.39	2.24	27.70	18.88	0
2024	17.89	2.95	32.62	24.38	2.17
Difference (2024-2020)*	1.50	0.71	4.92	5.49	2.17

Table S5: *Surface change results from 2020 to 2024.*

2020 to 2024	**ODSVRA sub-area**	**OHV Riding Area**	**South Oso Flaco**	**North Oso Flaco**
Vegetation Gain (km^2)	0.93	0.33	0.18	0.02
Vegetation Loss (km^2)	0.21	0.04	0.04	0.01
No Change (km^2)	15.67	5.92	2.11	0.25
Vegetation Gain (%)	5.48	5.10	7.66	7.74
Vegetation Loss (%)	1.22	0.55	1.81	2.24
Net Change (km^2)	0.73	0.29	0.02	0.14
Net Change (%)	**4.26**	**4.55**	**5.85**	**5.51**

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June 26, 2025

Memo: SAG Review of UCSB Report - "Recent (2020-2024) Changes in Vegetation Cover within the Oceano Dunes SVRA"

From: Scientific Advisory Group[1]

To: Jon O'Brien, California Department of Parks and Recreation

Cc: Ronnie Glick, California Department of Parks and Recreation

The Scientific Advisory Group (SAG) received a copy of the University of California, Santa Barbara (UCSB) report *"**Recent (2020-2024) Changes in Vegetation Cover within the Oceano Dunes SVRA**"* on June 10, 2025. SAG members have had the opportunity to review the document and this memo provides feedback on the UCSB report. Additional comments and editorial suggestions can be found in the PDF included with this memo.

This UCSB report provides an update to vegetation cover change analyses from previous studies. The objective of the report was to map and quantify changes in vegetation cover, specifically for 2020–2024, using aerial photography to extend the analysis (1930–2020) of vegetation changes from previous studies.[2] The report suggests that in recent years total vegetation cover (foredune and backdune zones) and foredune plant cover in each of the analytical zones increased in percent cover and rates of change in all analytical zones in the OSDVRA, reaching their highest levels in 2024 relative to the past 95 years. Between 2020–2024 increased vegetation cover occurred near existing vegetation islands, with most gains in the backdune zones. Vegetation losses were small and due to sand inundation, inland dune migration on existing vegetation, and local erosion in the foredune zone. The analysis is thorough and the report well-written. However, SAG members raised concerns regarding the zonation used in this report. Specifically, the zones used were based on previous studies and do not align well with those used in the DRI model, making it challenging to interpret results within the context of the current management zones. The SAG recommends that UCSB consider rezoning for future reports while also maintaining the original zones during a transition year (or perhaps recalculating percentages for the new zones for the full period, 2020-2024.

Respectfully,

The Scientific Advisory Group

Bernard Bauer (Chair), Jack Gillies, Jenny Hand, Leah Mathews

[1] SAG member Dr. Ian Walker recused himself from SAG review of this document due to potential conflict of interest.

[2] Swet, N. Hilgendorf, Z., and Walker, I.J., 2022. UCSB Historical Vegetation Cover Change Analysis (1930-2020) within the Oceano Dunes SVRA. Report prepared for CDPR for the 2022 ARWP. 86 p.

Summary of Comments on Recent 2020 - 2024 changes in veg cover within ODSVRA report-DRAFT-6-9-25 - Google Docs

Page: 2

Number: 1 Author: SAG Date: 6/23/2025 11:57:52 AM

This is not a zone that is generally recognized in the mapping of the ODSVRA.

What about the Plover Exclosure?

Number: 2 Author: SAG Date: 6/23/2025 11:58:05 AM

Define acronyms at first use. Maybe include a list prior to the executive summary

Number: 3 Author: SAG Date: 6/23/2025 11:58:14 AM

It strikes me as odd that there is any vegetation in the riding area, unless fenced off as veg islands.

Number: 4 Author: SAG Date: 6/23/2025 11:58:28 AM

What is the ODSVRA "sub-area" given that the ODSVRA is the entire area of the park?

Number: 5 Author: SAG Date: 6/23/2025 11:58:44 AM

Once again, I'm a bit confused about the terminology used here to identify areas/zones. I'll read on to see how the riding area was classified for this report, but hopefully it is the same zonation used by CDPR and in the DRI model.

