Memorandum

Date:	March 7, 2016
To:	Charlie Karustis New Dimension Energy Company 221 Crescent Street, Suite 103 Waltham, MA 02453
From:	Brad Norton
Subject:	**Sand Hill Siting Process and Evaluation**

This memorandum describes the process and evaluation undertaken by Sand Hill Wind, LLC (Sand Hill) to locate its turbines for the Sand Hill Wind Repowering Project. Sand Hill is proposing a wind energy repowering project on multiple parcels in three distinct areas encompassing approximately 875 acres in northeastern Alameda County, California (project area) (Figure 1). The proposed project elements include the following.

- Removal of 433 existing wind turbines.
- Installation of 12–14 new 2.5-3 megawatt (MW) wind turbines (for a maximum of 35 MW) with 90 m tall towers (hub height) and foundations.
- Installation of pad-mounted transformers.
- Use of existing roads that provide access throughout much of the project area with development of new project roads, only as necessary.
- Installation of an underground electrical collection system.
- Use of existing underground and overhead electrical power transmission lines, where feasible, to convey the wind energy produced by the project to local and regional energy markets.
- Use of existing substations and switchyards (with potential upgrades of the existing equipment within the footprint of the project area).
- Construction of a new operations and maintenance (O&M) facility.
- Ongoing O&M.

Initially, Sand Hill selected the project's parcels, negotiated wind leases, secured a Power Purchase Agreement (PPA), facilitated the environmental analysis, and obtained permits for the project with the intent to deploy wind turbines employing a new, shrouded design. However, obstacles associated with electrical interconnection required Sand Hill to repower with conventional utility-scale turbines. This memorandum focuses on the factors considered when redesigning the project to accommodate new larger turbines.

The turbine siting process considered the following variables.

- Wind resource and topography
- Wind turbine spacing requirements
- Impacts from neighboring wind projects
- County setback requirements
- Terrestrial and wetland resources
- Avian resources
- Shadow flicker analysis
- Noise analysis
- Public health and safety (e.g., blade throw)

Based on these considerations, siting turbines has been particularly challenging. Two primary layout configurations were initially developed based on this information: Layout 1 and Layout 2 ; however, based on new information regarding wind turbine locations upwind of the project, inability to contact an adjacent landowner, and feedback from the County on Layouts 1 and 2, Sand Hill also developed Layout 3. Turbine locations associated with these three layouts are illustrated on Figure 2. Alameda County's (County's) program environmental impact report (Program EIR) and subsequent California Environmental Quality Act (CEQA) analysis for this project is anticipated to help ensure that potential impacts on these and other resource topics are avoided, minimized, and mitigated. Specifically, potential impacts on other topics such as cultural and historical resources, visual resources and aesthetics, socioeconomics, communications, transportation and traffic, solid and hazardous waste, air quality and climate, are addressed in the program EIR and project-specific CEQA document. These other topics did not substantially influence the turbine siting decisions.

The following sections summarize the variables considered in the siting process and evaluation.

Wind Resource and Topography

The Altamont Pass Resource Area (APWRA) sustains a strong and predictable wind resource due mainly to the funneling of cool marine winds from the Pacific Ocean eastward through the pass to replace the rising hot summer air of the Central Valley (Figure 3). The terrain complexity surrounding and within the project area is considered high, with undulating hills and ridges. The terrain elevation within the project area ranges from approximately 80 m to 150 m (above mean sea level), with the lowest elevations located in those areas along the eastern edge of the APWRA. Higher elevations exceeding 350 m are located approximately 3.5 km to the west-southwest.

To define the wind resource and energy production potential of the Sand Hill project area, a Phase I meteorological measurement campaign was initiated in December 2013 with the installation of three (3) onsite 50 m TallTower XHD masts, followed by the installation of a Triton sodar wind measurement device in February 2015. A Phase II campaign, running in parallel with Phase I, is scheduled to commence in March 2016 with the installation of two (2) 60 m XHD masts and an additional Triton sodar wind measurement device.

The findings of the Phase I measurement campaign were key inputs to state-of-the-art wind flow modeling software used to define the 90 m hub height wind speed variation across the Sand Hill project area. The wind flow modeling results were used to optimize the Sand Hill array design for maximum energy production. Included in the optimization process were considerations of constructability (minimize earthwork, extreme slopes), use of existing road corridors and facilities, County setback requirements, turbine spacing (wake and turbulence impacts), neighboring wind farm impacts, turbine vendor site suitability requirements, noise and shadow flicker impacts, among others. Two array designs were developed to reflect the County's alternative minimum setback and general setback requirements, designated as Layout 1 and Layout 2, respectively (Figure 4 and Figure 5). However, Sand Hill recently learned that NextEra will likely install several turbines immediately upwind of the project area, greatly influencing the wind resource and the productivity of the proposed turbine locations within Layouts 1 and 2. Layout 2 is 3.1% less productive than Layout 1 on a net capacity factor basis; this percentage reduction in energy, while seeming small, represents a significant impact on project economics, making Layout 2 financially infeasible. Therefore, taking this into consideration, as well as other constraints described below, Sand Hill developed a third layout, Layout 3 (Figure 6). As such, Layout 3yields the highest energy output of the 3 layouts and is and the preferred array configuration, given multiple site constraints.

Wind Turbine Spacing Requirements

Turbine spacing requirements are largely driven by a site's ambient turbulence and added wake-induced turbulence, and associated turbine and/or tower loads across the operational wind speed range. It is critical that these loads do not exceed the operating envelope of the wind turbine, and this is determined by conducting a detailed site suitability assessment using site specific data. For the Sand Hill turbine layout, the applicable minimum in-row turbine spacing is two rotor diameters and downwind turbine spacing is four rotor diameters.

County Setback Requirements

Turbine placement must conform to the setback conditions established in the County's Program EIR. According to the general setback requirements, all turbines should be sited no less than 3 times the total turbine height (i.e., from the ground surface to the tip of the blade in the 12 o'clock position) from any dwelling unit and 2.5 times the total turbine height from any public road, trail, recreation area, commercial, or residential zoning. Alternative setback requirements, as defined by the Program EIR, are allowable on request within a report prepared by a qualified professional and verified by the County demonstrating that a lesser setback is adequate. In no case would a setback less than 50% of the established setback be allowed. The general setback requirements for a 495-foot tall turbine, the size proposed for this project, is 1,485 feet from residences and 1,238 feet from roads and transmission lines. The alternative minimum setback for residences is 743 feet and for roads and transmission lines is 619 feet.

Setbacks from roads, residences, and utilities greatly constrain the placement of turbines on these parcels, and the setback requirements substantially influence the placement of turbines. The general setback requirements provide an on-site developable window of approximately 142 acres (16% of the project area) because of the narrow width of the parcels, and the proximity of the parcels to roads, transmission lines, and residences. Sand Hill's layout configurations tried to site many of the turbines within the general setback requirements, but some turbines will require waivers of the general setback requirements. Table 1 provides a summary of the setback distances for each turbine and the distance of the turbine to adjacent constraints for those turbines within general setback distances.

Table 1. Distances to Receptors by Layout and Turbine for Turbines between the Alternative Minimum Setback and General Setback Distance

Setback, Layout and Turbine	Feature/Distance (ft)							
	R1	R2	R3	Utility Line	Altamont Pass Road	Mountain House Road	I-580	Property Boundary
General Setback	1,485	1,485	1,485	1,238	1,238	1,238	1,238	600
Alt. Minimum	743	743	743	619	619	619	619	By waiver
Layout 1								
5A	1,533*	-	-	-	701	-	-	-
6A	-	-	-	932	-	-	-	-
7A	1,077	1,636*	-	1,351*	652	-	-	-
8A	1,339	2,419*	-	-	1,107	-	859	-
9A	-	-	1,048	633	-	1,270	-	-
10A	-	-	-	669	-	1,270	-	-
11A	-	-	-	592	-	911	-	-
12A	-	-	-	637	-	647	-	-
Layout 2								
5G	-	-	-	932	-	-	-	-
6G	-	-	-	-	-	-	-	494
7G	1,211	-	-	2,237*	-	-	-	-
Layout 3								
5R	1,533*	-	-	-	701	-	-	-
6R	-	-	999	719	-	-	-	533
7R	-	-	-	817	-	-	-	-
8R	-	-	-	714	-	1,043	-	-
9R	-	-	-	748	-	761	-	-
10R	-	-	-	1,023*	-	-	-	-
11R	-	-	-	682	-	-	-	-
12R	-	-	-	695	-	-	-	-

* Distance shown though conforms to the general setback requirement.

\- = Not applicable.

Layout 1 would require the following waivers:

1. Alameda County Public Works Department for five turbines, three near Altamont Pass Road (turbine locations 5A, 7A and 8A) (Figure 7a) and two near Mountain House Road (turbine locations 11A and 12A) (Figure 7b); the centerline for turbines 9A and 10A follow the general setback requirements.
2. Pacific Gas & Electric Company (PG&E) for 5 turbines, including turbine 6A (Figure 7a) and turbines 9A, 10A, 11A and 12A (Figure 7b).
3. California Department of Transportation (Caltrans) for 1 turbine, turbine 8A (Figure 7a).
4. Landowner at residence R1 for 2 turbines, 7A and 8A (Figure 7a).
5. Landowner at residence R3 for 1 turbine, 9A (Figure 7b).

Layout 2 would require the following waivers:

1. PG&E for 1 turbine, including turbine 5G (Figure 8a); the centerline for turbines 8G and 10G (Figure 8b) and turbine 12G (Figure 8c) follow the general setback requirements.
2. Landowner at residence R1 for 1 turbine, 7G (Figure 8a).
3. Landowner at residence R3 for 1 turbine, 8G (Figure 8b).

Layout 3 would require the following waivers:

1. Alameda County Public Works Department for three turbines, one near Altamont Pass Road (turbine location 5A) (Figure 9a) and two near Mountain House Road (turbine locations 8R and 9R) (Figure 9b); the centerline for turbines 6R and 7R follow the general setback requirements.
2. Pacific Gas & Electric Company (PG&E) for 5 turbines, including turbines 6R, 7R, 8R, 9R (Figure 9b), and turbines 11R and 12R (Figure 9c).
3. Landowner at residence R3 for 1 turbine, 6R (Figure 9b).
4. Property line setbacks for turbine 6R (Figure 9b) and 10R (Figure 9c)

Sand Hill has initiated discussions with the County, PG&E, and the landowner and will provide waivers to the County when they are obtained.

Sand Hill attempted to site the turbines within the general setback requirements, but because the site is so constrained, Sand Hill is seeking waivers under both layouts.

Terrestrial and Wetland Resources

The project area includes aquatic and upland habitat for sensitive species including two federally and state-listed species, California tiger salamander and California red-legged frog. Because most individuals are found within proximity to aquatic habitats, Sand Hill selected turbine locations that avoided impacts to aquatic habitats. Minor, but unavoidable impacts would occur at two ephemeral drainages where culverts need to be replaced. However, the proposed site layouts avoid impacts on ponds and other permanent wetlands. Where possible, Sand Hill also designed its permanent facilities to be located more than 250 feet from wetlands to avoid indirect effects on these species' habitat (Figure 10a, 10b, and 10c). Sand Hill will mitigate for temporary and permanent impacts as outlined in the Program EIR and

East Alameda County Conservation Strategy (EACCS). Sand Hill has been working with a conservation banker to identify appropriate turn-key mitigation for this project and will provide this information to the County prior to final building permit issuance.

Avian Resources

The APWRA is home to a wide diversity of sensitive avian species including golden eagle, American kestrel, red-tailed hawk, and burrowing owl. Sand Hill is still in the process of reviewing its siting efforts on raptor species. Substantial data has been collected for the project area as long-term APWRA observation points were located in base layer operating group boundaries (BLOB) areas 9, 10, 15, 16, 17, 18, and 22 (Figure 11). Monthly 30-minute eagle use observation data was collected between January 2013 and September 2014 as part of APWRA monitoring. Further, additional site-specific behavioral data was collected by Dr. Sean Smallwood. To the degree possible, Sand Hill will follow Dr. Smallwood's recommendations to site turbines away from areas with known eagle fatalities where past problem turbines were located and ridges with numerous fatalities. This micro-siting evaluation will be based on avian behavioral data that has been collected for the project area in accordance with the Program EIR Mitigation Measure BIO-11b. The final siting plan will be provided to the Technical Advisory Committee (TAC) in advance of construction in accordance with the Mitigation Monitoring and Reporting Plan.

Shadow Flicker Analysis

As described in the Program EIR, blade rotation could cause shadow flicker that could be a visual intrusion to viewers and could be especially disruptive to residents exposed to these conditions for long periods of time. The County setback requirements are intended to help address this. However, these setbacks may not be sufficient to prevent shadow flicker with the new, taller turbines. Therefore, the County also has developed the following mitigation measure to help resolve this issue.

> **Mitigation Measure AES-5: Analyze shadow flicker distance and mitigate effects or incorporate changes into project design to address shadow flicker**
>
> Shadow flicker could result from the installation of taller wind turbines that could be sited near residents and businesses. Accordingly, Alameda County will require that the project applicant model and evaluate shadow flicker impacts on nearby residences and businesses. No shadow flicker in excess of 30 minutes in a given day or 30 days in a given year will be permitted. If it is determined that existing setback requirements as established by the County are not sufficient to prevent shadow flicker impacts on residences and businesses, Alameda County will require an increase in the required setback distances to ensure that residences and businesses are not affected. If any residence or business is affected by shadow flicker within the 30-minute/30-day thresholds, the applicant will implement measures to minimize the effect, such as relocating the turbine, providing opaque window coverings for the affected receptor, or shutting down the turbine during the period shadow flicker would occur. Such measures may be undertaken in consultation with the affected resident or business owner. If the shadow flicker study indicates that any given turbine would result in shadow flicker exceeding the 30-minute/30-day thresholds, the turbine would be relocated to reduce the effect to acceptable limits.

A shadow flicker analysis was conducted for the project to help determine the impacts of shadow flicker (Attachment A, Flicker Analysis); a supplemental analysis is anticipated in the next several weeks that addresses Layout 3. The analysis for Layout 1 and 2 indicated that one adjacent (R1) and one on-site residence (R3) are most susceptible to the effects of flicker from the rotation of the turbines. Sand Hill evaluated the position of the turbines in relation to the residences and tried to adjust the turbine locations to minimize these effects. However, because of other constraints on site (i.e., topography, developable area, wetland impacts), there were limited opportunities to move or relocate the turbines far enough away from these residences to avoid the flicker effects. Therefore, Sand Hill has proposed operational adjustments of the turbines that cause the flicker to bring the turbines into compliance with the County's standards. Sand Hill will continue to work with the affected residences to determine if an alternative agreement or implementation of other measures (i.e., installation of vegetation screening, or other measure) can be used to address these impacts. The analysis for Layout 3 is expected to produce similar or reduced results and demonstrate that operational adjustments will be able to bring this layout into compliance with the County's standards.

Noise Analysis

As described in the Program EIR, construction and operational noise could affect adjacent residences and commercial businesses. Because of the potential to exceed noise ordnance standards, the Program EIR required the following mitigation measure.

> **Mitigation Measure NOI-1: Perform project-specific noise studies and implement measures to comply with County noise standards**
>
> The applicant for any proposed repowering project will retain a qualified acoustic consultant to prepare a report that evaluates noise impacts associated with operation of the proposed wind turbines. This evaluation will include a noise monitoring survey to quantify existing noise conditions at noise sensitive receptors located within 2,000 feet of any proposed turbine location. This survey will include measurement of the daily A-weighted and C-weighed Ldn values over a 1-week period and concurrent logging of wind speeds at the nearest meteorological station. The study will include a site-specific evaluation of predicted operational noise levels at nearby noise sensitive uses. If operation of the project is predicted to result in noise in excess of 55 dBA (Ldn) where noise is currently less than 55 dBA (Ldn), result in a 5 dB increase where noise is currently greater than 55 dBA (Ldn), or result in noise that exceeds 70 dBC (Ldn), the applicant will modify the project, including selecting new specific installation sites within the program area, to ensure that these performance standards will not be exceeded. Methods that can be used to ensure compliance with these performance standards include increasing the distance between proposed turbines and noise sensitive uses and the use of alternative turbine operational modes to reduce noise. Upon completion of the evaluation, the project applicant will submit a report to the County demonstrating how the project will comply with these performance standards. After review and approval of the report by County staff, the applicant will incorporate measures as necessary into the project to ensure compliance with these performance standards.

