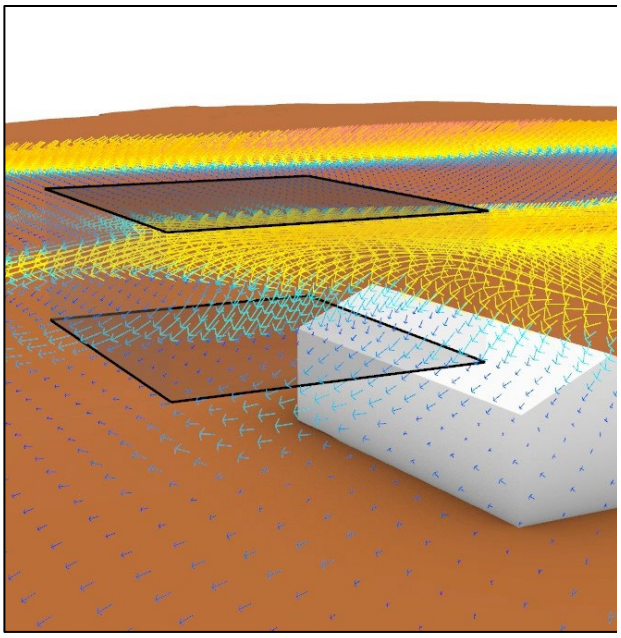
Moran Lake Monarch Butterfly Habitat and Tree Management Assessment
April 2025 DRAFT



Wind Model Output

Monarchs at Moran Lake

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April 2025

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Santa Cruz County Parks

CREEKSIDE SCIENCE

ALTHOUSE AND MEADE, INC.

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Moran Lake monarchs clustering Creekside area November 2022

Executive Summary

To assess the effects of tree hazard management at the Moran Lake monarch overwintering site, we did intensive modeling of 10 m/s (22 mph) wind within the forest canopy under current conditions and under various management scenarios. We concentrated on the cluster zone in the grove NE of the sanitation yard.

Conclusions include:

1) Monarchs have opportunities to make small changes in distribution to track wind and sunlight within the cluster zone. The cluster zone grove itself provides significant, but not complete, wind shelter from SW winds.
2) The Placer Street trees provide a critical windbreak from SW winds but could be topped to 80 ft and still provide suitable wind shelter from SW winds for the cluster zone NE of the sanitation facility yard
3) An idealized scenario that tops trees to heights that eliminate houses as targets (strike height) also provides suitable SW wind shelter for the cluster zone. The practicality of this configuration needs arborist input.
4) The cluster zone is currently well-sheltered from SSW winds. Removal of the SE and S Lakeside groves has a minimal effect on SSW wind speeds in the cluster zone, which are below 2 m/s (5.2 mph). Removal of the N Lakeside grove in addition does increase SSW wind exposure so that 27% of the cluster zone experienced S-winds greater than 2 m/s.
5) Reducing the heights of these Lakeside groves to 50-70 ft provides better shelter than complete removal
6) Topping trees along the N-edge to strike height has minimal effect on N-wind exposure in the cluster zone. A previous recommendation for planting cypress trees in the “Boneyard” to block wind penetrating through an existing road/trail opening would secure this N-edge.
7) Several trees in the Creekside area are regularly occupied by monarchs, so no major modifications (beyond trimming immediate hazard branches) in this area are acceptable for monarchs.
8) These constraints and opportunities now require input from an arborist about the degree of tree removal/topping that is compatible with tree health and long-term commitments to grove management as trees regrow

Objectives

Overwintering monarch butterflies are highly sensitive to wind, which along with sun exposure, is a fundamental driver of site occupancy and movements. Creating and maintaining suitable wind shelter is a critical aspect of overwintering site management, while addressing public safety concerns from hazard trees. A detailed assessment of Moran Lake habitat conditions is presented by Weiss (2022).

The primary objective of this study is to model baseline wind conditions within the Moran Lake Monarch Overwintering Site (Xerces Society Site Identification 2983). and assess the effects of potential canopy modifications (to reduce treefall hazards to property) on the distribution of wind within the monarch cluster zone. We considered 7 scenarios designed to test various management treatments to different groups of trees across the site. The scenarios include (Table 1, Map 1)

Table 1. Scenarios considered:

Scenario Number	Description
1	Placer Street Windbreak Critical Height and Baseline
2	Placer Street Windbreak Below Strike Height
3&4	Complete Removal of Southern Groves
5	50–70-foot Canopy Height at Southern Groves
6	North Edge Below Strike Height
7	South Creekside at Critical Heigh

Scenario 1 includes simulations of 10 ft incremental topping of the Placer Street trees to identify the critical height from 140 ft down to 30 ft. A complete removal was simulated as an "end member" to evaluate the isolated sheltering effect of the forest edge in the cluster zone.

Scenario 2 postulates a windbreak design that removes all canopy within striking distance (Strike Height) of the houses along Placer Street with a "stepped back" design.

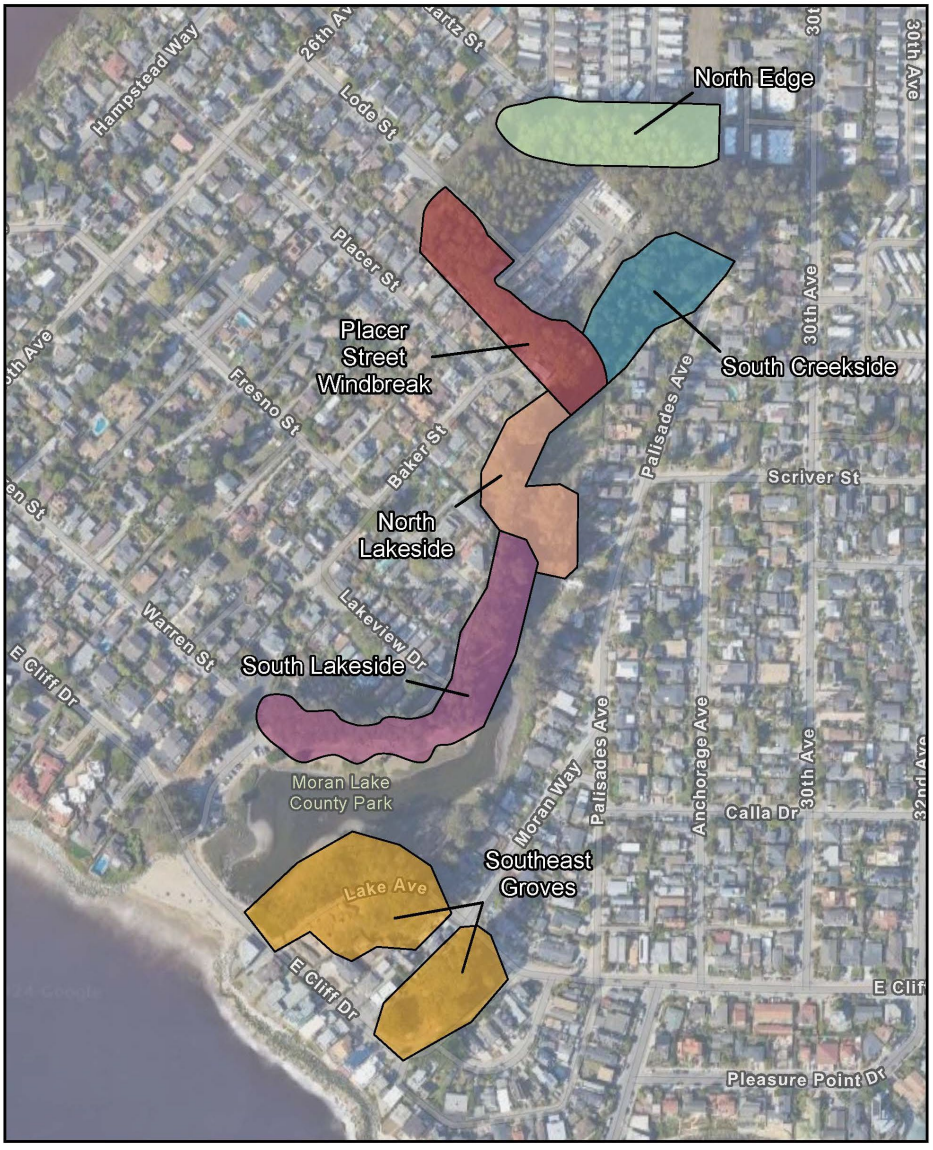
Scenarios 3 and 4 postulate complete removal of stands of trees around Moran Lake, south of the main monarch habitat around the sanitation yard.

Scenario 5 postulates reducing those southern groves to 50-70 ft.

Scenario 6 postulates the same Strike Height modifications, only on the northern edges of the monarch grove.

Scenario 7 considers topping of trees in the Creekside Zone, SE of the yard.

Map 1. Groves Overview



N

0 200 400 Feet

Moran Lake Monarch Butterfly Habitat and Tree Assessment
Map Center: 36.95846°N 121.97596°W
Santa Cruz, California

Imagery Source: Google Imagery, 09/11/2022. Street Reference Source: ESRI

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Map Updated:
October 02, 2024 07:55 PM by CDM

Methods

The basic workflow to simulate wind conditions was as follows:

First we acquired LiDAR data from NOAA's Data Access Viewer (OCM Partners, 2025). The LiDAR dataset had an estimated point spacing of 0.19 meters. The LiDAR data was part of a collection effort that spanned the timeframe of 2020-03-22 to 2020-04-15.