Number: 1 Author: SAG Date: 6/23/2025 11:58:57 AM
Is this value correct or a typo? An error of less than a mm sounds too good to be true.

Page: 7

Number: 1 Author: SAG Date: 6/23/2025 12:18:23 PM
add ", respectively"

Number: 2 Author: SAG Date: 6/23/2025 12:18:34 PM
between 2020 and 2024

Number: 3 Author: SAG Date: 6/23/2025 12:18:46 PM
I would recommend some further detail added about this area. While it is within the "OHV Riding Area" zone as outlined in this report, there has been no riding here since 2020, and it makes up an important percentage of the riding area zone as outlined in this report.

Number: 4 Author: SAG Date: 6/23/2025 12:19:06 PM
A bit misleading. The last new projects leading to acreage reductions were in 2022, so 2023 and 2024 were mostly about maintenance (with no net increase in acres planted)

Number: 5 Author: SAG Date: 6/23/2025 12:19:21 PM
Could be rephrased...plant cover percentage doesn't care what kind of plants, so the increasing trend can't be 'confounded' by invasive grasses. You may think that invasive grasses are less desirable from an ecosystem perspective, but they often provide very efficient surface cover.

Number: 6 Author: SAG Date: 6/23/2025 12:19:39 PM
Figure 3??

Number: 1 Author: SAG Date: 6/23/2025 12:19:49 PM
straw and south oso flaco are both grey

Page: 10

Number: 1 Author: SAG Date: 6/23/2025 12:20:00 PM

the number of significant figures for some the entries in this table are inconsistent.

Number: 2 Author: SAG Date: 6/23/2025 12:20:10 PM

Small font...tough to read. Same comment for the table. Please reformat.

Page: 12

Number: 1 Author: SAG Date: 6/23/2025 12:20:21 PM

This is a bit of a mish-mash of units (m2 vs km2) and percentages (i.e., increases vs absolute percents).

Number: 2 Author: SAG Date: 6/23/2025 12:20:31 PM

I appreciate that the zonation used in this report follows that of Swet et al., but I really think this is problematic at this stage. According to Figure 5, the percent veg cover in the foredune zone is greater for the OHV riding area than for the FRA. This is extraordinary given that the FRA was planted and fenced off from OHV access. And yet, there is MORE veg in the riding area. The only way this makes any sense is if the Plover Exclosure is lumped in with the riding area, and we know that there has been no riding in the PE for several years now. It also suggests that plant recovery in the PE is actually more effective than in the FRA (despite all the treatments).

Perhaps I have this wrong, but the results shown in Figure 5 are very counter-intuitive. Why not use the zones that were established for the DRI model, and forget about the Swet et al zones? Or present both, for continuity with the old way.

Page: 13

Number: 1 Author: SAG Date: 6/23/2025 12:20:56 PM

confusing...how can you have negative vegetation cover? If you mean negative cover change, then how is this different from negative loss rates?

Number: 2 Author: SAG Date: 6/23/2025 12:21:13 PM

I see the trends in Figure 5, but I'm surprised that the CDPR vegetation planting efforts since 2013 have yielded negative vegetation cover trends until just recently. How can we explain the declines in 2017-2020 when some 700 acres were replanted?

Or is it more complex than this. The veg cover in the Oso Flacos decreased (due to natural causes), and the planting efforts by CDPR prevented similar losses in the other sections of the ODSVRA.

It is hard to know what is going on given that the zones used by Swet et al don't align very well with the DRI model (and management zones). Maybe it's too late this year, but a re-think of appropriate analysis zones might be in order.

Page: 15

Number: 1 Author: SAG Date: 6/23/2025 12:21:27 PM

consider using colors other than red/green- can be hard to distinguish for color blind.

Number: 2 Author: SAG Date: 6/23/2025 12:21:36 PM

where are the circles?