A noise analysis was conducted to assess the operational noise generated by the project (Attachment B, Noise Analysis); revisions to the report are anticipated in the next several weeks to addresses Layout 3.

The analysis for Layout 1 and Layout 2 indicated that the operational sound of the turbines would likely be lower than operation of on-site legacy turbines, but would likely exceed the County's thresholds at one adjacent residence (R1) and one on-site residence (R3), and be just under the thresholds at one residence (R2). Therefore, Sand Hill developed Layout 3 to adhere to the noise standards; ICF's preliminary findings show R1 and R2 will be below the County's noise standards for Layout 3.. The resident at R3 is leasing the wind rights to Sand Hill so will provide a waiver.

Public Health and Safety

Sand Hill also sited its turbines to minimize potential health and safety impacts should a turbine blade dislodge from the nacelle (i.e., throw a blade and have the blade land on a nearby road, transmission line, or property). Minimizing health and safety impacts generally requires adherence to the County's minimum setbacks, but a study was also prepared to evaluate the potential risk of "blade throw" (Attachment C, Blade Throw Analysis); a supplemental analysis is anticipated by March 18 that addresses Layout 3. This study showed that blade throw distances could range from 575 to 633 feet (175–193 meters). Specifically, the analysis shows Layout 1 will require Sand Hill to move Turbine 11A approximately 10 feet to the east to ensure a blade throw does not intersect with a transmission tower footing and that Turbine 8A blade throw could extend over the property line by approximately 10 feet. Layout 2 would require a waiver from the adjacent landowner as the blade throw analysis indicates a blade throw could extend over the property boundary by 100 feet. The County expressed concerns about the proximity of the turbines to Altamont Pass Road; therefore, Layout 3 includes fewer turbines near Altamont Pass Road. Layout 3 was also designed to ensure blade throw does not intersect with the transmission lines or tower footings. The blade throw analysis represents an unlikely event, and a worst-case scenario, given a blade would have to be released at an appropriate angle to reach these distances. Regardless, obtaining waivers as described above and adherence to the County's alternative minimum setbacks is adequate to protect public health and safety should a blade become dislodged.

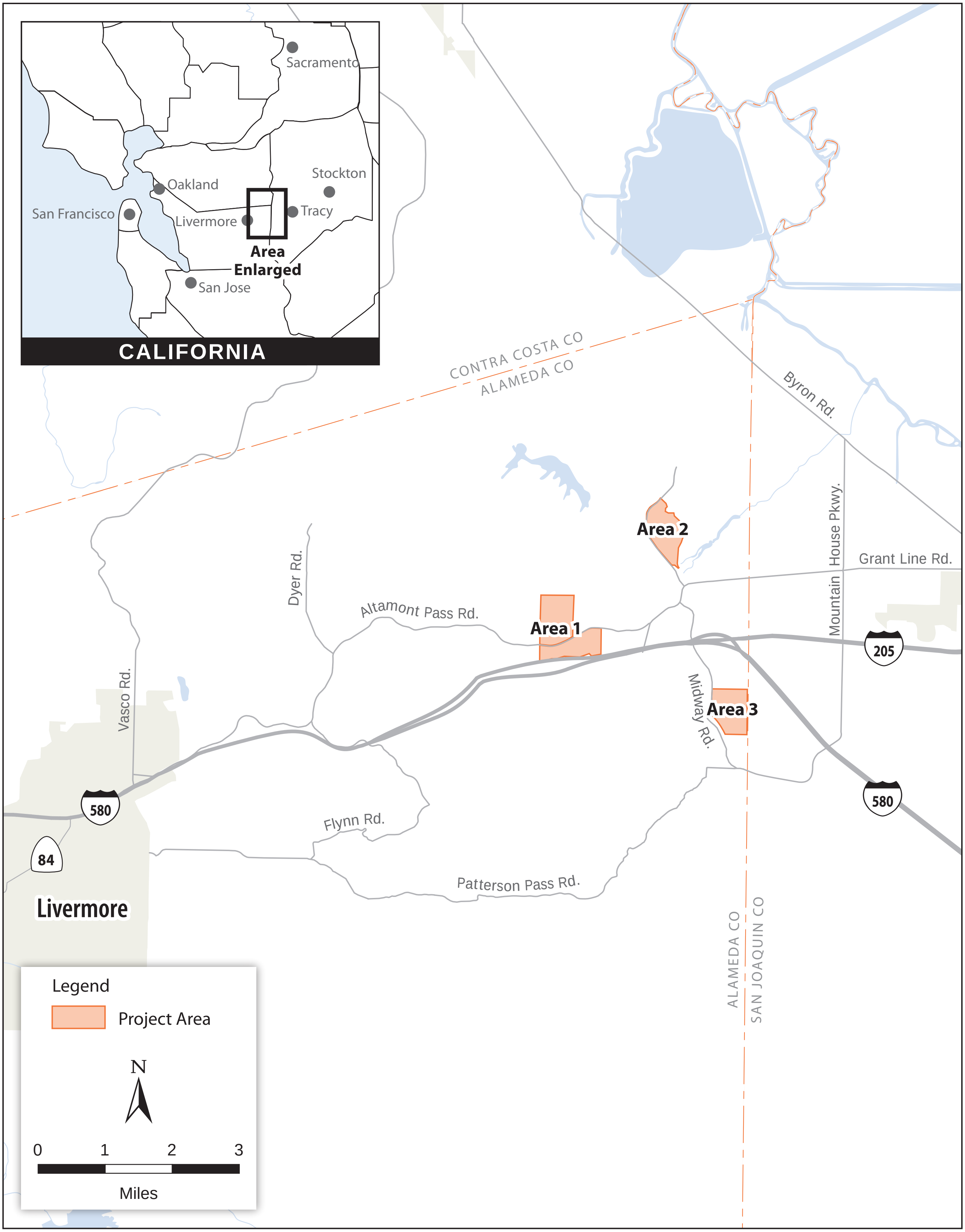
Sand Hill will also adhere to Federal Aviation Administration (FAA) lighting requirements to ensure the nacelles are appropriately lit for nighttime aviation. Implementation of appropriate lighting is expected to ensure the safety of pilots flying over the APWRA in the vicinity of the project.

Summary

Overall, Sand Hill considered multiple variables when siting its turbines. Sand Hill's siting efforts focused on avoiding and minimizing impacts where possible, and mitigating those impacts that could not be avoided. Sand Hill considered the local wind resource and topography, the County's standards and requirements, wildlife, wetland and avian resources, shadow flicker, noise levels, and public safety when siting its turbines. All three layouts represent a project that balances multiple considerations and, with mitigation or waivers, will adhere to the County's requirements. Sand Hill is currently seeking to construct Layout 3, because it is the most efficient and productive layout that achieves the project's objectives. Sand Hill will continue to work to obtain the waivers necessary to implement this layout. Sand Hill will also conduct additional studies to inform additional turbine micro-siting, if feasible, for birds. Once these efforts are completed, Sand Hill will finalize the layout for review by the TAC.

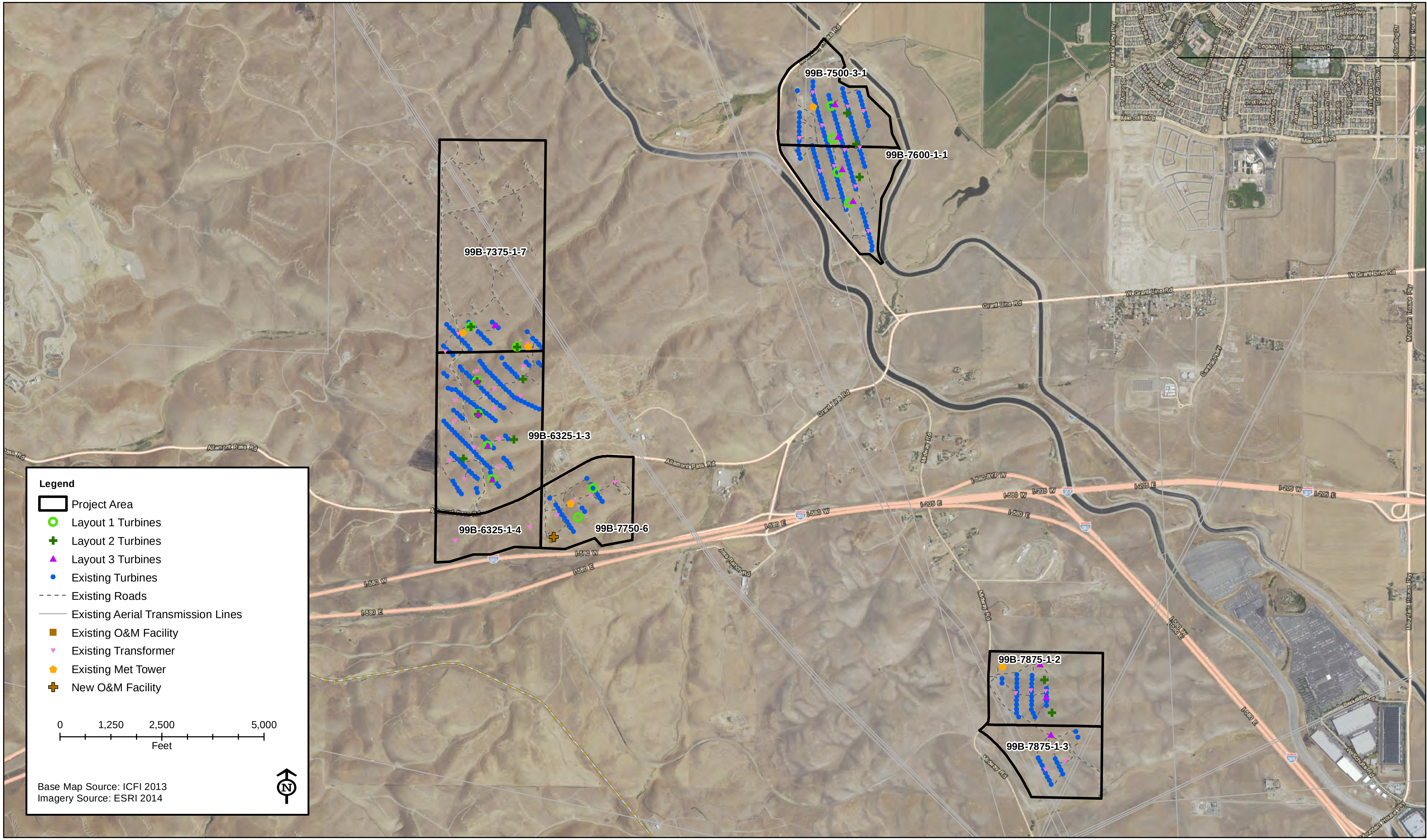
Attachments:
Figures
Attachment 1. Flicker Analysis
Attachment 2. Noise Analysis
Attachment 3. Blade Throw Analysis

Figures



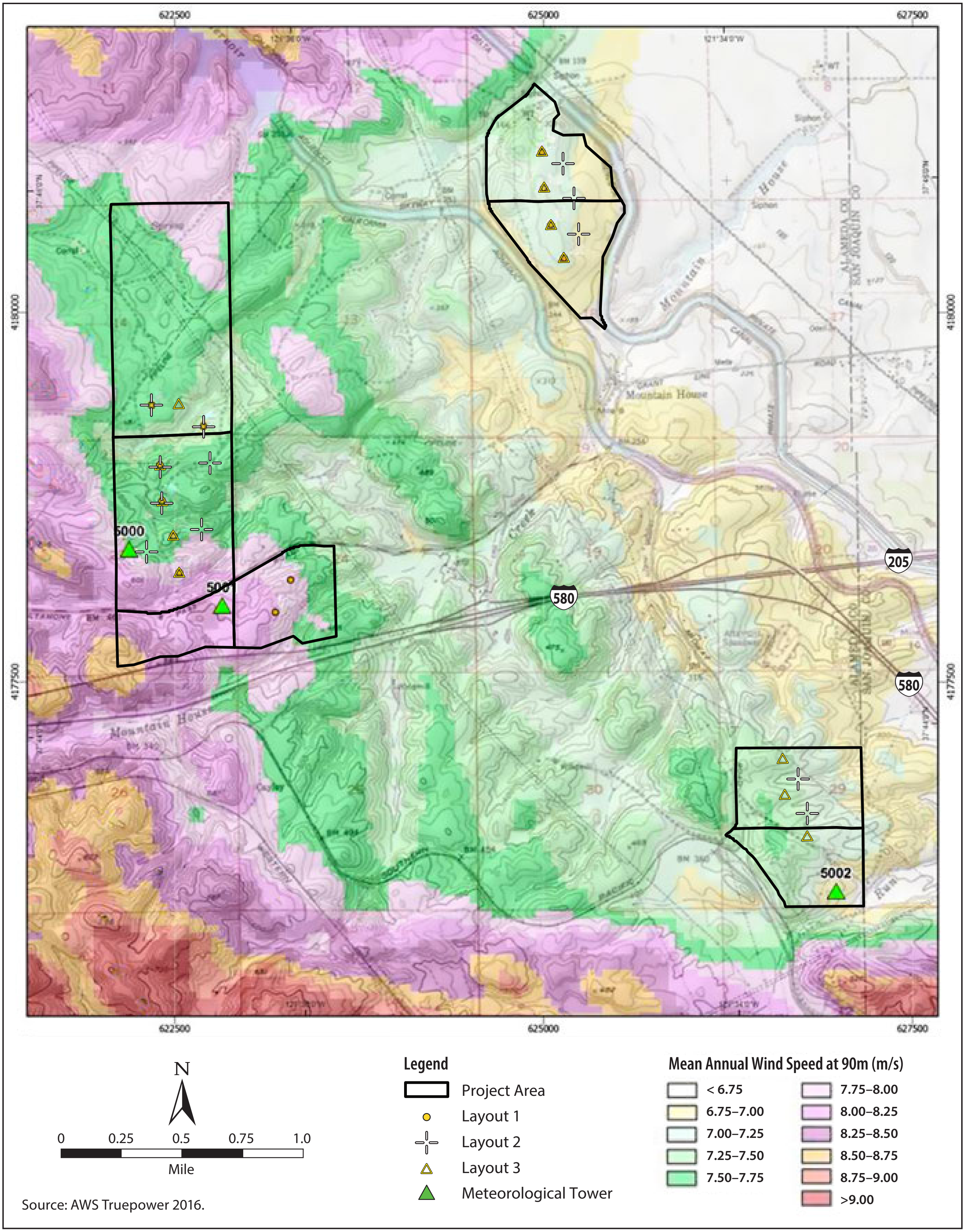
Graphics ... 00151.13 Sand Hill EIR (09-13) SS

Figure 1
Project Location



Path: K:\Projects_1\New_Dimension_Energy\P0776_15_Sand_Hills\mapdoc\TechMemo_20160304\Figure_2_Project_Overview_.mxd; Author: ; Date: 3/7/2016

Figure 2
Project Overview



Source: AWS Truepower 2016.