The LiDAR point cloud came in the .las file format. Our first step in processing the point cloud was to load it in CloudCompare, where we separated the point cloud into classifications of ground, and unclassified points. We then exported the point clouds to the .e57 file format.

Next, we loaded the .e57 point cloud of ground classified points in Rhino 7 using Grasshopper and Volvox, plugins for Rhino 7. In Rhino 7 we used a Delaunay triangulation method to connect the ground points into a mesh surface representing ground terrain. In order to resolve imperfections in this resulting geometry we had to perform three iterations of quad-remeshing to smooth the geometry and produce a valid "good" mesh representing the ground. Some of the imperfections eliminated by this process include self-intersecting faces, mesh surfaces with aspect ratios greater than 1:5, and angles less than 60°.

We created building geometries by manually extruding box geometries to the maximum height and extent of each building nearest to the Placer Street windbreak, and north edge groves. Buildings within the sanitation yard were modeled with greater precision than those buildings surrounding the groves. This includes matching roof slope for the building closest to the main monarch cluster location.

Canopy/tree geometries were created using a voxel technique in which a 1 cubic meter voxel would be generated within a standard grid across the site if there were unclassified points located within that volume.

The software used to simulate wind conditions given these input geometries was Eddy3D. Eddy3D uses the OpenFOAM computational fluid dynamics toolbox to simulate wind conditions.

For each scenario we set the wind direction to be in-line with the canopy volume of interest and the main cluster zone. We used a standard wind speed of 10 m/s (22 mph), which represents a moderately strong wind that is likely to occur in any given year. Incoming wind directions were as follows for the scenarios:

Scenario 1: 225° SW

Scenario 2: 225° SW

Scenario 3&4: 200° SSW

Scenario 5: 200° SSW

Scenario 6: 0° N

Scenario 7: 180° S

Voxels were inputted to the Eddy3D model domain as Eddy3D tree objects with a 'Type' set to 'dense'.

Data Visualizations

We use a variety of data visualizations and statistical characterizations to compare scenarios. These include:

1) Oblique views with colorized wind vectors, and a birds-eye view for current conditions
2) A consistent vertical slice taken perpendicular to the Placer Street windbreak (SW to NE) at the thinnest portion of the windbreak. This is the primary visualization of wind vectors for the Placer Street modifications. A similar vertical slice was taken for the N-edge simulation.
3) Statistical characterization of wind speeds within the cluster zone, based on 4,825 points within an 80 ft (along the fence line) x 65 ft. (depth from the forest edge) x 30 ft. (30 ft to 60 ft height from ground) box that encompassed the cluster sites NE of the yard.
    a. Depth profiles of absolute wind speed, with density quantiles
    b. Height depth profiles of differences from current conditions (including a scenario with no Placer Street windbreak to characterize the local sheltering effect of the NE forest edge).
    c. Histograms of differences
    d. Percentiles of wind speeds with different Placer Street heights.
    e. Histograms of absolute wind speed in Scenarios 3-7

Scenarios

Scenario 1: Placer Street Windbreak Baseline and Critical Height

Scenario 1 first establishes a baseline model of current conditions according to the state of the canopy at the time of LiDAR collection. All scenarios are compared with current conditions. We seek to identify the "critical height," meaning the minimum height of the trees that would maintain acceptable wind conditions for the main cluster site of Monarch butterflies. We identified the critical height by successively reducing the canopy height from current conditions (~ 145 ft tall). And produced a scenario with complete removal of Placer trees to understand the intrinsic shelter provided by the cluster zone trees themselves.

Wind patterns as the result of different canopy geometry can vary in counter-intuitive ways at fine scales because turbulent wind shadows behind obstacles tumble and create eddies. Eddies and waves downwind of canopy obstructions can direct wind in any direction depending on the specifics of the canopy geometry and wind speed. Especially when combined with planar visualizations, which only shows one dimension of the wind conditions, these patterns can cause wind speeds to increase in specific areas even when additional windbreak geometry is added. The inverse is also true, and some areas may show lower windspeeds when windbreak geometry is reduced. The wavelengths of the eddies also depend on the absolute wind speed modeled.

With these caveats in mind, we are looking for robust results that do not depend on these noisy aspects of wind modeling and provide some margin of safety for monarchs and people/property.

Photo 1. Panorama of Placer Street windbreak looking NE showing large gap in center

The vertical slice chosen for visualization runs through the gap, as a worst-case position with the highest wind speed. However, all statistics are done on the entirely of the cluster zone volume so the effects of this gap and more dense parts of the windbreak are spread over a larger volume.

Photo 2. Hemiphotos from an interior cluster location (949) and the N corner of yard (957), The Placer trees extend 10-15° above the horizon from the cluster site. Note that E and W are reversed from map views because the photos are taken looking upward.

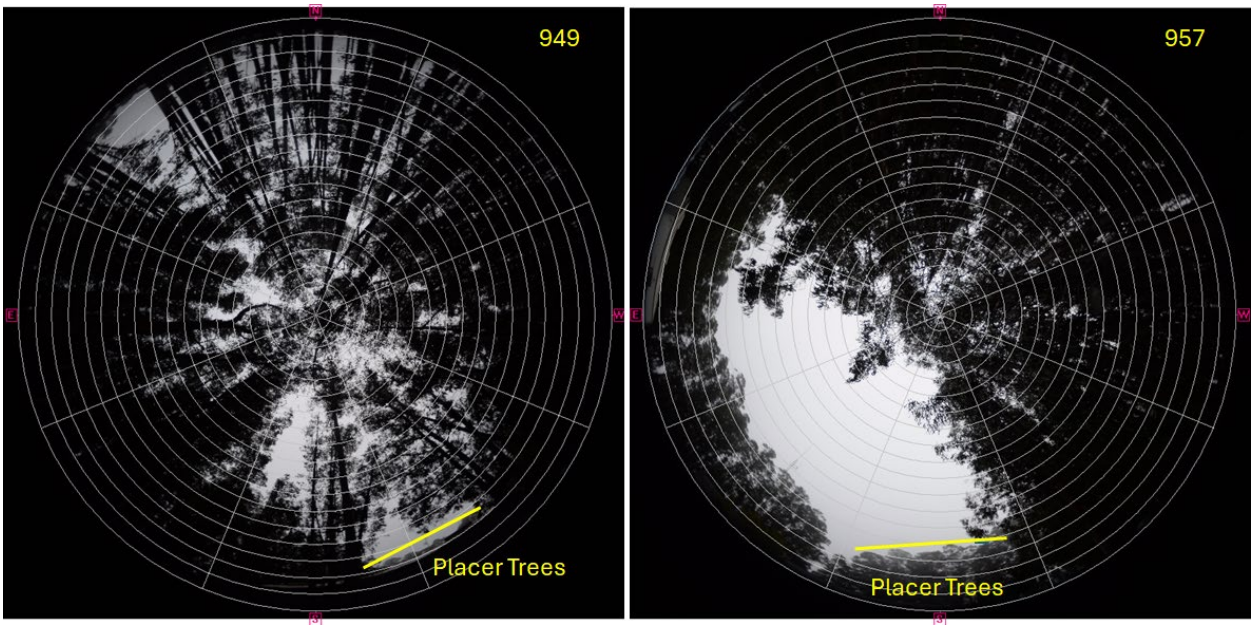


Photo 949 is a cluster site along the opening to the NE (old road access), 50 ft from the forest edge to the SE). The Placer trees occupy 10-15° above the horizon from the cluster site. Photo 957 is at the N corner of the yard; the Placer trees occupy ~20° above the horizon.

Figure 1. Oblique View of Placer Street Windbreak in the model, showing the same gaps as in the photo above. Vectors are wind conditions 30 feet above ground. Canopy voxels shown. The cluster zone is the white box visible at the end of the yard.