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ODSVRA Dust Control Program Draft 2025 ARWP

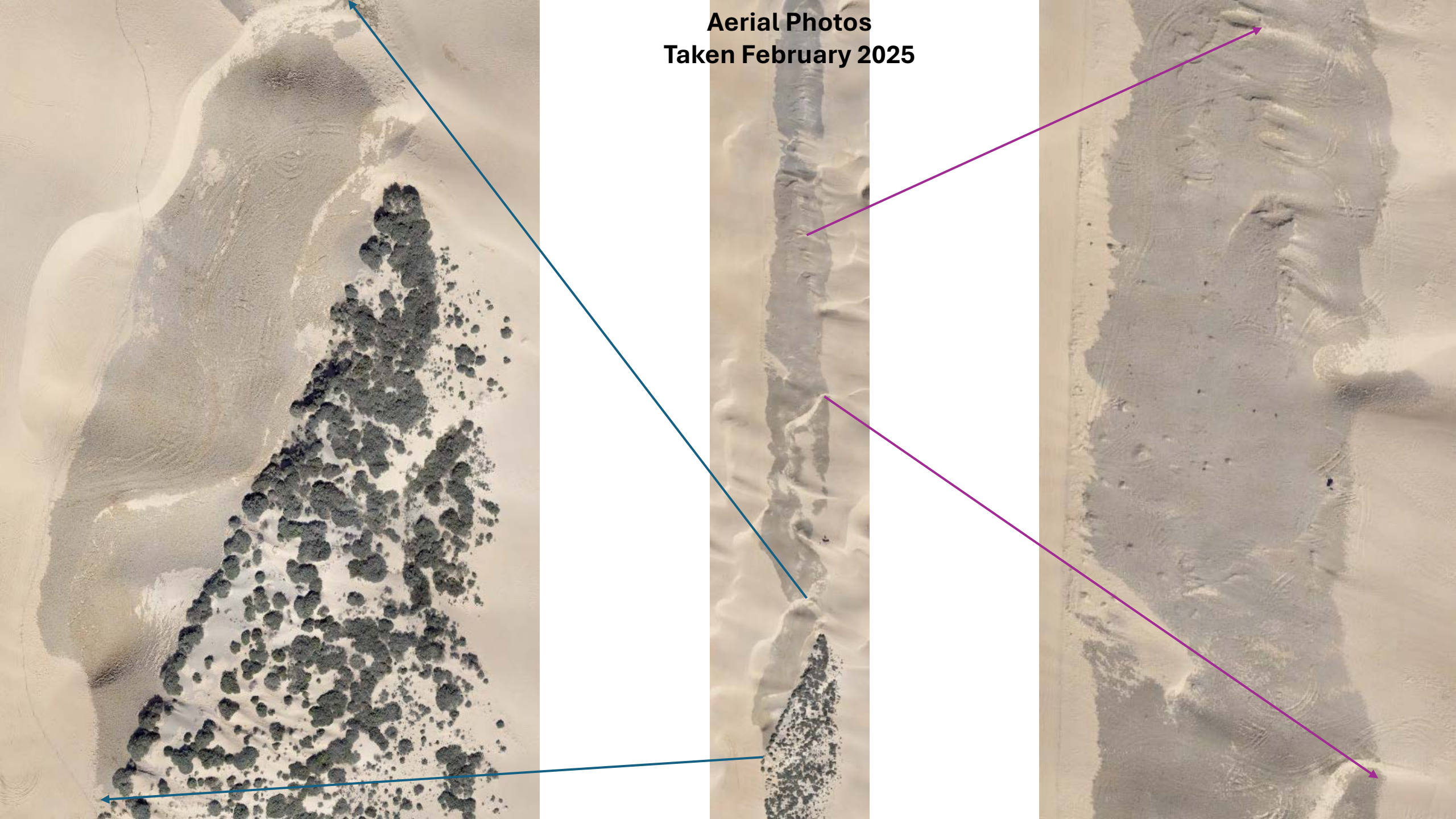
ATTACHMENT 10

Ground Cover Information for Dust Control Projects 2022-VG-01 and 2022-VG-02 (State Parks ARWP Work Product)

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Ground Cover Imagery for 2022-VG-01 and 2022-VG-02

Aerial Photos
Taken February 2025




Facing North
Drone Photos
Taken September 9, 2025
Facing South

Ground Photos
Taken September 8, 2025













ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 11

Modeling to Determine the Condition of Excess Emissions for 2025 ODSVRA (DRI Documents)