Graphics ... 00716.15 (3-7-2016)

Figure 3
Mean Wind Speed at 90 Meters

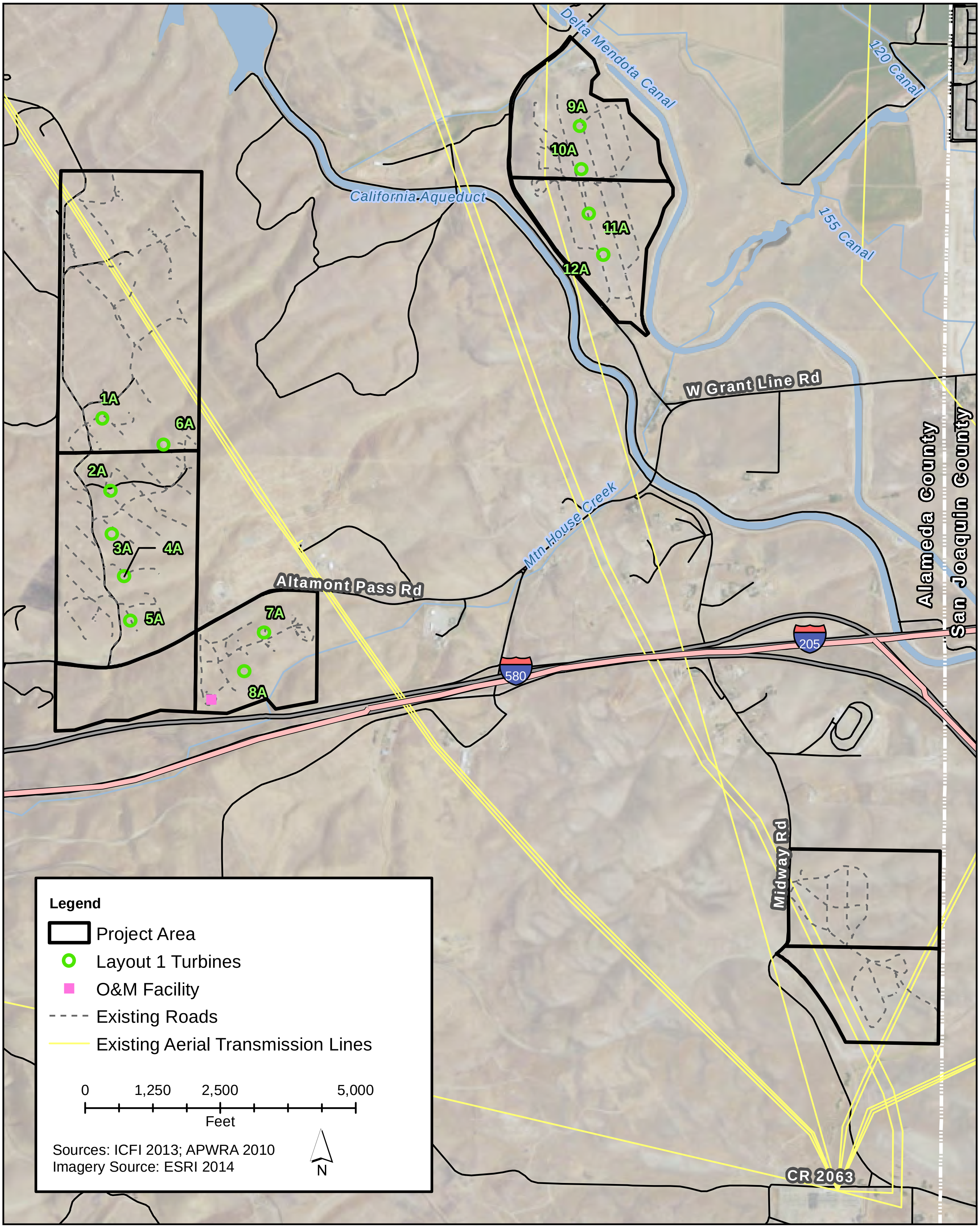
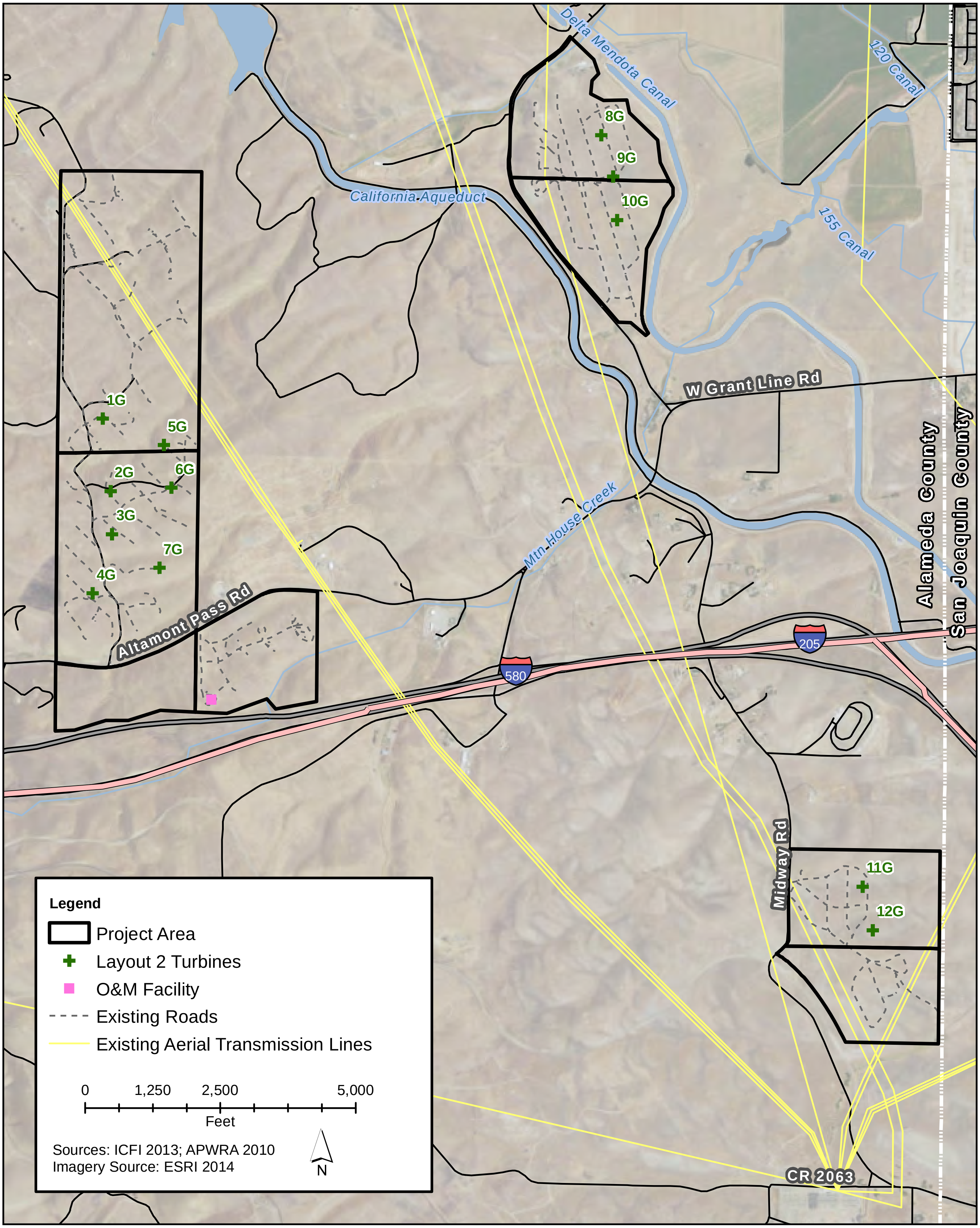
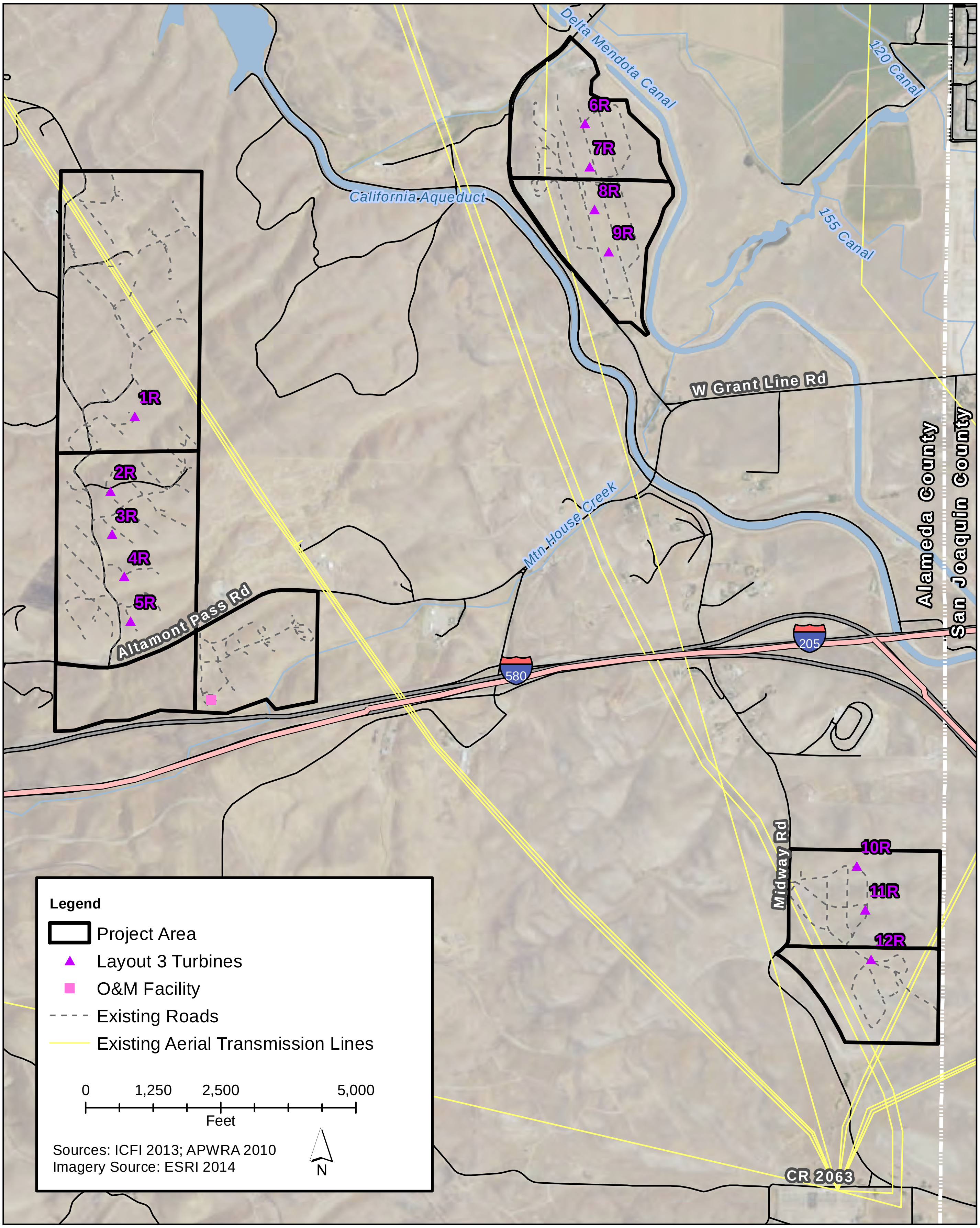


Figure 4
Sand Hill Repowering Project - Layout 1



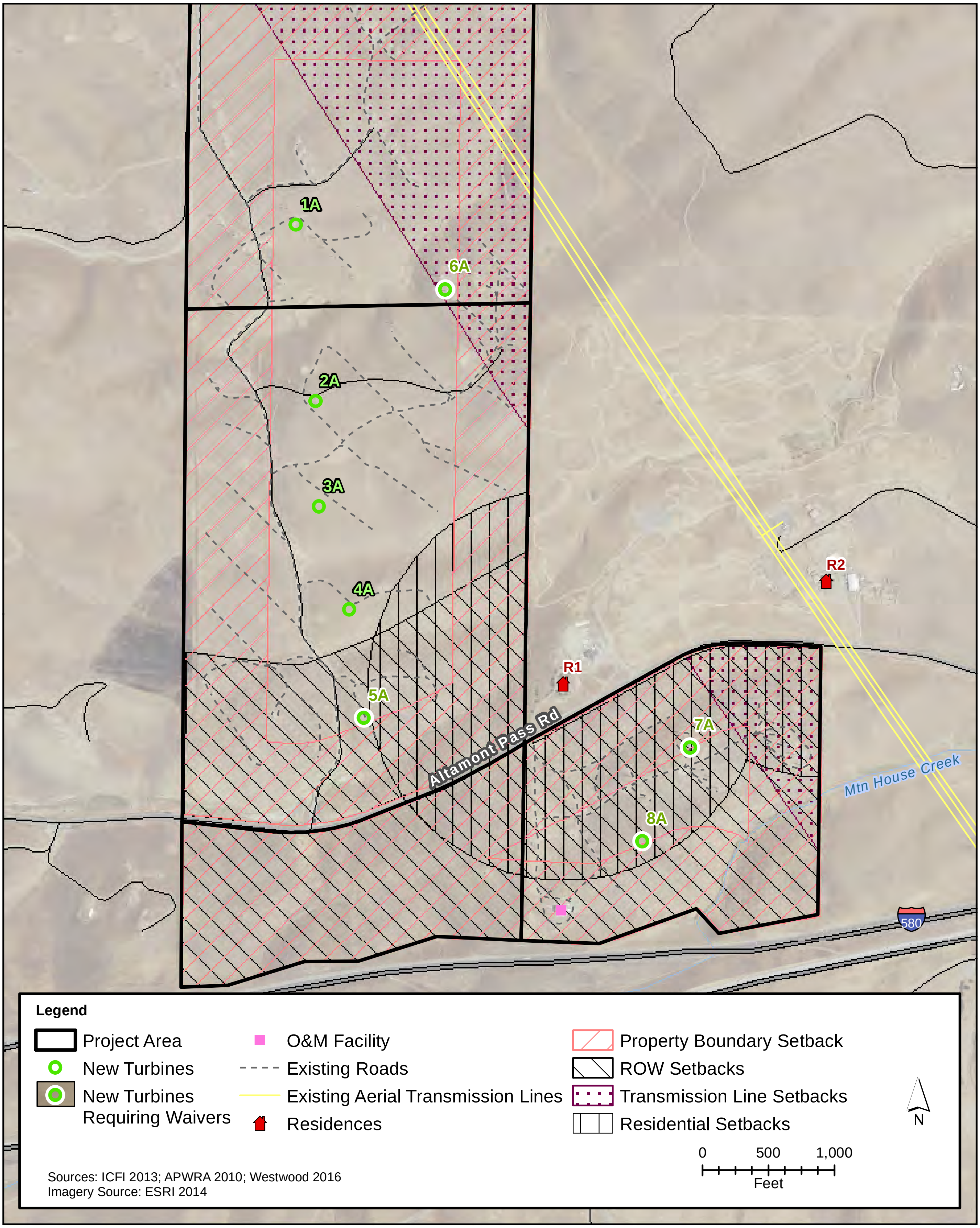
Sources: ICFI 2013; APWRA 2010
Imagery Source: ESRI 2014