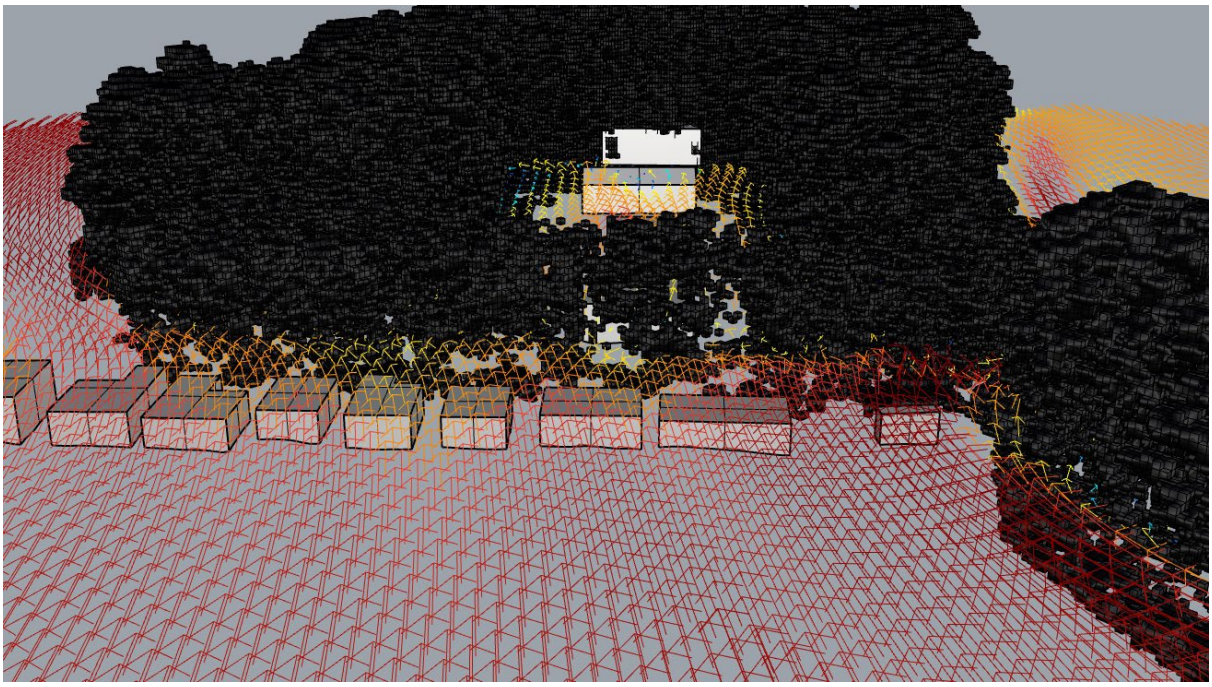


Figure 2. Oblique View of Placer Street Windbreak, Canopy Voxels Hidden. Current wind conditions 30 feet above ground.

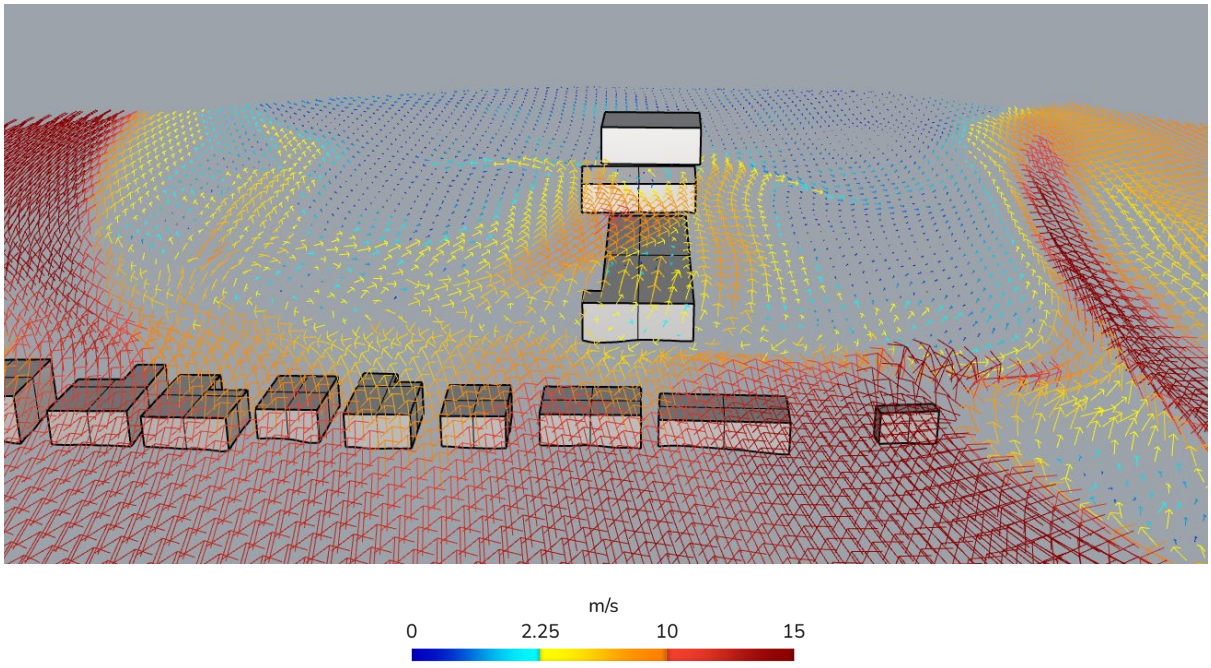


Figure 3. Vertical slice profile of wind through center of yard. Note the vertical variations in direction. From now on the vertical slice profile will be standard graphic.

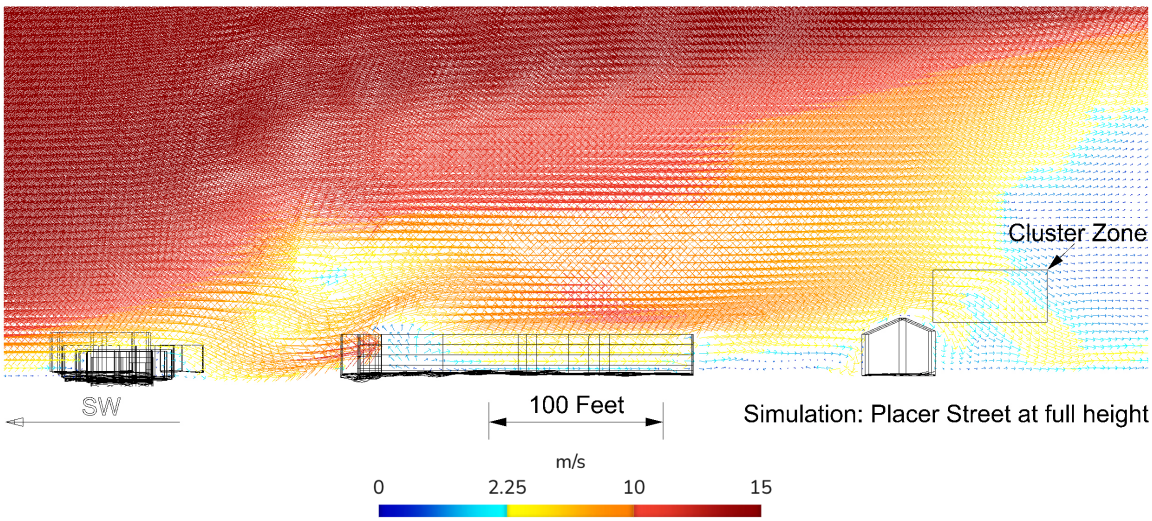
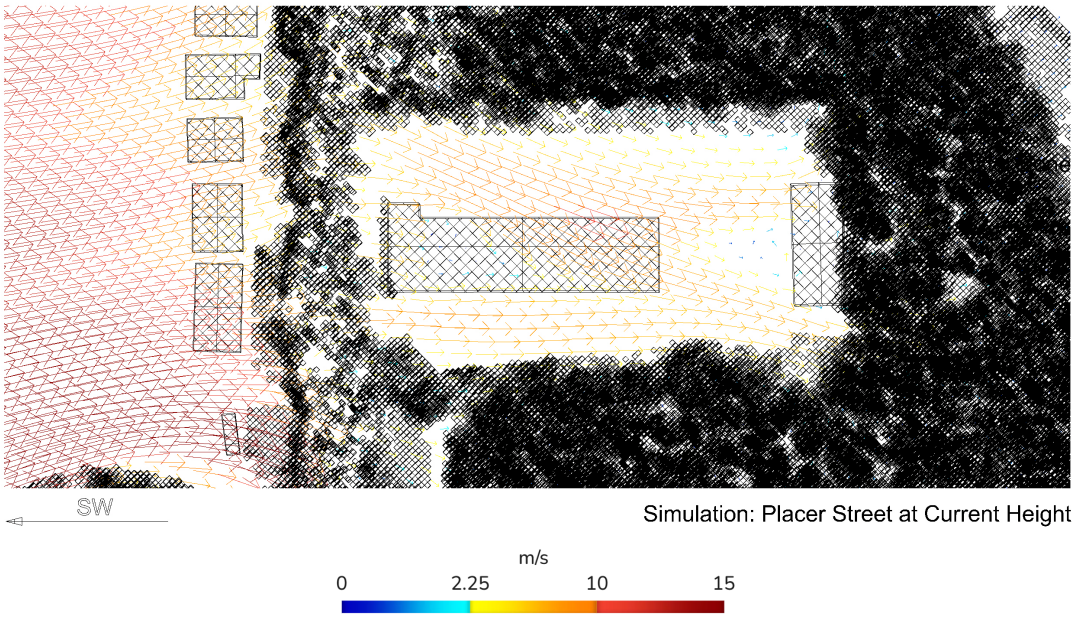


Figure 4. Bird's-eye View of Yard with incoming SW wind, tree voxels shown. Note the changes in wind direction within the yard.



Figures 3 and 4 show the current conditions from two views. Under current conditions, wind penetrates the Placer windbreak most in-line with the main building in the sanitation yard. The highest wind speeds over the yard are dispersed by the far building and canopy edge of the cluster zone (canopy voxels hidden in the representation). The slice of the cluster zone is all yellow and blue (wind speeds 1-3 m/s). The statistics of the entire cluster zone are shown below (Figure 6).