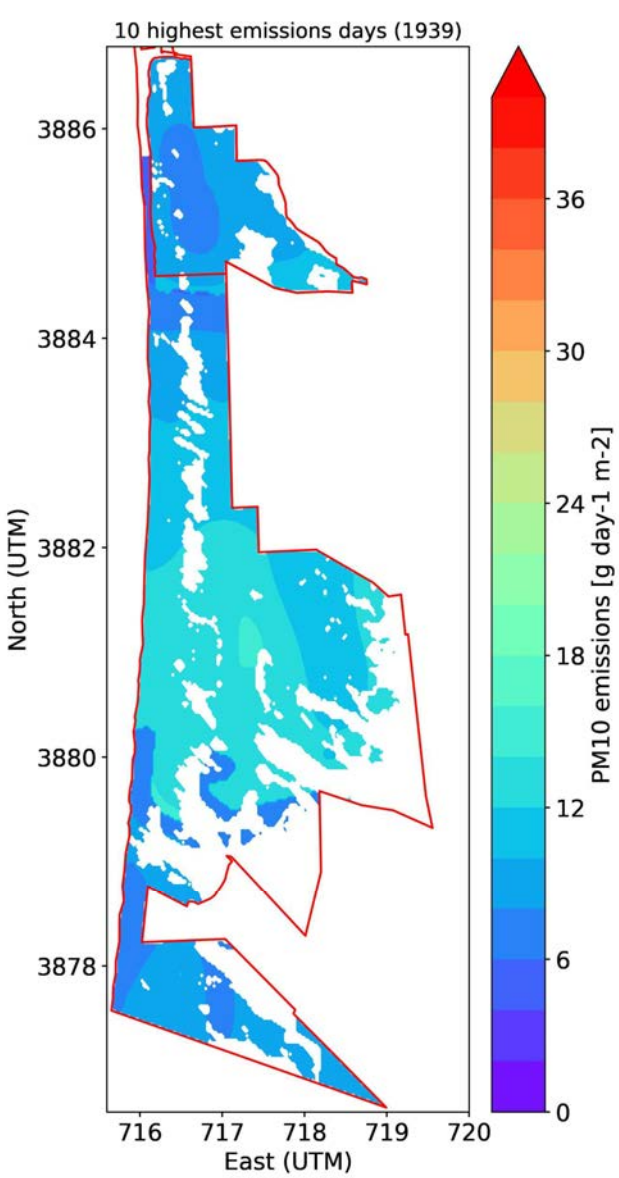
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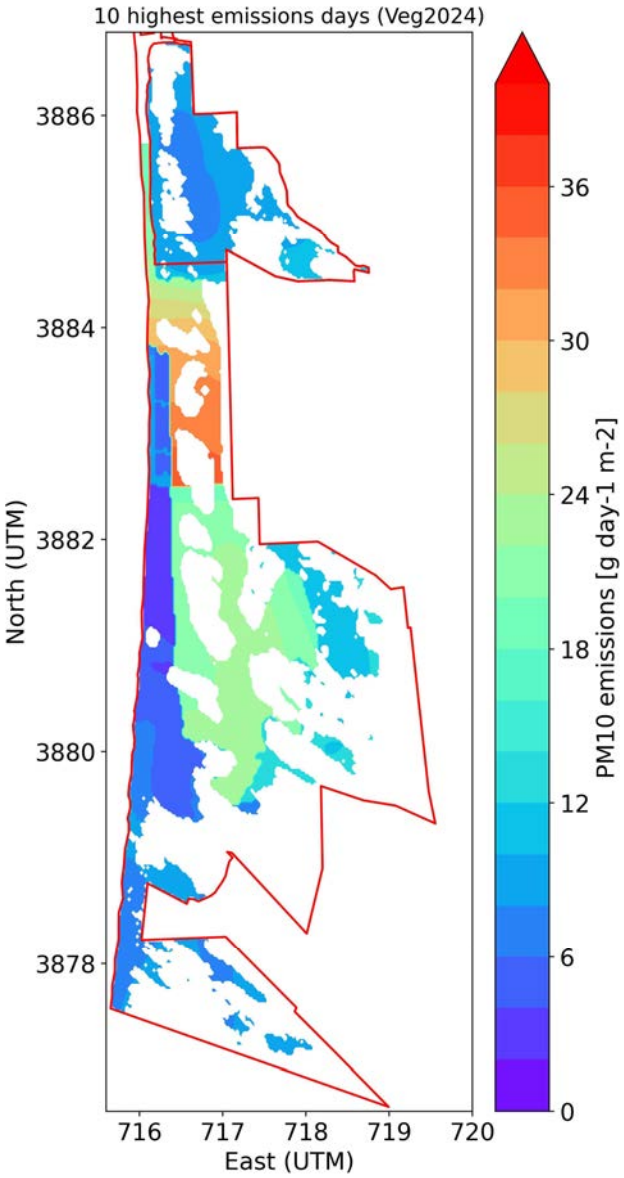
Emissions by zone [Metric Tons/day]	Area of contributing grid points	All		ORA	
		10 highest	22-May	10 highest	22-May
Non Riding Area Central	1922.2	91.4	136.6	67.6	99.6
Non Riding Area North	617.9	21.9	24.6	0.0	0.0
Non Riding Area South	660.1	22.0	36.0	0.0	0.0
Total	3200.2	135.2	197.2	67.7	99.6