Figure 5
Sand Hill Repowering Project - Layout 2



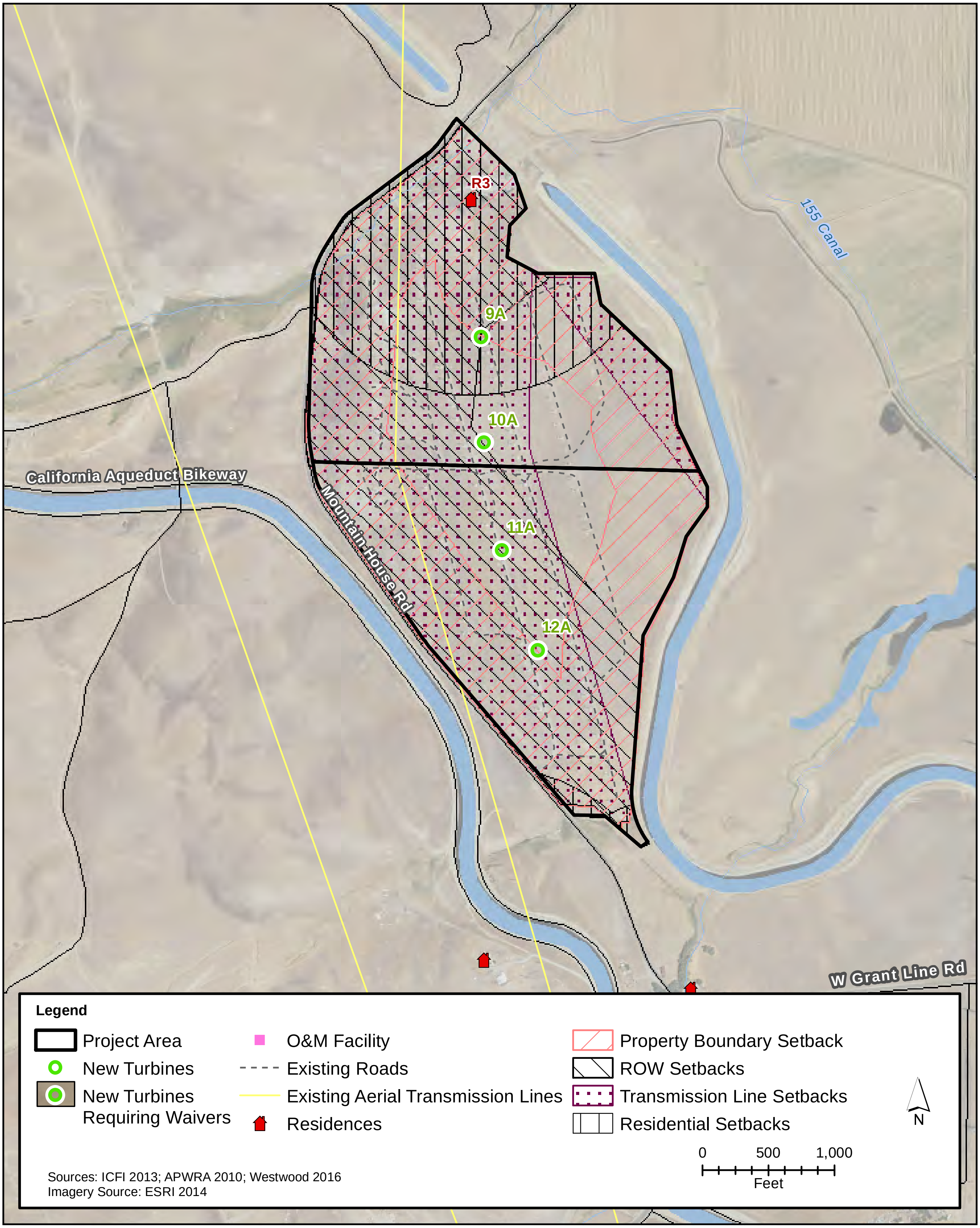
Sources: ICFI 2013; APWRA 2010
Imagery Source: ESRI 2014

Figure 6
Sand Hill Repowering Project - Layout 3



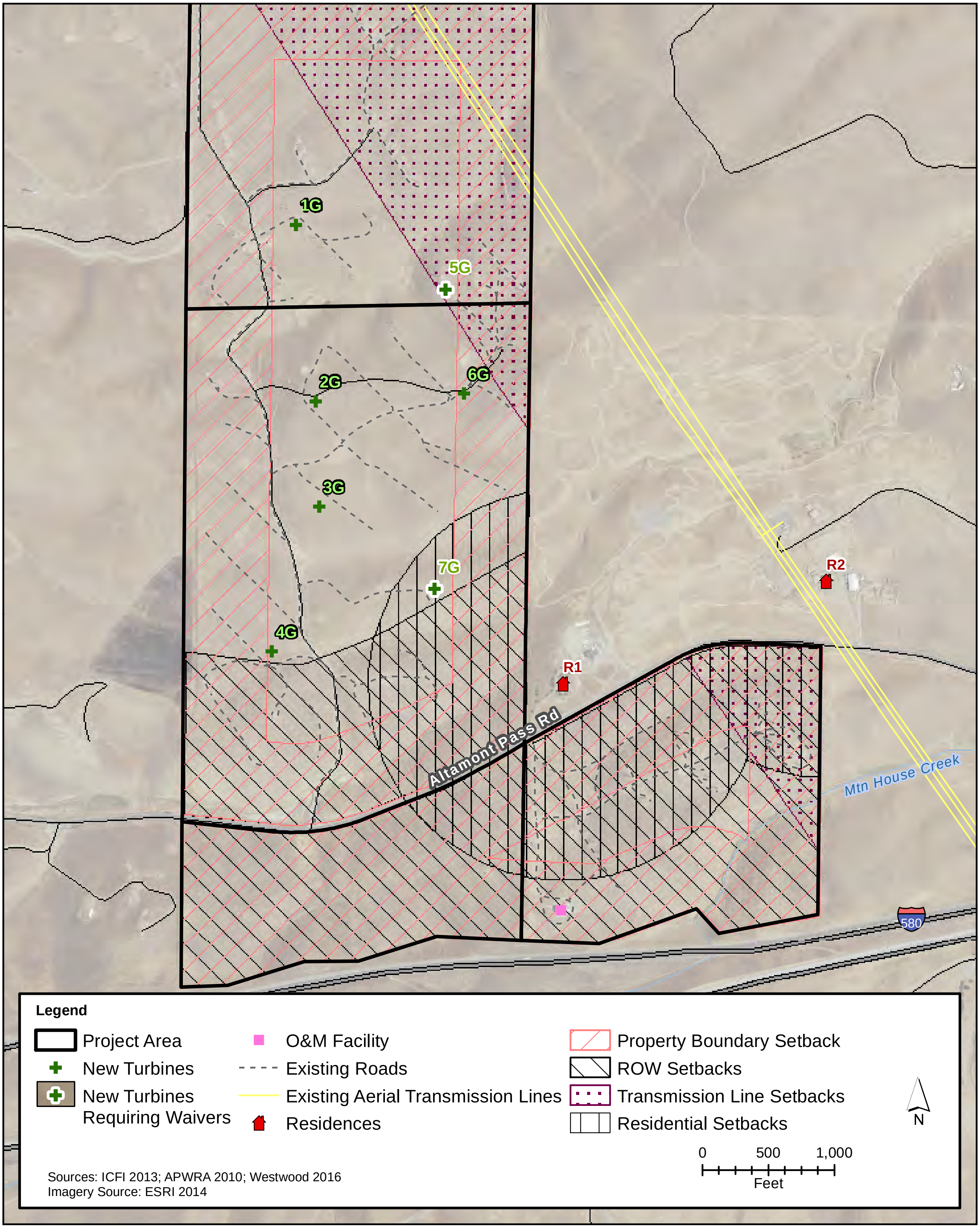
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 7a
General Setbacks for Layout 1



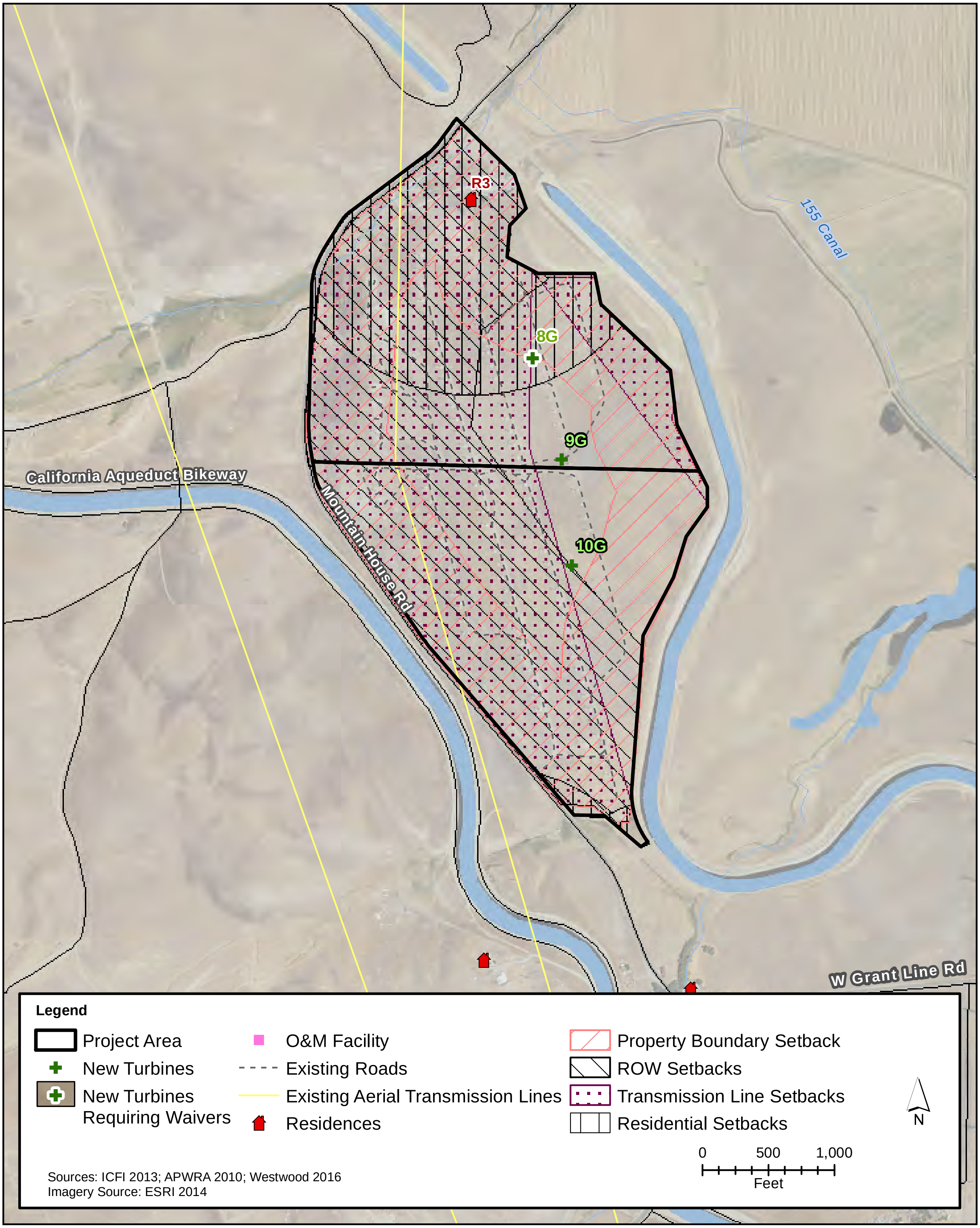
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 7b
General Setbacks for Layout 1



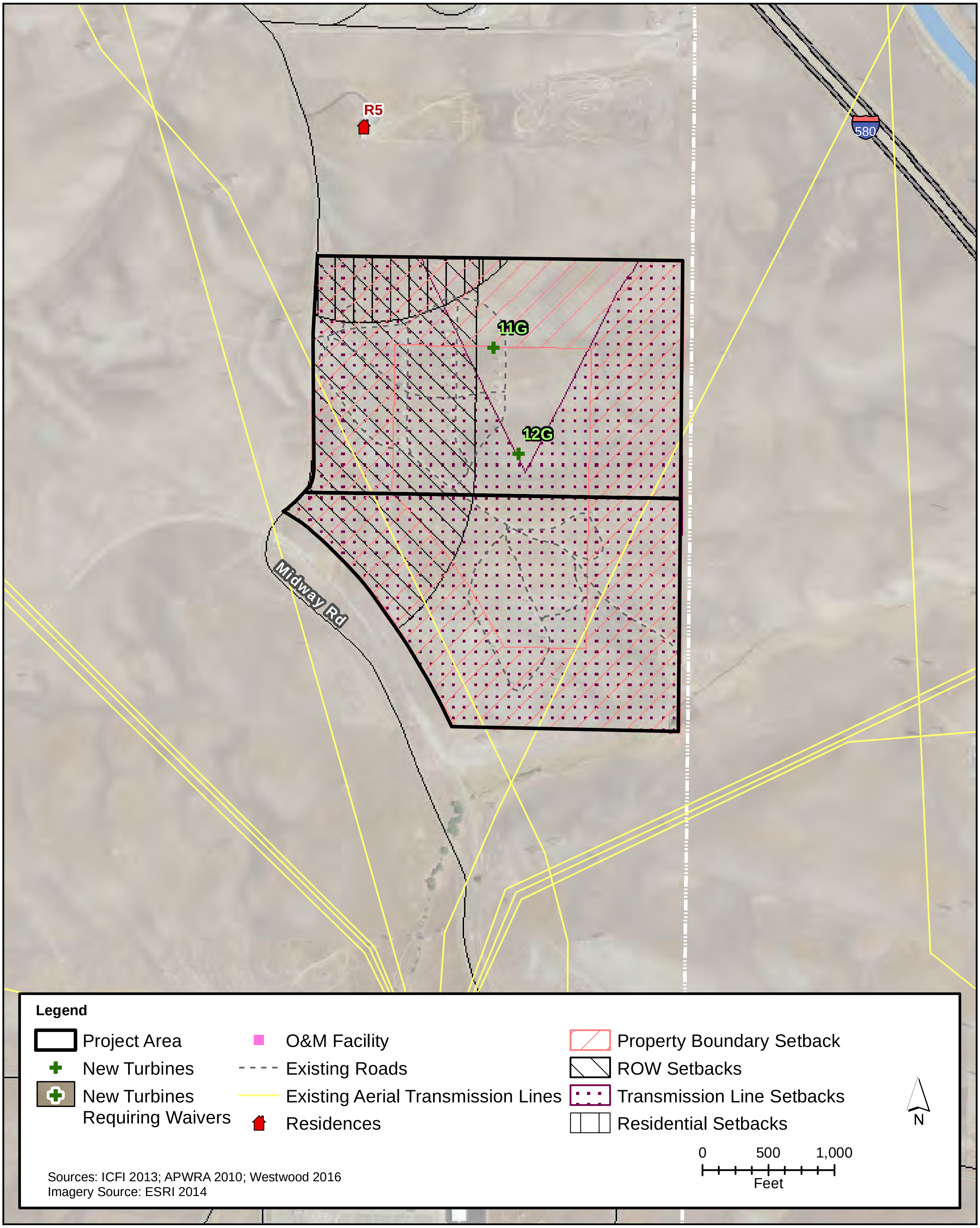
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 8a
General Setbacks for Layout 2