Figure 5A. Vertical Slice for Current Conditions, canopy voxels not shown

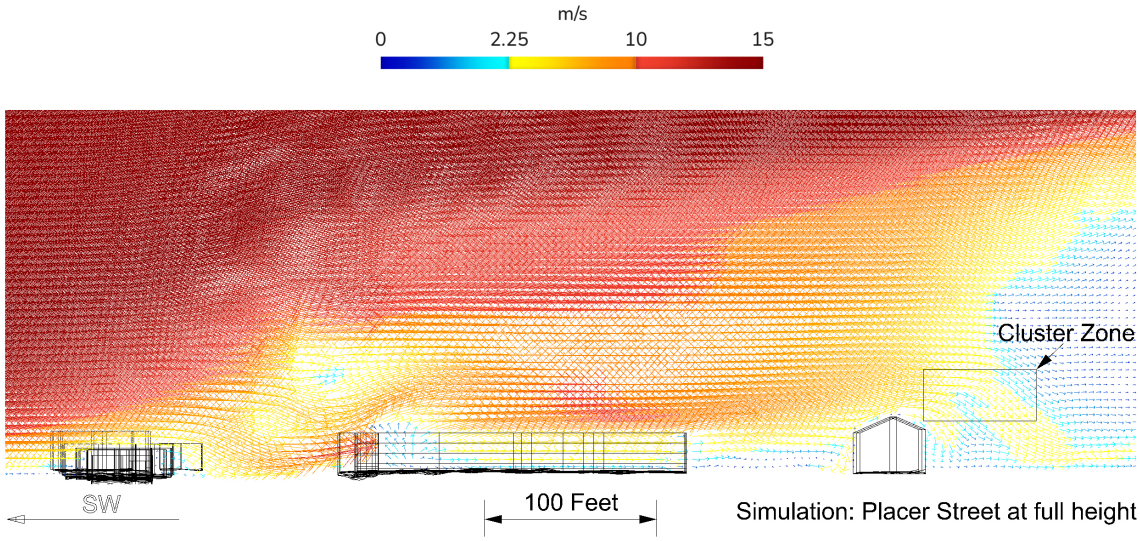


Figure 5B. Vertical Slice for Complete Removal.

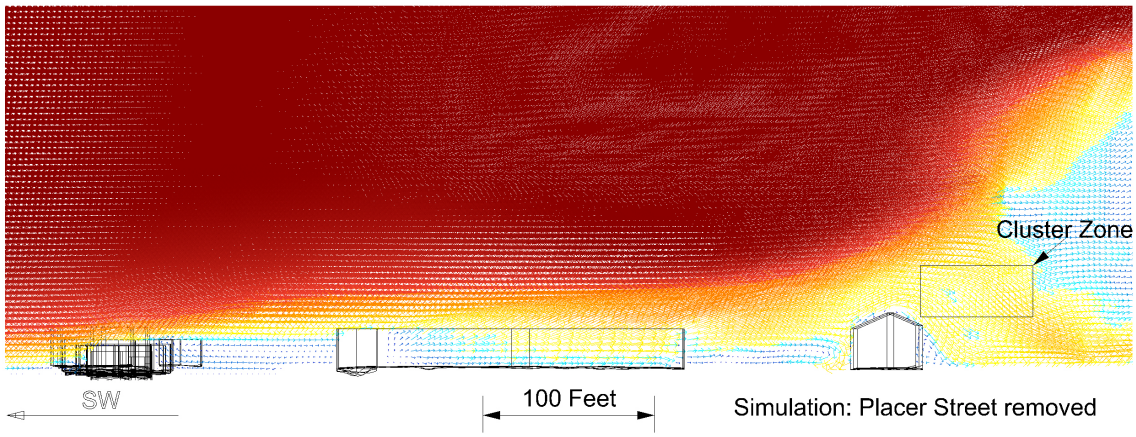
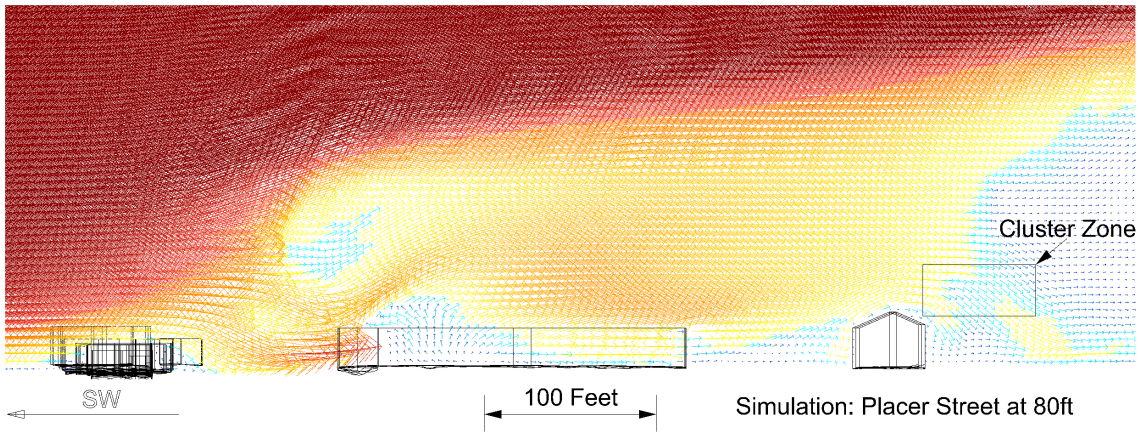


Figure 5C. Vertical Slice for 80 ft Placer Height

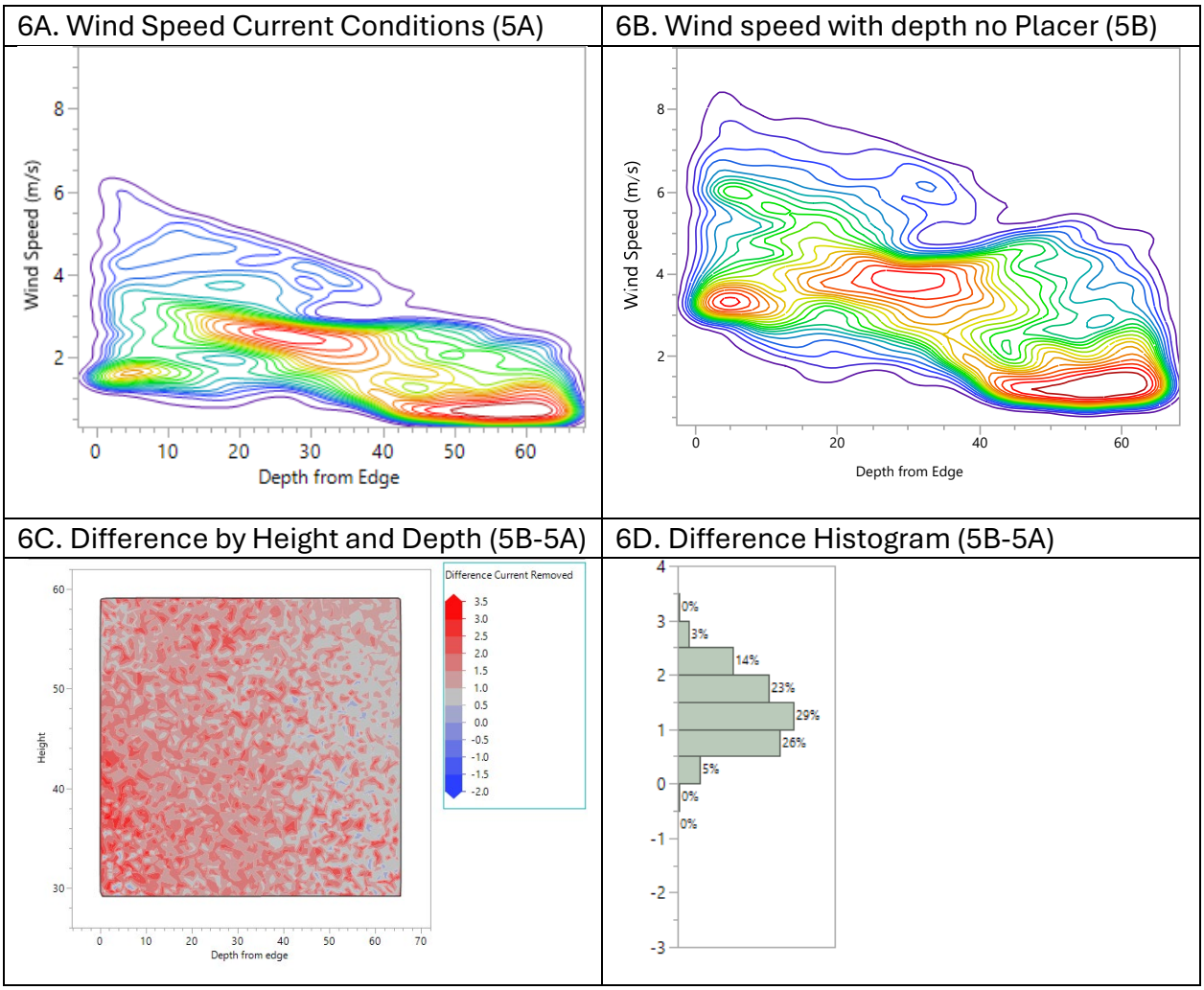


Some of the interesting details of Figure 5 and the variations include:

1) Under current conditions (5A), wind ascend over the Placer trees, and there is a calm spot in the middle of the trees.
2) The wind shadow of the Placer trees extends downwind over the entire reach shown.
3) Wind penetrates at low heights through the gap in Photo 1 and Figure 1. That wind ascends and an eddy forms over the main building.
4) The wind accelerates back to ~10 m/s again past that eddy just above the main building.
5) Wind slows to ~3-5 m/s (yellow) at the edge of the cluster zone above the far-right building.
6) The wind descends over the far-right building, and the cluster zone is primarily blue and yellow. The taller trees above the cluster zone attenuate the wind to less than 2 m/s. The open understory below the cluster zone allows wind to remain above 2 m/s near ground level.
7) Under complete removal (5B), the wind stays at 10 m/s across the yard, the friction effect of the main building slows the wind in the first 20 ft above.
8) The red zone of high wind ascends at the forest edge above the cluster zone, but the high interior of the grove is below 2 m/s.
9) The blue vectors in the cluster zone virtually disappear with full removal.
10) The 80 ft. Placer scenario (5C) is very similar to the current condition (5A).