Vegetation June 30, 2025

Emissions by zone [Metric Tons/day]	Area of contributing grid points	All		ORA	
		10 highest	22-May	10 highest	22-May
Foredune Restoration Area	49.1	0.9	1.3	0.9	1.3
Non Riding Area Central	243.7	11.7	18.4	0.2	0.3
Non Riding Area North	442.3	15.5	17.4	0.0	0.0
Non Riding Area South	330.5	10.6	17.3	0.0	0.0
Plover Exclosure	304.7	5.0	7.3	4.7	6.8
Riding Area Central-North	250.2	29.3	36.5	29.1	36.2
Riding Area Central-South	547.2	48.1	67.0	48.1	66.9
Seasonal Exclosure	33.7	1.2	1.6	1.2	1.5
Vegetation Islands	120.3	0.0	0.0	0.0	0.0
Revegetation	159.8	0.0	0.0	0.0	0.0
Total	2481.6	122.5	166.7	84.3	113.2

Emissions by Zone [Metric Tons/day]	Area of Contributing Grid Points	10 highest Emission Days
Foredune Restoration Area	49.1	0.9
Non Riding Area Central	243.7	11.7
Non Riding Area North	442.3	15.5
Non Riding Area South	330.5	10.6
Plover Exclosure	304.7	5.0
Riding Area Central-North	250.2	29.3
Riding Area Central-South	547.2	48.1
Seasonal Exclosure	33.7	1.2
Vegetation Islands	120.3	0.0
Revegetation	159.8	0.0
Total	2481.6	122.5





APCD Supplemental Modeling Scenario

Run 2

PE (area=304.71) represented by Central NRA emissivity (a=35.232, b=8.687)

FRA (area=49.1) represented by Central NRA (a=35.232, b=8.687)

Seasonal Exclosure (beach in front and corridors in FRA) represented by Central NRA (a=35.232, b=8.687, area=33.67)

Two new polygons: VG-2022-VG-01 and 2022-VG02 at zero emissions if veg is >50% [polygons to be supplied by Tamar]

ODSVRA Emissivity Zone	Area of contributing grid points (acres)	Emission in Metric Tons per Day (10 highest days, 2013)
Foredune Restoration Area	49.11	2.01
Non Riding Area Central	243.71	11.75
Non Riding Area North	442.32	15.54
Non Riding Area South	346.41	10.64
Plover Exclosure	304.71	15.74
Riding Area Central-North	250.19	29.3
Riding Area Central-South	547.18	48.1
Seasonal Exclosure	33.67	1.4
Vegetation Islands	120.31	0.00
Revegetation	159.85	0.00
Total	2497.5	134.48

ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 12

2025 PMRP Evaluation Metrics

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PMRP Evaluation Metrics – Annual Record 2024-25

In 2021, the SAG, in consultation with State Parks, updated the PMRP evaluation metrics used to track dust control progress. The updated metrics provide a more streamlined dashboard that make it easier to track progress and to inform adaptative management. “Dust Mitigation Targets” refer to evaluation metrics with specific measurable endpoints. “Dust Mitigation Indicators” refer to values indicating progress but for which specific targets are not defined.

In 2022, the SOA amendments updated the metric for evaluating dust control progress, establishing a new excess emissions framework.

In October 2024, the SOA amendments extended the term of the SOA through December 2028, but did not materially change ARWP content or information requirements.

This attachment reports only on metrics both from the October 2022 and October 2024 amendments to the SOA (for the excess emissions framework, see Table 2).

Evaluation Metric table notes are provided at the end of this document.