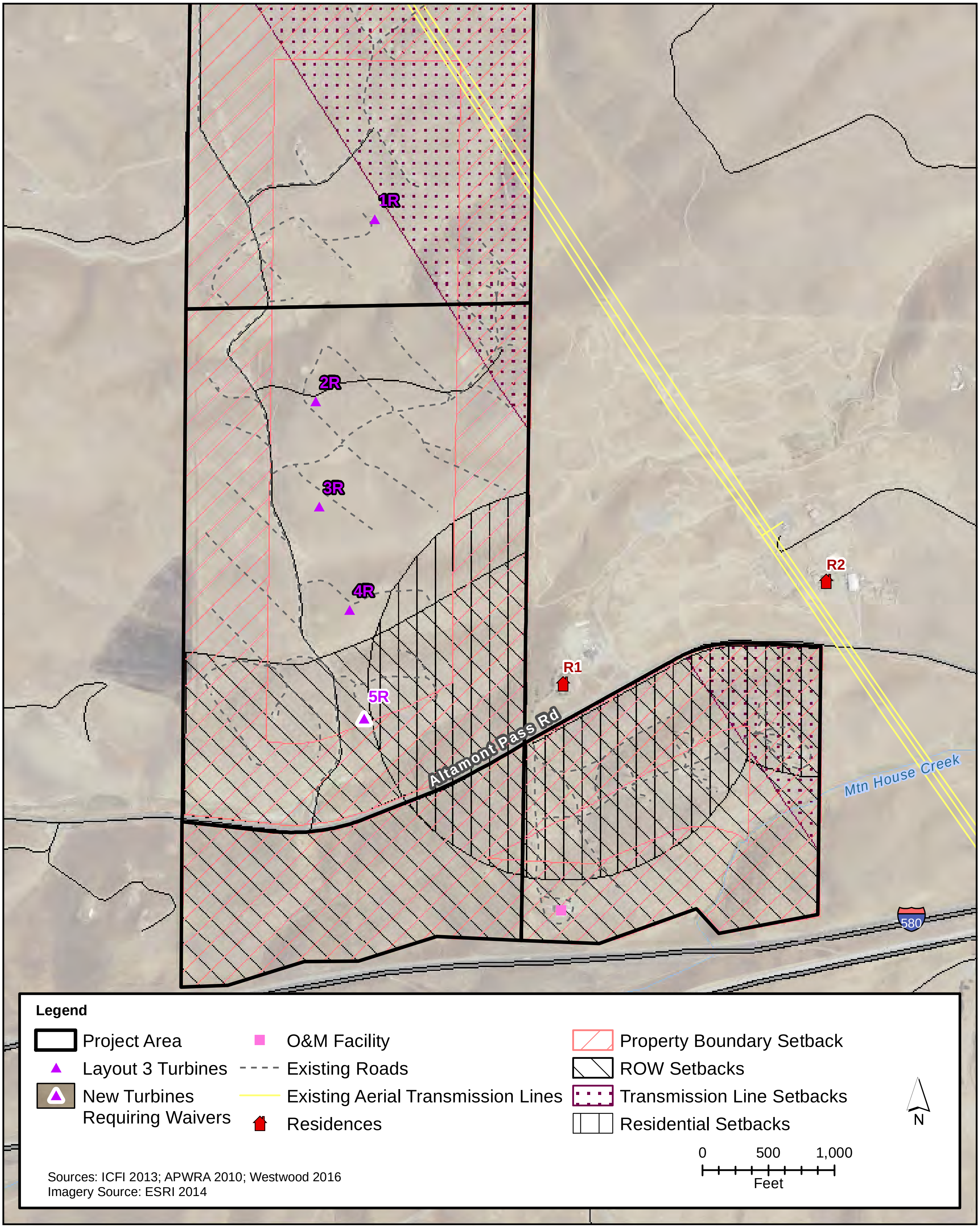
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 8b
General Setbacks for Layout 2



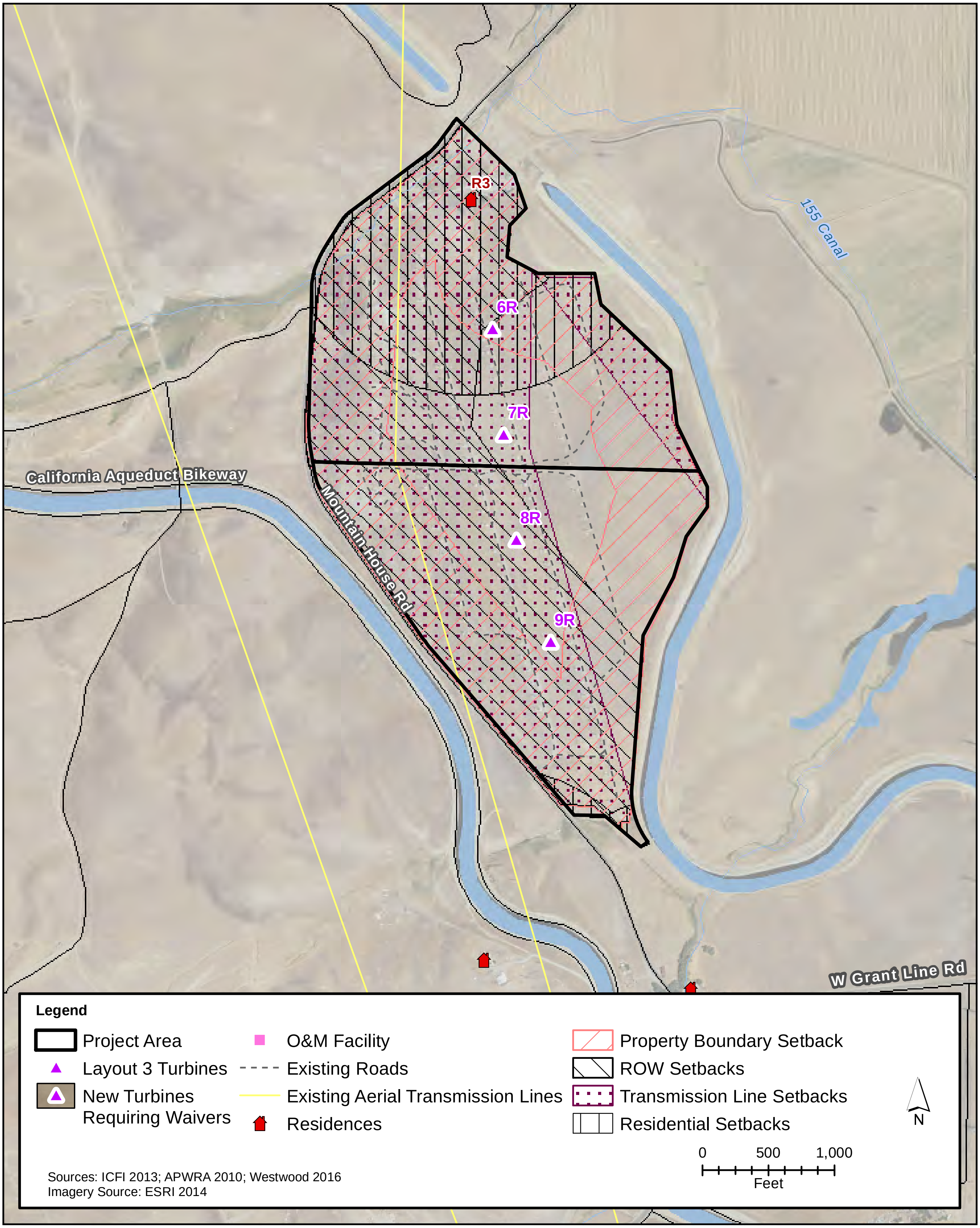
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 8c
General Setbacks for Layout 2



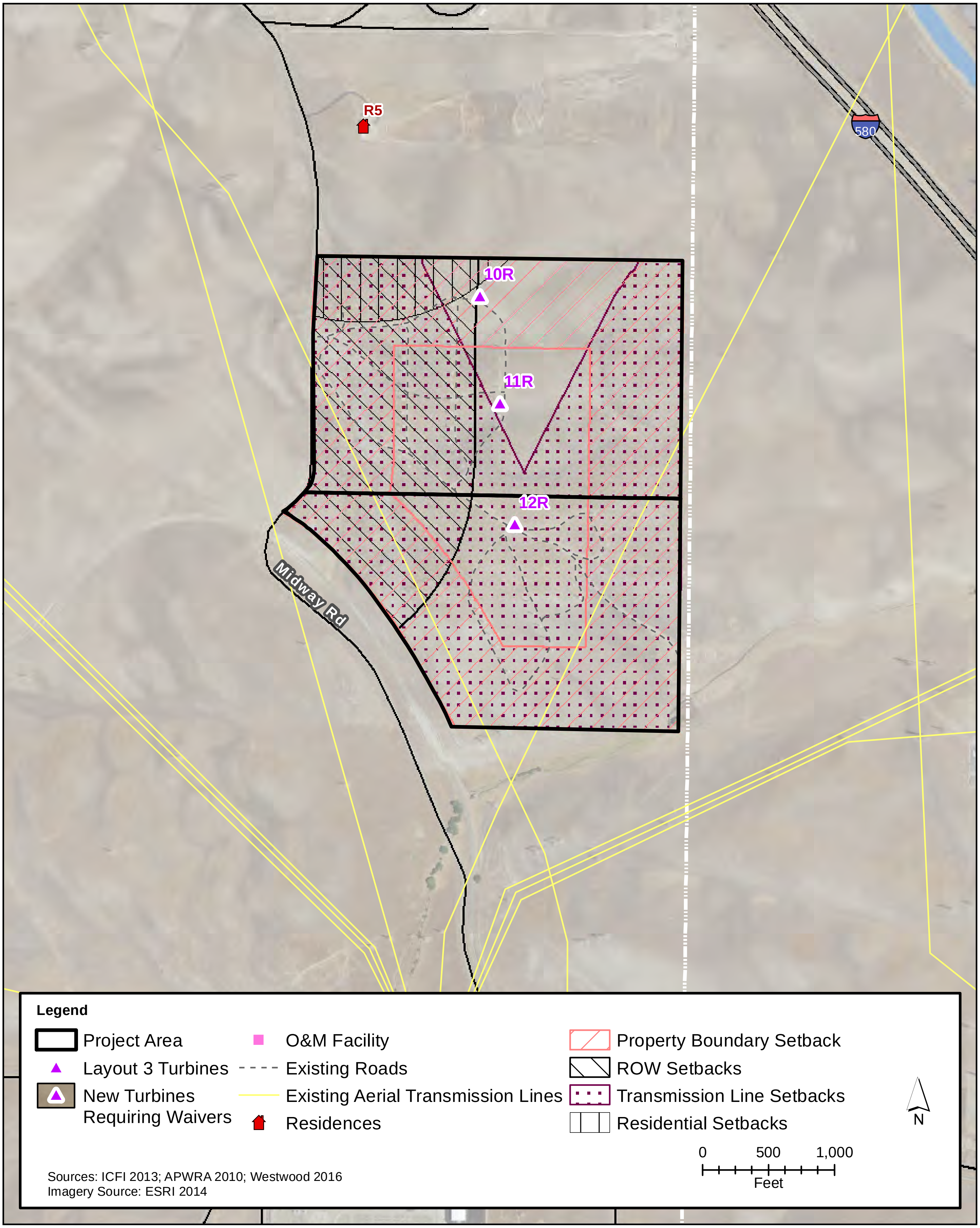
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 9a
General Setbacks for Layout 3



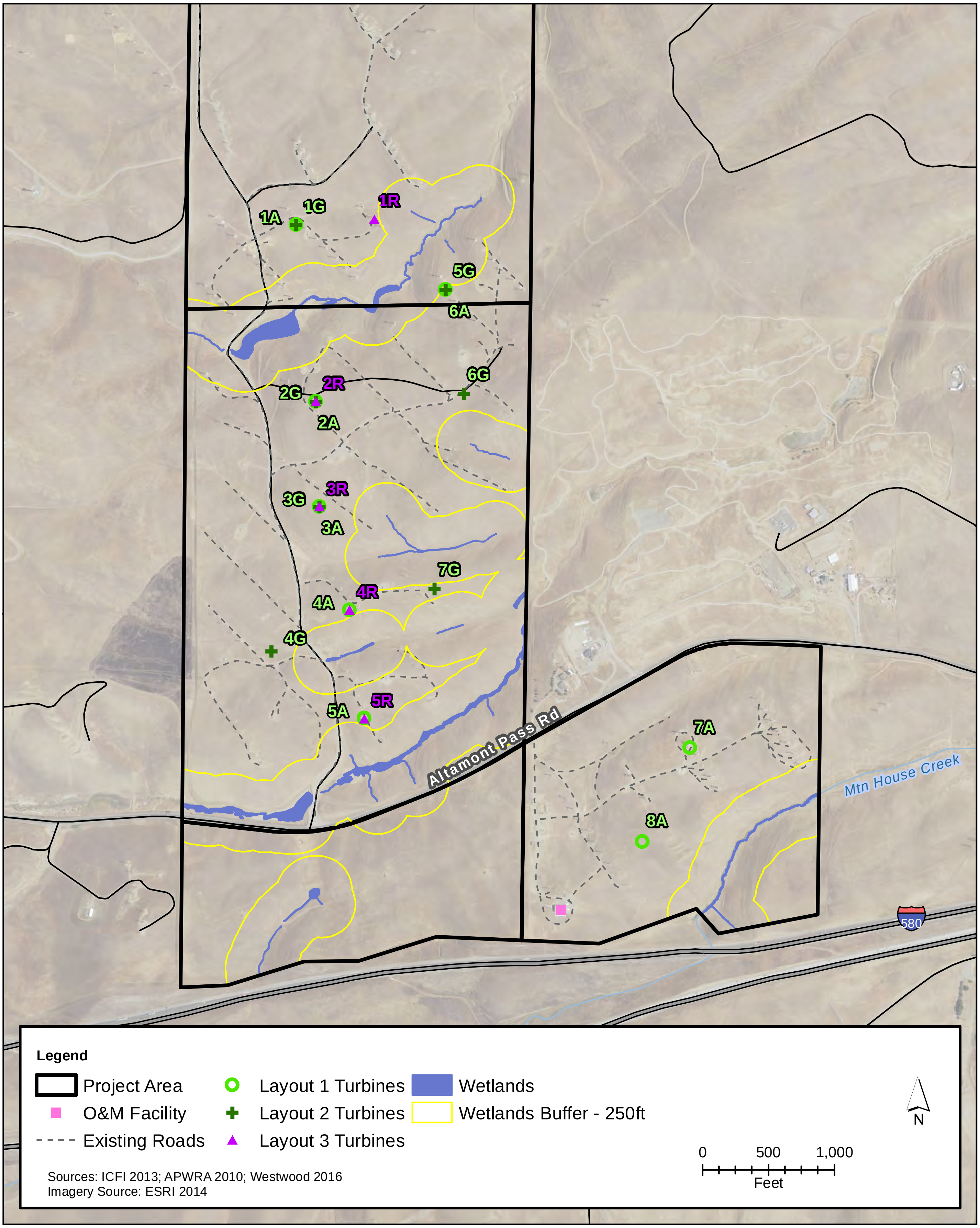
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 9b
General Setbacks for Layout 3