The full distribution of wind speeds within the cluster zone are treated in Figure 6 below.

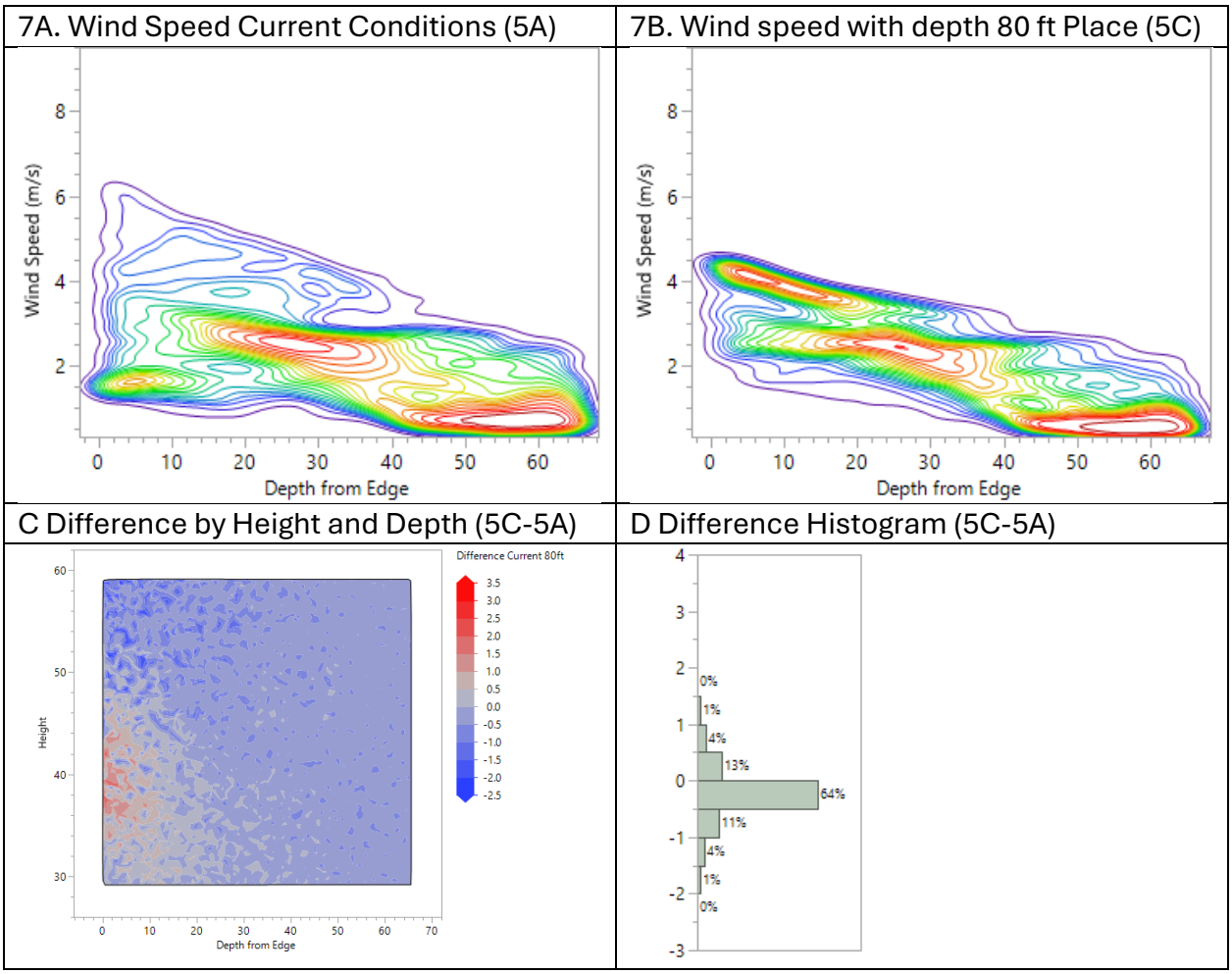
Figure 6. Comparison of current conditions (A) versus complete removal of Placer (B), with depth from edge. Orange and red quantile contours show the relative density of points. The difference by height and depth (C) and the difference histogram (D).



The complete removal scenario is an "end member" so that the wind attenuation of the cluster zone grove itself is isolated. With the current conditions (6A), there are many sites with wind less than 2 m/s at all depths, especially deeper into the cluster zone (40 ft and beyond). With complete removal (6B), the only sites below 2 m/s are greater than 40 ft from the edge. The contour plot of the differences (6C) shows increased wind speed throughout the height and depth of the cluster zone, up to 3 m/s near the edge. The histogram shows 69% of the sites increasing by 1 m/s or more, and 17% increasing by 2 m/s or more.

Remember that the cluster microsites are 40 – 60 ft from the edge.

Figure 7. Comparison of Current Versus 80 ft Placer with depth from edge. Layout is the same as previous figure.



With the 80 ft Placer, the zone close to the edge loses lower wind speeds, but the deeper zone remains less than 2 m/s (7B). When the difference is plotted with height and depth (7C), wind speeds increase (grey and red) primarily within ~20 ft of the edge. 64% of the cluster zone has no change (7D). The 40-60 ft depth zone where the monarchs cluster exhibits little change.

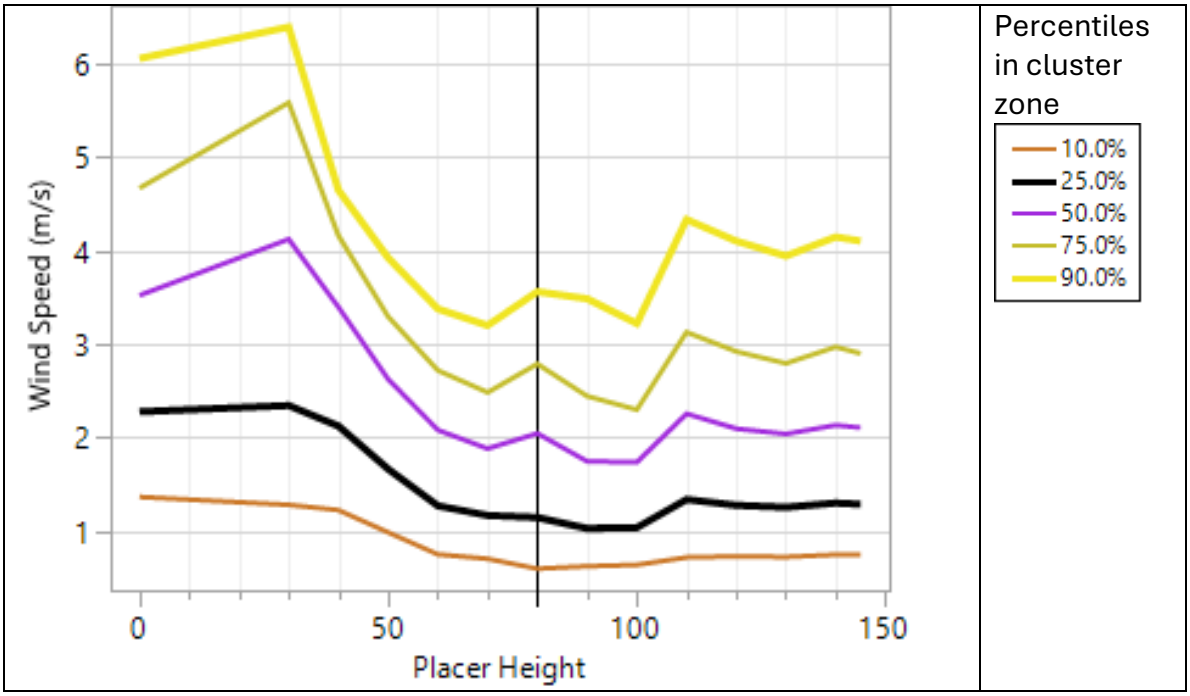
These graphics have been generated for all of the Placer heights considered, but these three scenarios provide sufficient examples of how the wind attenuation works that little will be gained by presenting them all. The synthesis of all the runs is below in Figure 8 with an analysis of wind speed percentiles within the cluster zone.