DUST MITIGATION TARGETS TABLE 1: DUST CONTROL ACREAGE									
Dust mitigation treatments		**2013 baseline**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025[1]**
A. Cumulative area under treatment within ODSVRA, as of July 31 of current year, relative to 2013 baseline (acres)	A1. Total	0	137.8	230.2	322.5	740.1	740.1	740.1	740.1
	A2. Back dunes inside riding area	0	103.1	195.5	213.2	288.3	288.3	288.3	288.3
	A3. Back dunes outside riding area	4.7	34.7	34.7	61.3	75.9	75.9	75.9	75.9
	A4. Foredunes	0	0.0	48.0	48.0	48.0	48.0	48.0	48.0
	A5. Nesting exclosure	0	0.0	0.0	0.0	293.3	293.3	293.3	293.3
	A6. Foredune beach and corridor	0	0.0	0.0	0.0	34.6	34.6	34.6	34.6

DUST MITIGATION TARGETS TABLE 2: EXCESS EMISSIONS FRAMEWORK								
PM_{10} mass emissions		**2019**	**2020**	**2021**	**2022**	**2023**	**2024[2]**	**2025[3]**
A. Mean PM_{10} emissions in all zones for 10 highest emission days – modeled (metric tons)	1939 Pre-disturbance scenario	N/A					166	135
	Current scenario	N/A					148	123

EVALUATION METRICS TABLE 3: DUST MITIGATION INDICATORS									
Air quality indicators		**2013 baseline**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
1. Actual number of high wind event days[4]		59	30	55	51	64	72	51	71
2. Actual number of exceedances of California air quality standard[5]	2a. at CDF	58	12	30	54	54	16	13	22
	2b. at Mesa2	43	14	28	38	38	11	11	16
3. Actual number of exceedances of Federal air quality standard[6]	3a. at CDF	1	0	0	0	0	0	0	0
	3b. at Mesa2	0	0	0	0	0	0	0	0
Foredune restoration		**2013 baseline**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
4. Foredune plant fractional cover, at time of spring survey (%)	4a. Treatment 1	N/A	N/A	N/A	0	0	0	0	0.6
	4b. Treatment 2				0.1	1.9	2.7	3.1	3.6
	4c. Treatment 3				4.0	12.3	10.1	6.7	14.0
	4d. Treatment 4				0.8	5.7	5.1	7.9	6.0
	4e. Treatment 5				0.4	2.1	6.4	11.3	5.3
	4f. Treatment 6				3.6	12.7	13.8	17.8	15.0
5. Foredune species richness index relative to Oso Flaco site (10 species in 2021)[7]	5a. Treatment 1	N/A	N/A	N/A	0	0	20	80	40
	5b. Treatment 2				33	40	30	50	30
	5c. Treatment 3				50	50	40	70	50
	5d. Treatment 4				100	60	70	100	90
	5e. Treatment 5				110	100	90	90	100
	5f. Treatment 6				110	80	100	100	100
6. Foredune sand volume, current spring survey relative to previous fall survey (m^3 m^{-2} mo^{-1})[8]	6a. Treatment 1	N/A	N/A	N/A	0.4	0.8	-0.7	0.0	1.0
	6b. Treatment 2				0.5	0.8	0.6	0.0	0.8
	6c. Treatment 3				0.6	0.7	1.0	0.0	0.3
	6d. Treatment 4				0.2	0.4	0.8	0.1	0.7
	6e. Treatment 5				0.1	0.3	0.8	0.1	0.7
	6f. Treatment 6				0.0	0.4	0.8	0.1	0.3

Back dune stabilization		**2013 baseline**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
7. Cumulative area of back dune stabilization within ODSVRA, as of July 31 of current year (acres)	7a. Planting area	TBD[9]	89.2	109.6	168.5	287.1	314.4	351.9	364.2
	7b. Fencing area	0	48.6	53.7	72.8	53.0	32.5	0	0
	7c. Straw bales area	0	0	18.9	27.3	24.1	17.3	12.3	0
	7d. Temporary vehicle exclusion areas	0	0	0	5.9	0.0	0.0	0	0
	7e. Stabilized vegetation surface area	TBD[10]	137.8	182.2	274.5	364.2	364.2	364.2	364.2
8. Native seed harvest for all plants during current ARWP reporting period (kilograms/year)		N/A	203.2	307.3	193.0	252.6	234.5	241.9	224.7
9. Plant species cultivation for all plants during current ARWP reporting period (#/year)			106,350	89,433	127,464	125,380	121,724	116,112	121,013

EVALUATION METRIC TABLE NOTES

[1] 2025 dust mitigation treatment acreage values are based on State Parks 2025 ARWP, Chapter 3, and are subject to change.