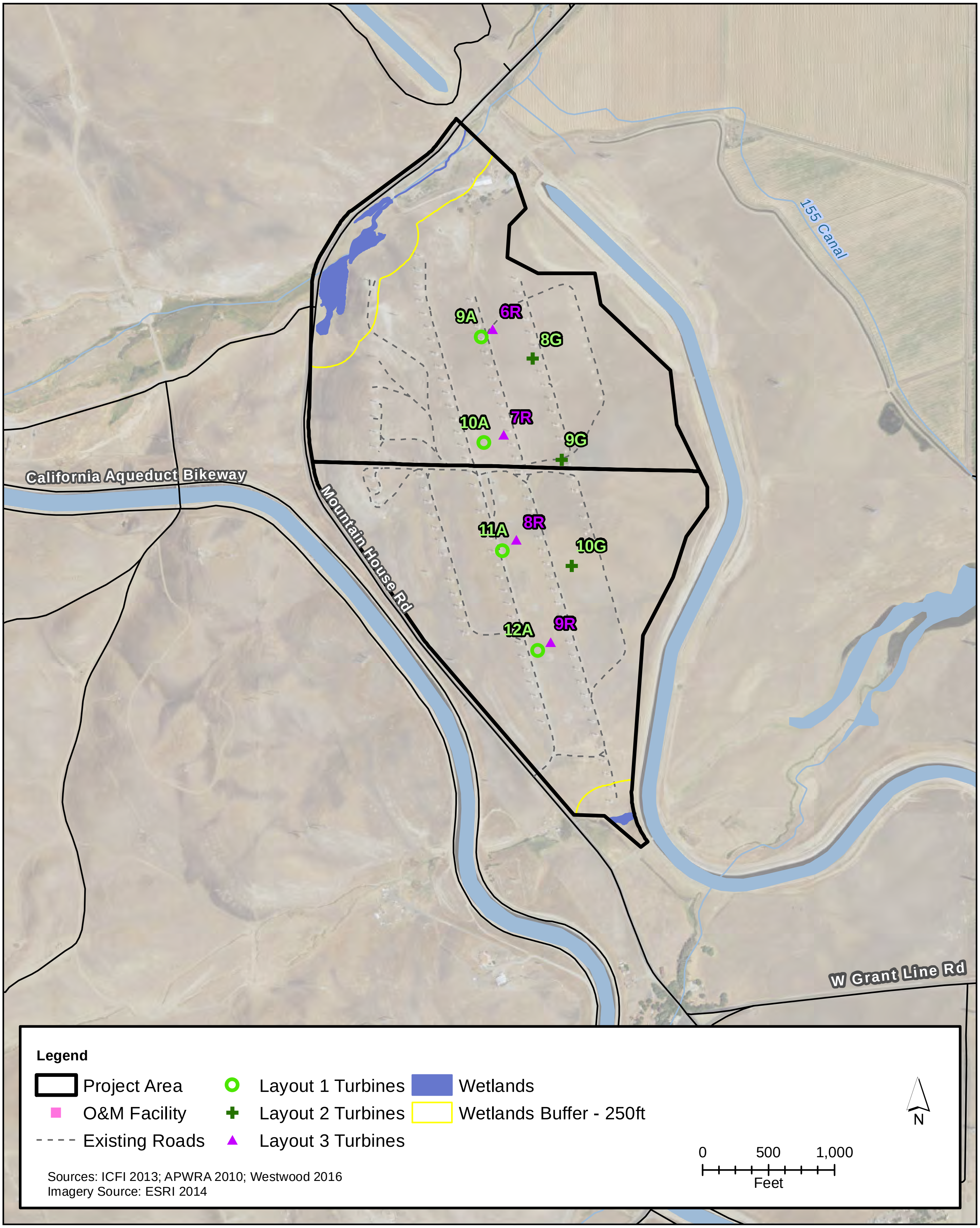
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 9c
General Setbacks for Layout 3



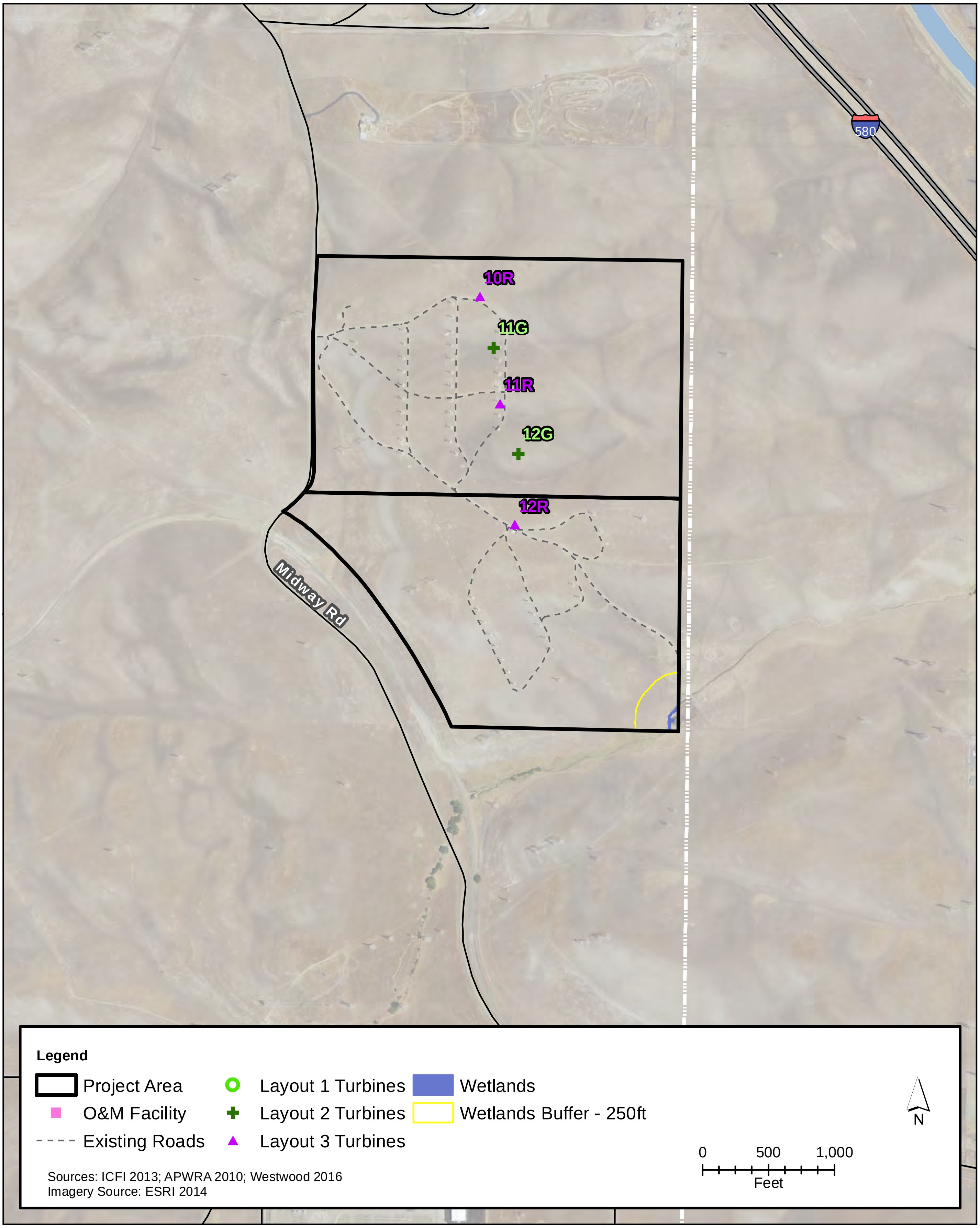
Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 10a
Wetland Resources



Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 10b
Wetland Resources



Sources: ICFI 2013; APWRA 2010; Westwood 2016
Imagery Source: ESRI 2014

Figure 10c
Wetland Resources

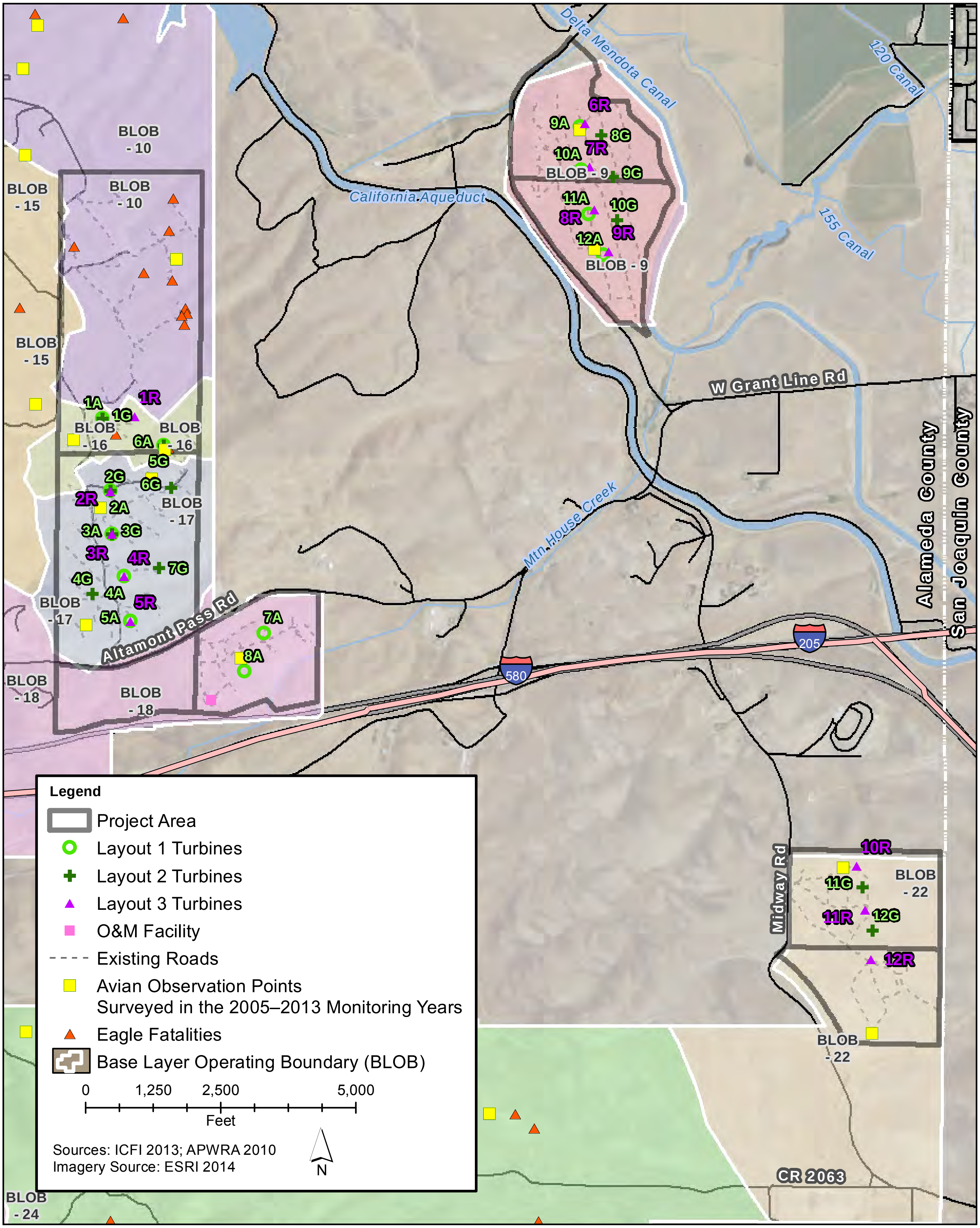


Figure 11
Avian Monitoring Locations

Attachment 1
Flicker Analysis

SHADOW FLICKER ANALYSIS – ALAMEDA COUNTY

Sand Hill Wind Project
Alameda County, California

Prepared for:

ICF International
630 K St., Suite 400
Sacramento, CA 95818

Prepared by:

Epsilon Associates, Inc.
3 Clock Tower Place, Suite 250
Maynard, MA 01754

February 5, 2016

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY 1-1

2.0 INTRODUCTION 2-1

3.0 REGULATIONS AND EVALUATION CRITERIA 3-1

4.0 SHADOW FLICKER MODELING 4-1
- 4.1 Modeling Methodology 4-1
- 4.2 Modeling Results 4-6
  - 4.2.1 Layout 1 (Preferred) Results 4-6
  - 4.2.2 Layout 2 (Alternate) Results 4-6

5.0 EVALUATION 5-1
- 5.1 Layout 1 (Preferred) 5-1
  - 5.1.1 Modeling Results Evaluation 5-1
  - 5.1.2 Mitigation 5-1
    - 5.1.2.1 Annual Limit 5-1
    - 5.1.2.2 Daily Limit 5-2
  - 5.1.3 Project Evaluation 5-2
- 5.2 Layout 2 (Alternate) Evaluation 5-3
  - 5.2.1 Modeling Results Evaluation 5-3
  - 5.2.2 Mitigation 5-3
  - 5.2.3 Project Evaluation 5-3

6.0 CONCLUSIONS 6-1

LIST OF APPENDICES

Appendix A Shadow Flicker Modeling Results: Discrete Points

Appendix B-1 Shadow Flicker Modeling Results: Graphical Calendars – Layout 1 (Preferred)

Appendix B-2 Shadow Flicker Modeling Results: Graphical Calendars – Layout 2 (Alternate)

Appendix C-1 Shadow Flicker Modeling Results: Calendars – Layout 1 (Preferred)

Appendix C-2 Shadow Flicker Modeling Results: Calendars – Layout 2 (Alternate)

LIST OF FIGURES

Figure 4-1 Shadow Flicker Modeling Locations – Layout 1 4-4

Figure 4-2 Shadow Flicker Modeling Locations – Layout 2 4-5

Figure 4-3 Layout 1 (Preferred) Annual Shadow Flicker Modeling Results 4-7

Figure 4-4 Layout 2 (Alternate) Annual Shadow Flicker Modeling Results 4-8

LIST OF TABLES

Table 4-1 Monthly Percent of Possible Sunshine 4-3

Table 4-2 Operational Hours per Wind Direction Sector 4-3

1.0 EXECUTIVE SUMMARY

Sand Hill Wind, LLC is proposing to repower an existing wind energy facility (Project) in Alameda County, California with 12 Goldwind (GW 121/2500) 2.5 megawatt (MW) wind turbines. Epsilon Associates, Inc. (Epsilon) has been retained by ICF International (ICF) to conduct a shadow flicker analysis for the proposed Goldwind turbines.

Shadow flicker analyses were conducted for a preferred and alternate Goldwind layout. The purpose of this assessment is to predict the expected annual and the worst-case daily durations of wind turbine shadow flicker at nearby residences. The applicable regulatory limits for acceptable amounts of shadow flicker are 30 hours per year and 30 minutes per day.

For Layout 1 (Preferred), the modeled maximum expected annual duration of shadow flicker at a sensitive receptor (R1) was 85 hours, 56 minutes while the maximum worst-case daily duration of shadow flicker at a sensitive receptor (R1) was 1 hour, 59 minutes. For Layout 2 (Alternate), the modeled maximum expected annual duration of shadow flicker at a sensitive receptor (R2) was 16 hours, 26 minutes, and the maximum worst-case daily duration at a sensitive receptor (R1) was 0 hours, 41 minutes. Elevated durations of shadow flicker will be mitigated through the implementation of a curtailment program. These operational curtailments will reduce the shadow flicker at all sensitive receptors to no more than 30 hours per year and 30 minutes per day.

2.0 INTRODUCTION

The proposed Sand Hill Wind Project (Project) will be located in Alameda County, California and will consist of 12 Goldwind (GW 121/2500) 2.5 MW wind turbines with a hub height of 90 meters and a rotor diameter of 121 meters. Currently two layouts are being considered: Layout 1 (Preferred) and Layout 2 (Alternate).

With respect to wind turbines, shadow flicker can be defined as an intermittent change in the intensity of light in a given area resulting from the operation of a wind turbine due to its interaction with the sun. Indoors, an observer experiences repeated changes in the brightness of the room as shadows cast from the wind turbine blades briefly pass by windows as the blades rotate. In order for this to occur, the wind turbine must be operating, the sun must be shining, and the window must be in the shadow of the wind turbine, otherwise there is no shadow flicker. A stationary wind turbine only generates a stationary shadow similar to any other structure.

This report presents the findings of the shadow flicker modeling and mitigation strategies for the wind turbines at the proposed Sand Hill Wind Project. The wind turbines were modeled in WindPRO using information provided by ICF International and Sand Hill Wind, LLC. The expected annual duration and worst-case daily duration of shadow flicker was calculated at discrete modeling locations and annual shadow flicker isolines for the area surrounding the Project were generated under two (2) 12-wind turbine layouts. The results of this analysis are found within this report.