Wind Speed Percentiles with Placer Height

The results of all the Placer height scenarios are summarized in Figure 8 below. The percentiles of wind speed within the cluster zone are plotted for each Placer height scenario and connected (145 is the current condition, 0 is complete removal as an end member). The black line is the 25th percentile (i.e. 25% of the points within the cluster zone are less than that wind speed). For the 80 ft. Placer scenario (vertical line), the 25th percentile (1.15 m/s) and the 50th percentile (2.04 m/s.) are virtually the same as in the current condition. Only when Placer is reduced to below 60 ft, do the 25th percentile and other percentiles start to rise. The irregularities in the curves (such as the bump at 110 ft) reflect some of the complex turbulent wavelengths generated by different Placer heights and may vary in shape for different wind speeds.

This analysis provides strong support for the 80 ft height being a safe option, leaving another 10 to 20 ft buffer before wind speed percentiles rise rapidly.

Figure 8. Percentiles of Wind Speed Within the Cluster Zone by the height of the Placer trees (X-axis)



Scenario 2: Placer Street Windbreak at Strike Height

This scenario models wind if the Placer trees were cut in a gradient below heights capable of striking buildings along Placer Street. The canopy geometry modeled is based on a selection of vegetation volume that does not account for actual tree structure and is strictly based on a 45-degree angle from the base of occupied buildings on Placer Street.

This scenario (9A) produces subtle changes from current conditions (9B). Those differences within the cluster zone are best viewed in Figure 10 below.

Figure 9A Vertical Wind Profile with Strike Height Scenario

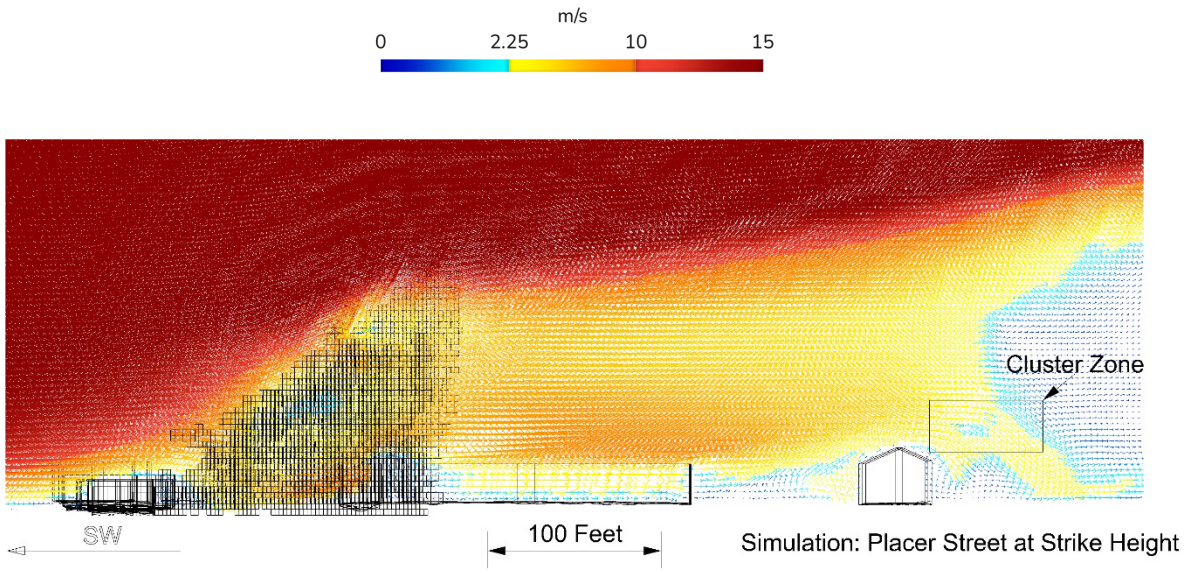


Figure 9B Vertical Wind Profile Current Conditions (same as Figure 5A)

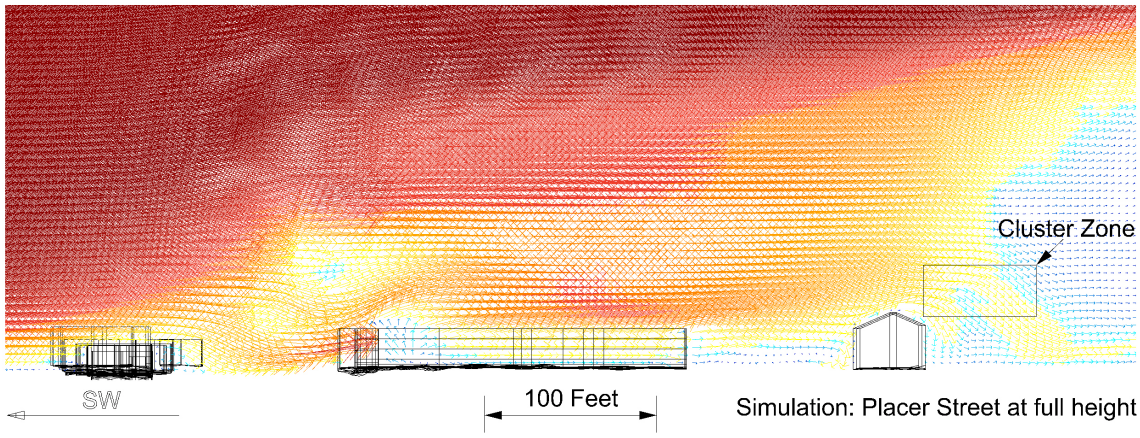
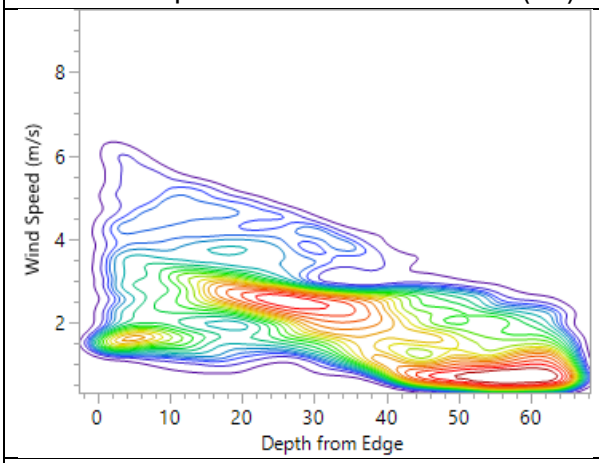
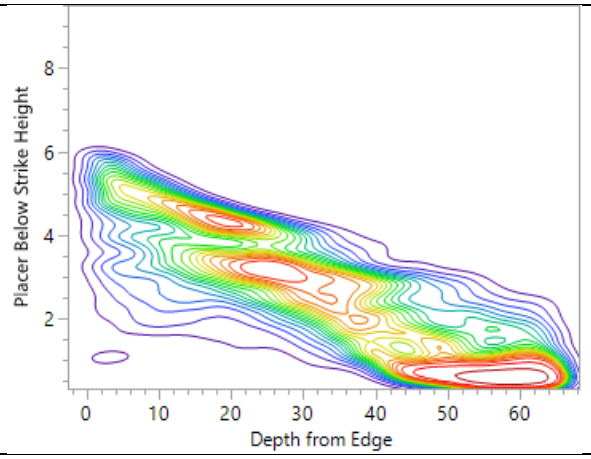
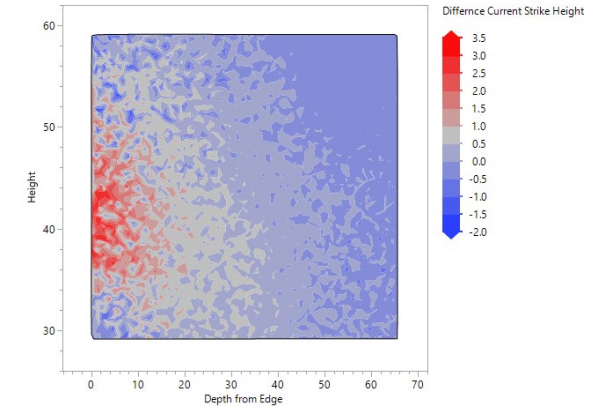
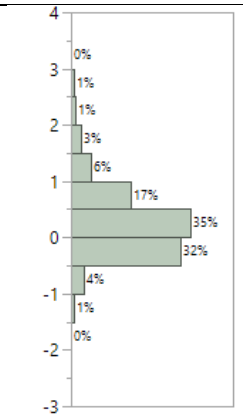
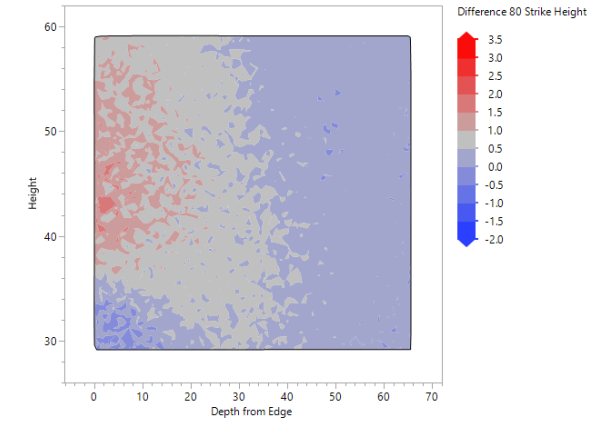
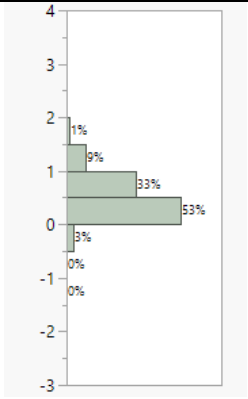


Figure 10. Strike Height Scenario Statistics

10A Wind Speed Current Conditions (9B)	10B Wind speed Strike Height (9A)
	
10C Difference from Current	**10D Difference Strike Height Histogram**
	
10E. Difference Strike Height vs 80 ft Placer	**10F. Histogram Strike Height vs 80 ft Placer**
	

In the Strike Height scenario, the only areas with wind below 2 m/s are greater than 40 ft depth (10B). The main impacts are within 20 ft of the edge, between heights of 35 to 50 ft (10C). The sites beyond 40 ft from the edge are little affected Compared with the 80 ft Placer scenario, Strike Height mainly changes in that same zone by ~ 1.5 m/s (10E).