[2] Pre-disturbance and current scenario emissions under the excess emissions modeling are from 2024 ARWP Table 2-9.

[3] Pre-disturbance and current scenario emissions under the excess emissions modeling are from 2025 ARWP Table 2-9.

[4] Values are determined using the ARWP definition of "high wind event day", defined, in consultation with the SAG, as any day when the 3 p.m. PST hourly wind speed at CDF exceeds 8 mph and the 1 p.m. PST hourly wind direction is between 290 and 360°. The period of consideration is January 1 - July 31, 2025. Data may be preliminary and subject to change. The ARWP definition of high wind event days may differ from the SLOAPCD's definition used in SLOACPD reports and studies.

[5] The California Ambient Air Quality Standard is a mean value of 50 $\mu g/m^3$ over a 24-hour period. The period of consideration is January 1 – July 31, 2025. Data may be preliminary and subject to change.

[6] The National Ambient Air Quality Standard is a mean value of 150 $\mu g/m^3$ over a 24-hour period. The period of consideration is January 1 – July 31, 2025. Data may be preliminary and subject to change.

[7] The number of native plant species recorded for each treatment area as compared to reference site at Oso Flaco (10 species in 2021). Long term goal is to have a stable or increasing richness value versus reference site.

[8] 2021 – 2023 normalized volumetric change by total area per month obtained from 2024 ARWP Table 2-3. Values represent the change between spring (February UAS survey) of the column year and fall (October UAS survey) of the previous year. For example, the estimate of foredune sand volume for 2022 for treatment 2 (0.008 $m^3\ m^{-2}\ mo^{-1}$) is based on Table 2-3 column "Oct. 2021 – Feb. 2022".

[9] The baseline 2013 back dune stabilization "planting area" metric may be estimated from UCSB's historic vegetation report; however, the SAG has not established the methodology for establishing baseline vegetation conditions. State Parks will coordinate with the SAG to finalize the methodology for determining baseline 2013 back dune stabilization planting areas. Currently, the yearly estimates of planting area for the Dust Control Program (e.g., 89.2 acres in 2019) are based on the amount of back dune vegetation planted under the Dust Control Program (i.e., excludes foredune vegetation and non-vegetation projects such as wind fencing).

[10] The baseline 2013 back dune "stabilized vegetation surface area" metric may be estimated from vegetation coverage estimates determined from aerial imagery; however, the SAG has not established the methodology for establishing baseline vegetation conditions. State Parks will coordinate with the SAG to finalize the methodology for determining baseline 2013 back dune stabilization planting areas. Currently, the yearly estimates of stabilized vegetation surface area for the Dust Control Program (e.g., 137.8 acres in 2019) reflect the sum of the stabilization approaches in metrics 7a to 7d.

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ODSVRA Dust Control Program Draft 2025 ARWP

ATTACHMENT 13

2025/2026 ODSVRA Dust Control Program Vegetation Restoration Projects

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2025-2026 Project List (subject to change)							
Project Name	**Project Acreage**	**Total Plants**	**Plants Per Acre**	**Native Seed (lbs)**	**Native Seed (lbs/Acre)**	**Sterile Grain Seed (lbs)**	**Large Straw Bales (3X4X8 ft)**
Supplemental Planting Areas							
Lagrille Hill (south) 2022-VG-07	22.7	61,801	2,723	272	12.0	454	272
Area 10 2021-VG-05	10.3	28,354	2,753	125	12.1	206	123
Area 11 2021-VG-06	4.2	11,625	2,768	51	12.1	84	51
North Boyscout Camp 2024-VG-01	3.8	10,980	2,889	46	12.1	76	46
Lagrille Hill 2022-VG-03	0.9	2,545	2,860	11	12.4	18	11
Area 3 2021-VG-02	0.7	1,786	2,748	8	12.3	13	8
Total	**42.5**	**117,091**	**2,752**	**513**	**12.1**	**851**	**511**

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