3.0 REGULATIONS AND EVALUATION CRITERIA

The Sand Hill Wind Project in Alameda County, California is subject to the following shadow flicker requirement from the California Natural Resources Agency (CEQA) Aesthetics section (AES-5):

> *Where shadow flicker could result from the installation of wind turbines proposed near residences (i.e., within 500 meters [1,640 feet] in a generally east or west direction to account for seasonal variations), the project applicant will prepare a graphic model and study to evaluate shadow flicker impacts on nearby residences. No shadow flicker in excess of 30 minutes in a given day or 30 hours in a given year will be permitted. If it is determined that existing setback requirements as established by the County are not sufficient to prevent shadow flicker impacts on residences, Alameda County will require an increase in the required setback distances to ensure that residences are not affected. If any residence is affected by shadow flicker within the 30-minute/30-hour thresholds, the applicant will implement measures to minimize the effect, such as relocating the turbine; providing opaque window coverings, window awnings, landscape buffers, or a combination of these features to reduce flicker to acceptable limits for the affected receptor; or shutting down the turbine during the period shadow flicker would occur. Such measures may be undertaken in consultation with owner of the affected residence. If the shadow flicker study indicates that any given turbine would result in shadow flicker exceeding the 30-minute/30-hour thresholds and the property owner is not amenable to window coverings, window awnings, or landscaping and the turbine cannot be shut down during the period of shadow flicker, then the turbine will be relocated to reduce the effect to acceptable limits.*

The Project will therefore be evaluated in this analysis against the annual shadow flicker duration limit of 30 hours per year and the daily flicker duration limit of 30 minutes per day.

4.0 SHADOW FLICKER MODELING

4.1 Modeling Methodology

Shadow flicker was modeled using a software package, WindPRO version 3.0.639. WindPRO is a software suite developed by EMD International A/S and is used for assessing potential environmental impacts from wind turbines. Worst-case shadow flicker in the area surrounding the wind turbines was calculated based on data inputs including: location of the wind turbines, location of discrete modeling points, wind turbine dimensions, calculation limits, and terrain data. Based on these data, the model was able to incorporate the appropriate sun angle and maximum daily sunlight for this latitude into the calculations. The resulting worst-case calculations assume that the sun is always shining during the day and that the wind turbine is always operating. The WindPRO shadow flicker module can be further refined by incorporating sunshine probabilities and wind turbine operational estimates by wind direction over the course of a year. The values for this further refinement, also known as the "expected" shadow flicker, are presented in this section.

Two (2) proposed wind turbine layouts for the Project dated December 2, 2015 were provided by ICF. Each layout includes 12 proposed wind turbines. Layout 1 wind turbine locations (Preferred) are shown in Figure 4-1. Layout 2 wind turbine locations (Alternate) are identified in Figure 4-2. All wind turbines are proposed to be Goldwind GW 121/2500 2.5 MW units. Each wind turbine has the following characteristics based on the technical data provided by ICF:

- Rated Power = 2,500 kW
- Hub Height = 90 meters
- Rotor Diameter = 121 meters
- Cut-in Wind Speed = 3 m/s
- Cut-out Wind Speed = 22 m/s

In the United States, shadow flicker is commonly evaluated out to a distance of ten times the rotor diameter or 1,000 meters. For example, the Ohio Power Siting Board has required shadow flicker to be analyzed out to 1,000 meters from a wind turbine. According to the Massachusetts Model Bylaw for wind energy facilities, shadow flicker impacts are minimal at and beyond a distance of ten rotor diameters.[1] Defining the shadow flicker calculation area has also been addressed in Europe where the ten times rotor diameter approach has been accepted in multiple European countries.[2] For this Project, ten times the rotor diameter of the proposed wind turbine corresponds to a distance of 1,210 meters. This

---

[1] Massachusetts Department of Energy Resources, "Model As-of-Right Zoning Ordinance or Bylaw: Allowing Use of Wind Energy Facilities" 2009.

[2] Parsons Brinckerhoff, "Update of UK Shadow Flicker Evidence Base" Prepared for Department of Energy and Climate Change, 2011.

analysis includes shadow flicker calculations out to this specified distance from each wind turbine in the model for both Layout 1 and Layout 2.

A sensitive receptor dataset was provided by ICF on November 24, 2015. A total of 37 locations were included in the analysis and are shown in Figure 4-1 and Figure 4-2, displaying their relative proximity to the proposed wind turbine locations. Each modeling point was assumed to have a window facing all directions ("greenhouse" mode) which yields conservative results. In addition, project parcels were provided by ICF on November 24, 2015. These parcels are shown on Figures 4-1 and 4-2.

The model was set to limit calculations to 1,210 meters from a wind turbine, the equivalent of ten times the rotor diameter. Therefore, the shadow flicker quantity at any of the 37 modeling receptors greater than 1,210 meters from a wind turbine was zero. In addition to modeling discrete receptors, shadow flicker was calculated at grid points in the area surrounding the modeled wind turbines. A 20-meter spacing was used for this grid.

The terrain height contour elevations for the modeling domain were generated from elevation information derived from the National Elevation Dataset (NED), which serves as the elevation layer of The National Map and was developed by the U.S. Geological Survey. Conservatively, obstacles, i.e. buildings and vegetation, were excluded from the analysis. When accounted for, such obstacles may significantly mitigate or eliminate the shadow flicker effect depending on their size, type, and location. In addition, shadow flicker durations were calculated only when the angle of the sun was at least 3° above the horizon.

Monthly sunshine probability values were input for each month from January to December. These numbers were obtained from a publicly available historical dataset for Sacramento, California from the National Climatic Data Center (NCDC).[3] Table 4-1 shows the percentage of sunshine hours by month used in the shadow flicker modeling. These values are the percentages that the sun is expected to be shining during daylight hours.

The number of hours the wind turbines are expected to operate for the 16 cardinal wind directions was input into the model. These hours were generated from a joint frequency distribution of wind speed and wind direction of extrapolated 90-meter wind data provided by ICF. These hours per wind direction sector are used by WindPRO to estimate the "wind direction" and "operation time" reduction factors. Based on this dataset, the wind turbines would operate 71% of the year due to cut-in and cut-out specifications of the proposed unit. Table 4-2 shows the distribution of operational hours for the 16 wind directions.

---

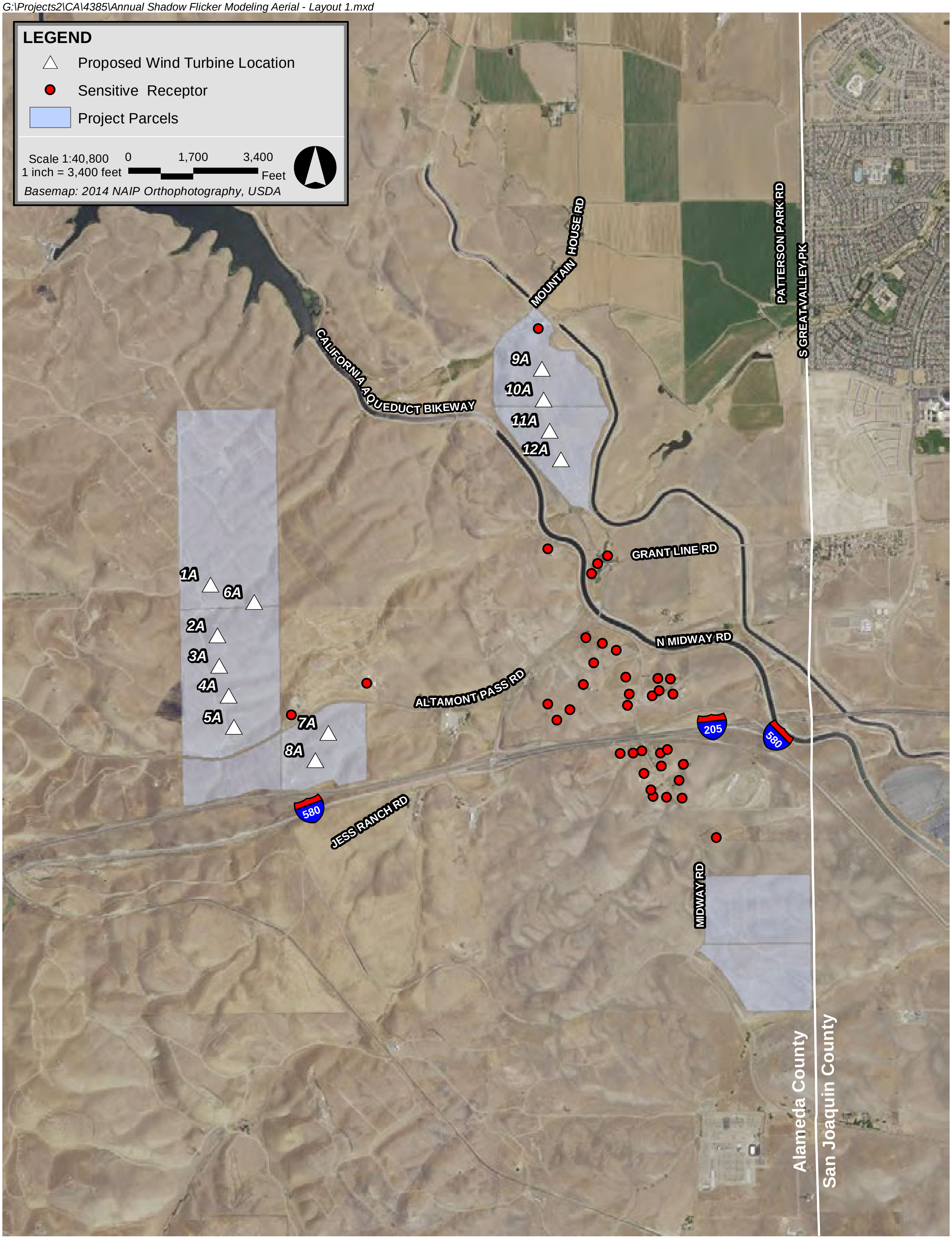
[3] NCDC, http://www1.ncdc.noaa.gov/pub/data/ccd-data/pctpos14.txt. Accessed in January 2016.

Table 4-1 Monthly Percent of Possible Sunshine

Month	Possible Sunshine
January	45%
February	62%
March	73%
April	82%
May	92%
June	94%
July	97%
August	96%
September	93%
October	84%
November	61%
December	47%

Table 4-2 Operational Hours per Wind Direction Sector

Wind Sector	Operational Hours
N	262
NNE	108
NE	40
ENE	36
E	61
ESE	125
SE	147
SSE	46
S	32
SSW	95
SW	2192
WSW	1875
W	366
WNW	140
NW	178
NNW	538
Annual	6,240



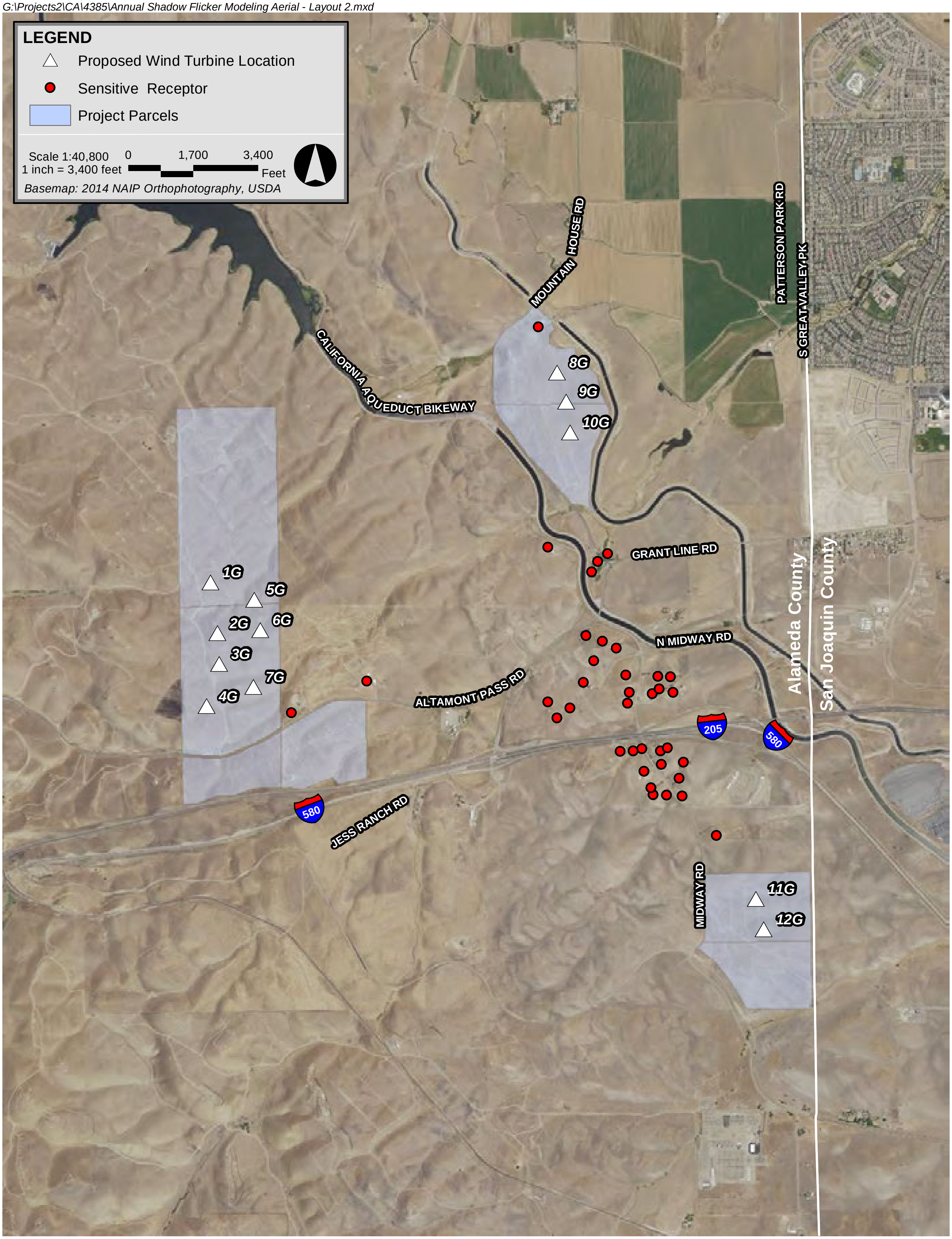
Sand Hill Wind **Alameda County, California**

Epsilon ASSOCIATES INC.

Figure 4-1

Shadow Flicker Modeling Locations - Layout 1

G:\Projects2\CA\4385\Annual Shadow Flicker Modeling Aerial - Layout 2.mxd



Sand Hill Wind **Alameda County, California**

Epsilon Associates Inc.

Figure 4-2

Shadow Flicker Modeling Locations - Layout 2

4.2 Modeling Results

Following the modeling methodology outlined in Section 4.1, WindPRO was used to calculate shadow flicker at the 37 discrete modeling points and generate shadow flicker isolines based on the grid calculations.

4.2.1 Layout 1 (Preferred) Results

Layout 1 consists of 12 wind turbine locations indicated by the letter "A" shown in Figure 4-1. Table A-1, in Appendix A, presents the modeling results for the 37 modeling receptor locations using wind turbine Layout 1. The predicted expected annual shadow flicker duration ranged from 0 hours, 0 minutes per year to 85 hours, 56 minutes per year. The majority of the modeling locations (34) were predicted to experience no annual shadow flicker. The results of the expected annual shadow flicker modeling, explicitly from Layout 1, are shown graphically with flicker isolines in Figure 4-3.