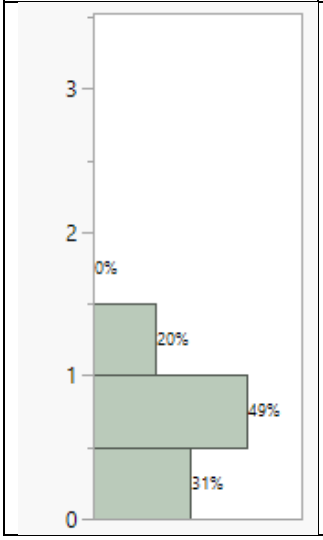
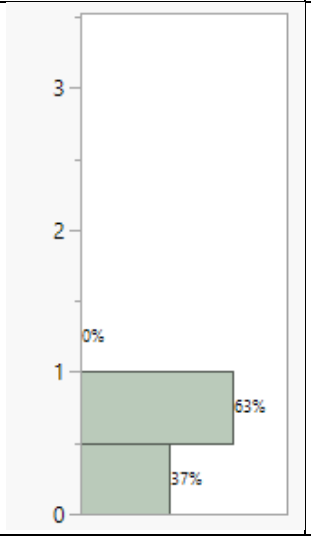
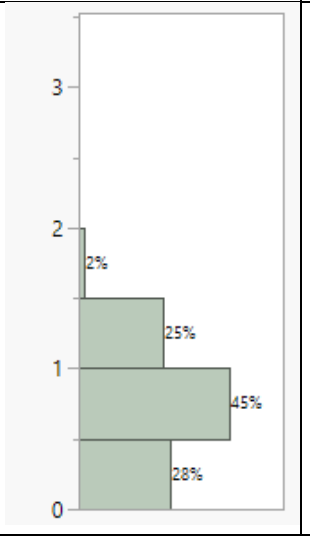
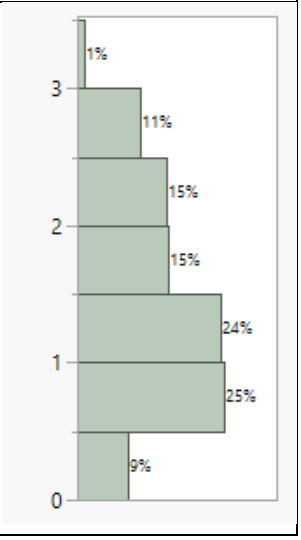
Scenario 3 & 4: Complete Removal of Southern Groves

The set of scenarios referred to as 3&4 includes the complete removal of groves south of the trees immediately sounding the sanitation yard. This includes the Southeast Groves, South Lakeside, and North Lakeside. In the simulations we iterated through removing the groves in the order mentioned above.

The effect of these changes was tested using an incoming 10 m/s wind direction of 200°. This wind direction puts the southern groves directly in line with the main cluster site. This allows us to establish the maximum amount of protection provided by the southern groves. We set the Placer trees at the critical 80 ft height.

The current conditions of the S, SE, and N groves provide excellent 200° (SSW) wind protection for the cluster zone, with only 20% of the volume greater than 1 m/s and none greater than 2 m/s. Removal of the SE and S groves does not create areas of higher winds. The only scenario that creates wind speeds greater than 2 m/s is complete removal of the three groves in question, an extreme scenario; 27% of the cluster zone volume has wind speeds greater than 2 m/s.

Figure 11. Histograms of Absolute Wind Speed in Cluster Zone for 200° 10m/s Wind.

11A. Current, Placer 80	11B. Cut 1 SE removed	11C. Cut 2 SE and S removed	11D. Cut 3 SE, S, and N Lakeside removed
			

Scenario 5: 50–70-foot Canopy Height at Southern Groves

This scenario is designed to test the effects of cutting the southern groves (same groves as discussed in scenarios 3&4) to a height of approximately 50-70 feet. Given that the results of scenarios 3&4 suggest that the conditions felt at the main cluster site with complete removal of the southern groves are still well within comfortable parameters, it was deemed unnecessary to test the 50–70-foot condition of the southern groves. Wind conditions can be assumed to be suitable given this treatment.

Scenario 6: North Edge Below Strike Height

This scenario uses the same approach as scenario 2, except for with buildings nearest to the North Edge grove. The buildings on this northern side of the groves are farther from the North Edge grove than those buildings along Placer Street, with the "Boneyard" occupying most of the space between buildings and North Edge trees. The modifications result in minor changes to the canopy of the North Edge. Cutting would be limited to the highest sections of the trees.

Figure 12 shows a vertical slice for current and strike height. The wind is N (0°) at 10 m/s. In the current configuration, there is a "wind tunnel" along the road opening (the jet of yellow/red near the ground). This opening can be seen in Photo 2, 949 as the near-horizon gap to the NE. This wind vulnerability, which drives the monarchs away from the NE cluster zone during strong northerly winds, was confirmed with actual wind measurements in the habitat assessment (Weiss 2022). Sealing this gap with new cypress trees in the Boneyard across from the opening was a key recommendation in that report.

The strike height modification results in minimal changes to wind conditions in the cluster zone - in fact they are almost indistinguishable both visually (Figure 12) and in the histograms (Figures 13 A, B). The slight differences are captured in a difference histogram (Figure 13C). The distribution of wind with height along the NW-SE canopy edge (Figures 13 D, E) shows the wind tunnel along the road opening clearly in the lower left corner between 0 and 20 ft. and below 40 ft height.

The actual trimming would be well up in the canopy, above the cluster zone and there would still be several rows of trees to provide wind shelter. Combined with sealing up the wind tunnel with Boneyard cypress plantings, the north edge of the grove will be more secure for both monarchs and building safety.

Figure 12A. N-Edge Current Conditions

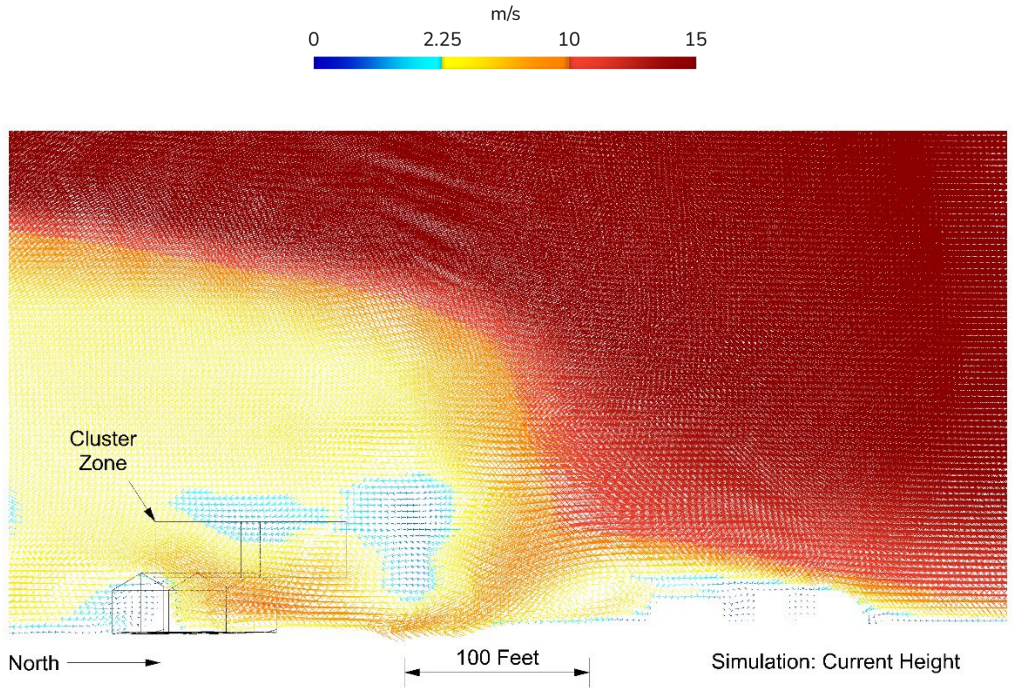


Figure 12B. N-Edge Strike Height

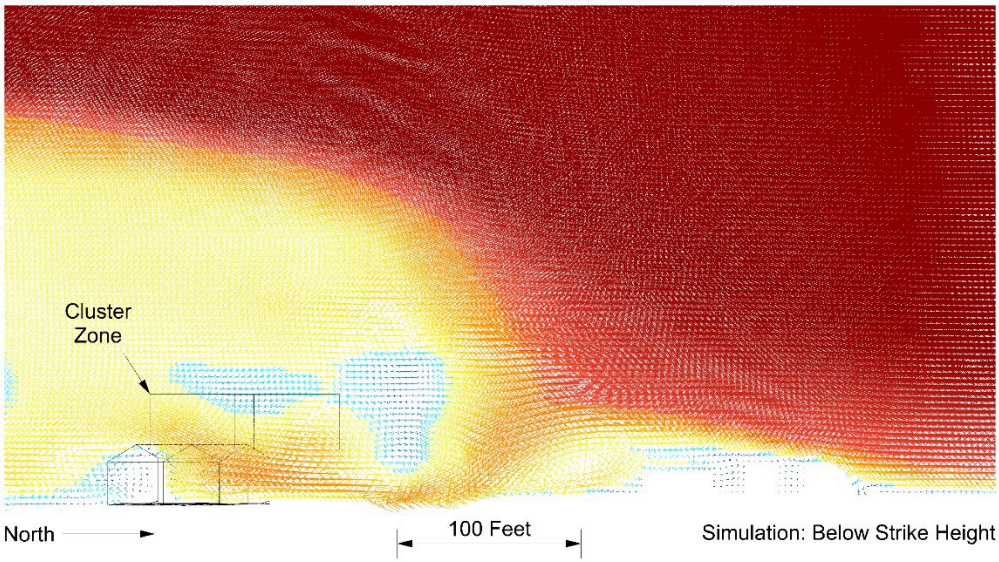
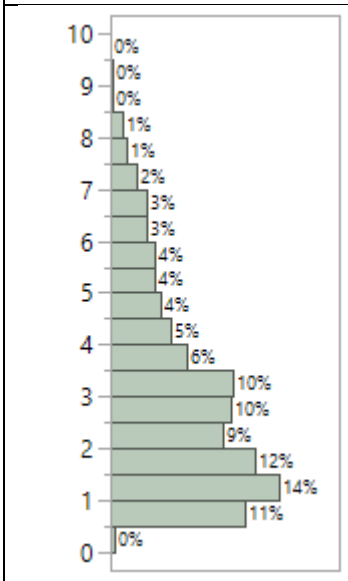
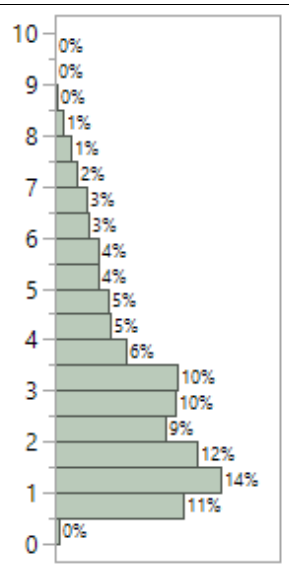
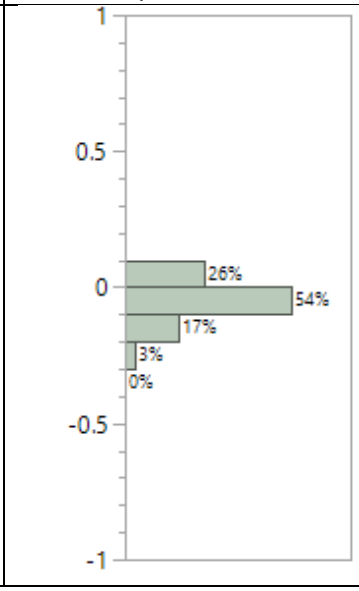
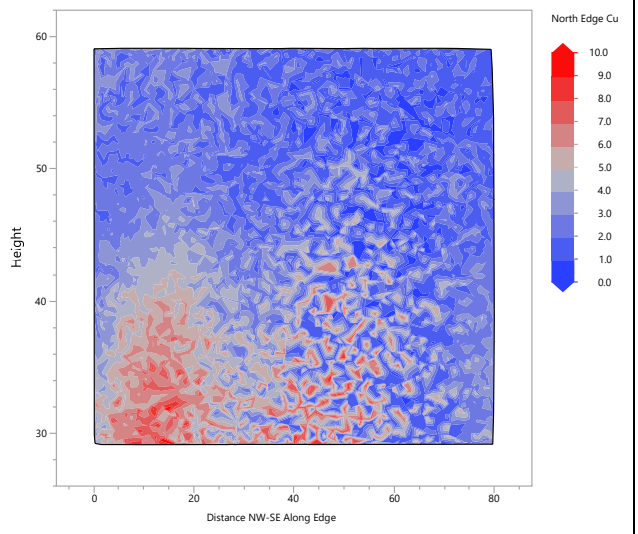
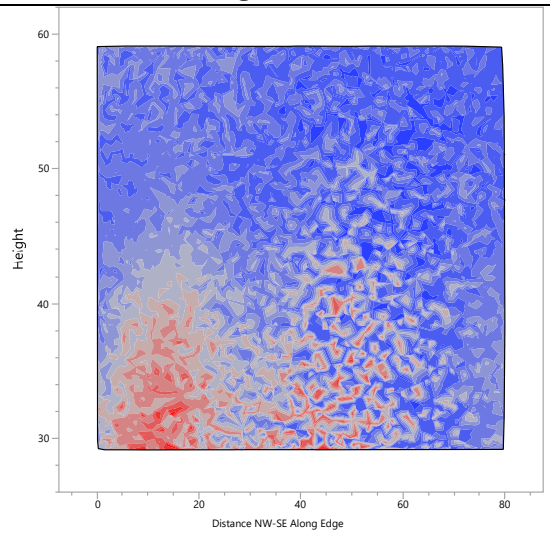


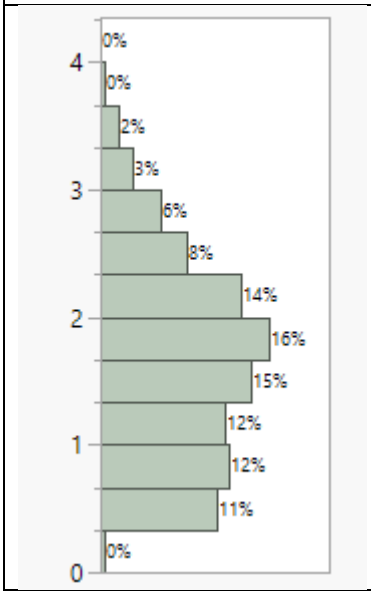
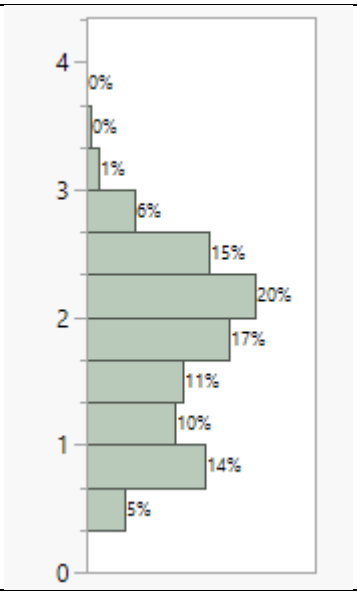
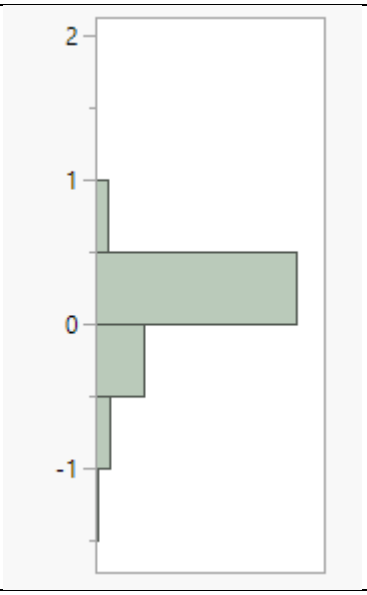
Figure 13. Strike Height on North Edge Histograms

13A. Current Conditions N wind	13B. N Strike Height	13C. Difference (mean = -0.05 m/s)
		

13D. Current Conditions	13E. N Strike Height
	

Scenario 7: South Creekside at Critical Height

Figure 14 Histograms of Wind Speed for Creekside Topping

7A. Creekside at Full Height, Placer at 80 ft.	7B. Creekside at 80 ft. Placer at 80 ft.	7C. Difference mean = 0.11 m/s
		

Topping the Creekside trees to 80 ft has a small effect on the cluster zone, a mean increase of 0.11 m/s. It actually decreases the very maximum wind speeds (> 3 m/s) slightly.

This treatment is not a realistic option for monarchs, because of the presence of consistent cluster trees in this area. Those cluster sites would likely be disrupted by topping.

References

OCM Partners, 2025. 2020 San Mateo RCD Lidar: Santa Cruz County, CA, https://www.fisheries.noaa.gov/inport/item/63258.

Weiss, S.B. 2022. Assessment of Moran Lake Monarch Overwintering Habitat. Report by Creekside Science for Santa Cruz County Parks.