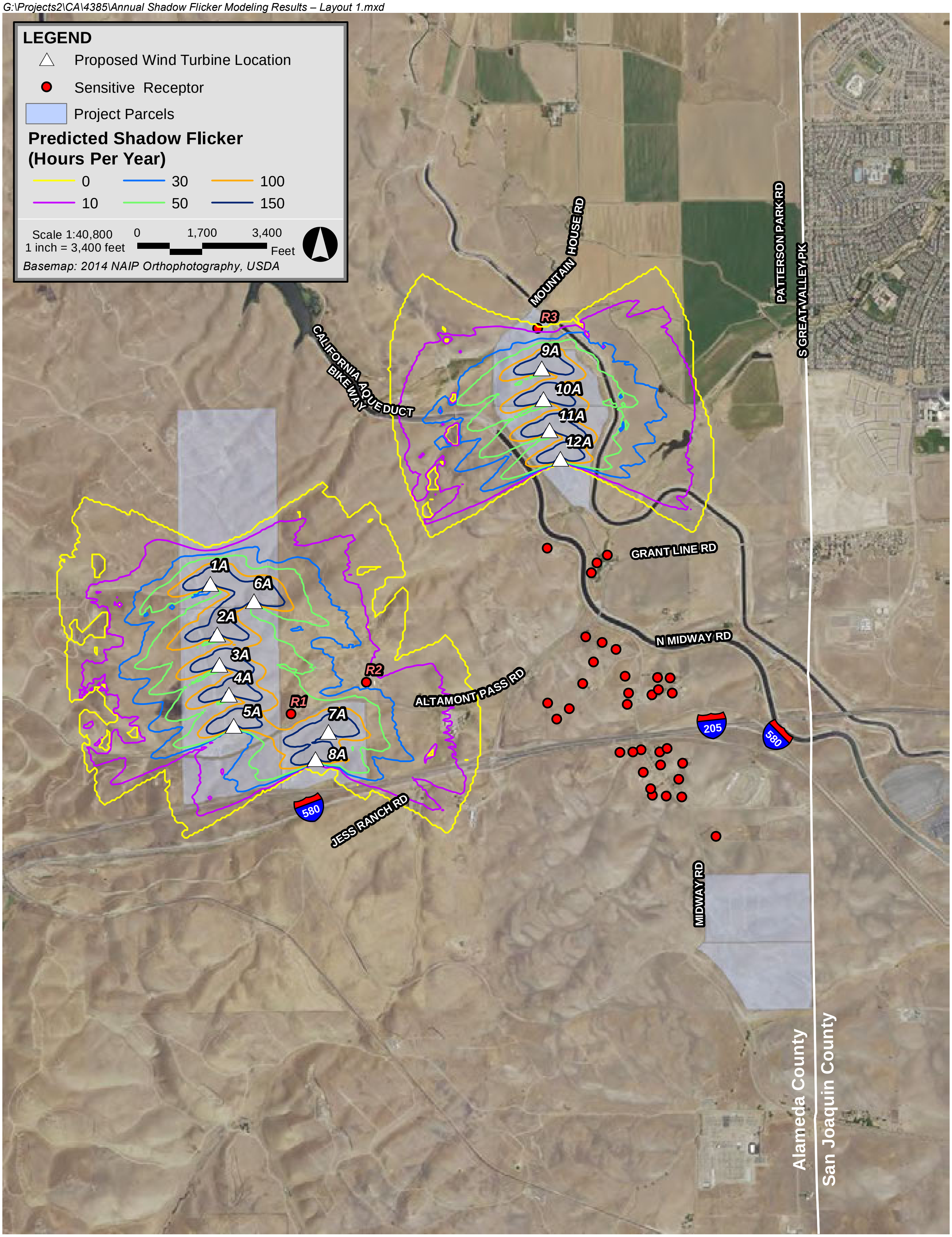
The predicted worst-case daily shadow flicker duration ranged from 0 hours, 0 minutes per day to 1 hour, 59 minutes per day. The majority of the modeling locations (34) were predicted to experience no daily shadow flicker. These results are presented numerically in Table A-1 of Appendix A.

4.2.2 Layout 2 (Alternate) Results

Layout 2 consists of 12 wind turbine locations indicated by the letter "G" shown in Figure 4-2. Table A-2, in Appendix A, presents the modeling results for the 37 modeling receptor locations using wind turbine Layout 2. The predicted expected annual shadow flicker duration ranged from 0 hours, 0 minutes per year to 16 hours, 26 minutes per year. The majority of the modeling locations (35) were predicted to experience no annual shadow flicker. The results of the expected annual shadow flicker modeling, explicitly from Layout 2, are shown graphically with flicker isolines in Figure 4-4.

The predicted worst-case daily shadow flicker duration ranged from 0 hours, 0 minutes per day to 0 hours, 41 minutes per day. The majority of the modeling locations (35) were predicted to experience no daily shadow flicker. These results are presented numerically in Table A-2 of Appendix A.

G:\Projects2\CA\4385\Annual Shadow Flicker Modeling Results – Layout 1.mxd

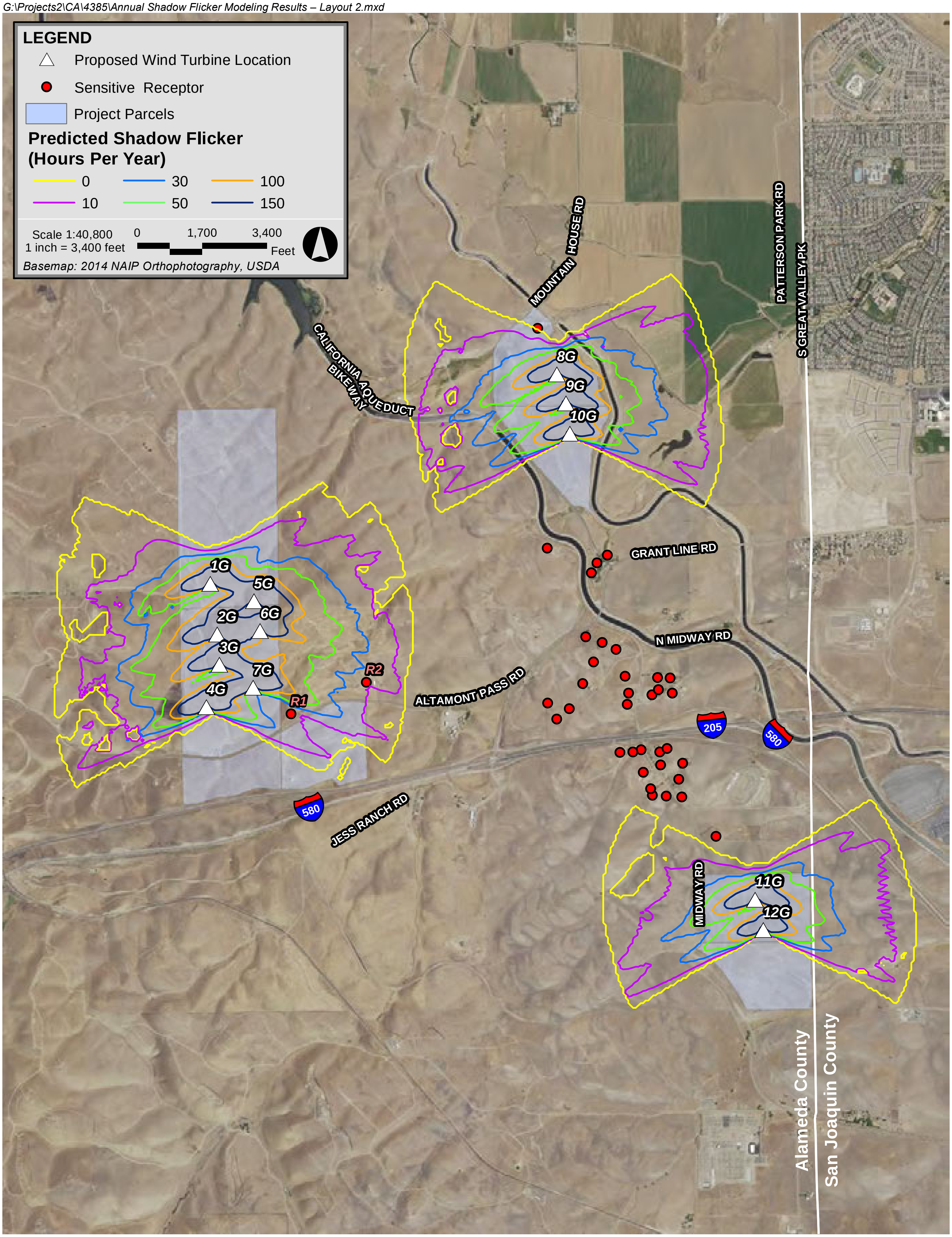


Sand Hill Wind   **Alameda County, California**

Figure 4-3

Annual Shadow Flicker Modeling Results – Layout 1

G:\Projects2\CA\4385\Annual Shadow Flicker Modeling Results – Layout 2.mxd



Sand Hill Wind **Alameda County, California**

Figure 4-4

Annual Shadow Flicker Modeling Results – Layout 2

5.0 EVALUATION

5.1 Layout 1 (Preferred)

5.1.1 Modeling Results Evaluation

Three (3) out of 37 modeling receptors were predicted to experience shadow flicker from the proposed wind turbine Layout 1 (Preferred). Of these three locations, two (2) are predicted to experience less than 30 hours per year while one (1) location is predicted to exceed 30 hours of shadow flicker per year, on an expected flicker basis. All three (3) of these locations are predicted to exceed 30 minutes per day, on a worst-case flicker basis. Therefore, mitigation will be necessary in order to achieve compliance with the 30 hours per year and 30 minutes per day limits.

5.1.2 Mitigation

In order to achieve compliance with the annual shadow flicker limit of 30 hours per year and 30 minutes per day, the curtailment of individual wind turbines will be incorporated into the operation of the wind energy facility. The key objective of the mitigation is to curtail operations for an adequate number of hours when shadow flicker is possible (worst-case) resulting in a sufficient reduction in the actual duration of shadow flicker in order for the 30 hour per year limit and 30 minute per day limit to be met.

5.1.2.1 Annual Limit

Based on the shadow flicker modeling results, one (1) location (R1) is expected to exceed 30 hours per year of shadow flicker with 85 hours, 56 minutes predicted. This location (R1) is identified in Figure 4-3. The expected annual durations of shadow flicker shown in Table A-1 include reductions taken for overcast conditions, wind speeds below cut-in or above cut-out, and wind direction. A "total reduction" factor is used by the model to calculate the expected shadow flicker from the "worst-case" shadow flicker. The graphical calendar for location R1 is provided in Appendix B-1 while Appendix C-1 includes the tabular calendar for this location. Both calendars show, on a daily basis, the period when shadow flicker may occur at a particular modeling receptor (worst-case). These daily values are summed for each month and then a unique monthly "total reduction" factor is applied to the worst-case duration to obtain expected shadow flicker durations.

One curtailment approach is to temporarily shut down the wind turbine(s) for the number of worst-case minutes which would result in the required reduction in expected flicker based on the total reduction factors incorporated into the modeling. For example, if the expected shadow flicker needed to be reduced by 82 minutes at location R1, one option would be to curtail operations in January during periods when shadow flicker has the potential to occur at this location. During the month of January wind turbine 7A would be shut down for approximately 546 minutes (9.1 hours) based on the total reduction factor for that month of 0.15 (82 / 0.15 = 546.7).

The preferred approach with respect to periods for curtailments and specific wind turbines has not been determined at this time. The owner/operator of this wind energy facility will specify a detailed mitigation plan based the shadow flicker modeling results, operational considerations, and supervisory control and data acquisition (SCADA) options in order to ensure compliance with the annual limit.

5.1.2.2 Daily Limit

Based on the shadow flicker modeling results, three (3) locations (R1, R2, and R3) are expected to exceed 30 minutes per day of flicker. Location R1 was modeled to experience a daily maximum of 1 hour, 59 minutes with 241 days over 30 minutes, worst-case. Location R2 was modeled to experience a daily maximum of 0 hours, 43 minutes with 33 days over 30 minutes, worst-case. Location R3 was modeled to experience a daily maximum of 0 hours, 45 minutes with 23 days over 30 minutes, worst-case. These three locations are identified in Figure 4-3. The graphical calendars for locations R1, R2, and R3 are provided in Appendix B-1 while Appendix C-1 includes the tabular calendars for these locations. In the case of mitigating worst-case daily shadow flicker, curtailment periods will occur for a period of sufficient duration in order to reduce the daily occurrence of flicker to no more than 30 minutes per day. Ogin, Inc. has expressed that the minimum shutdown period on any given day be 30 minutes for a curtailment. This minimum curtailment duration will meet the daily shadow flicker limit at receptors R2 and R3; however, a longer duration will be required for receptor R1. Curtailments will be needed on all days presented when shadow flicker exceeds 30 minutes as shown in Appendix C-1 unless the mitigation approach is supplemented with personal observations or sensors to account for sunshine or lack thereof which could reduce the number of curtailments.

5.1.3 Project Evaluation

Shadow flicker resulting from the operation of the 12 wind turbines in Layout 1 was calculated at 37 sensitive receptors. One location, R1, was predicted to exceed the annual limit of 30 hours per year. Implementation of curtailment following the general mitigation methodology presented to wind turbines 4A, 5A, and/or 7A will reduce the expected annual shadow flicker at receptor R1 to below 30 hours per year. This reduction will yield annual shadow flicker duration at sensitive receptor R1 that meets the 30 hours per year limit.

Three locations (R1, R2, and R3) were predicted to experience daily flicker in exceedance of 30 minutes per day. Applying the above general mitigation methodology to wind turbines 4A, 5A, 7A, and/or 9A will reduce the worst-case daily shadow flicker at all three receptors to below 30 minutes per day. This reduction will yield daily shadow flicker durations at sensitive receptors R1, R2, and R3 that meet the 30 minute per day limit.

5.2 Layout 2 (Alternate) Evaluation

5.2.1 Modeling Results Evaluation

Two (2) out of 37 modeling receptors were predicted to experience shadow flicker from the proposed wind turbine Layout 2 (Alternate). Of these two locations, both are predicted to experience less than 30 hours per year, on an expected flicker basis. Both of these locations are expected to exceed 30 minutes per day, on a worst-case flicker basis. Therefore, this layout is predicted to be in compliance with the annual limit, but mitigation will be necessary in order to achieve compliance with the 30 minutes per day limit.

5.2.2 Mitigation

In order to achieve compliance with the annual shadow flicker limit of 30 minutes per day, the curtailment of individual wind turbines will be incorporated into the operation of the wind energy facility. The key objective of mitigation is to curtail operations for an adequate number of hours when shadow flicker is possible (worst-case) resulting in a sufficient reduction in the actual duration of shadow flicker in order for the 30 minute per day limit to be met.

Based on the shadow flicker modeling results, two (2) locations (R1 and R2) are expected to exceed 30 minutes per day of flicker. Location R1 was modeled to experience a daily maximum of 0 hours, 41 minutes with 39 days over 30 minutes, worst-case. Location R2 was modeled to experience a daily maximum of 0 hours, 31 minutes with 3 days over 30 minutes, worst-case. These two locations are identified in Figure 4-4. The graphical calendars for locations R1 and R2 are provided in Appendix B-2 while Appendix C-2 includes the tabular calendars for these locations. In the case of mitigating worst-case daily shadow flicker, curtailment periods will occur for a period of sufficient duration in order to reduce the daily occurrence of flicker to no more than 30 minutes per day. Ogin, Inc. has expressed that the minimum shutdown period on any given day be 30 minutes for a curtailment. This minimum curtailment duration will meet the daily shadow flicker limit at both sensitive receptors R1 and R2. Curtailments will be needed on all days presented when shadow flicker exceeds 30 minutes as shown in Appendix C-2 unless the mitigation approach is supplemented with personal observations or sensors to account for sunshine or lack thereof which could reduce the number of curtailments.

5.2.3 Project Evaluation

Shadow flicker resulting from the operation of the 12 wind turbines in Layout 2 was calculated at 37 sensitive receptors. No locations were predicted to exceed the annual limit of 30 hours per year; therefore, the annual limit of 30 hours per year is met.

Two locations (R1 and R2) are predicted to experience daily flicker in exceedance of 30 minutes per day. Applying the above general mitigation methodology to wind turbines 3G, 4G and/or 7G will reduce the worst-case daily shadow flicker at all three receptors to below

30 minutes per day. This reduction will yield daily shadow flicker durations at sensitive receptors R1 and R2 that meet the 30 minute per day limit.

6.0 CONCLUSIONS

A shadow flicker analysis was conducted to calculate the duration of shadow flicker on sensitive receptors near the proposed Sand Hill Wind Project. A total of 12 Goldwind GW 121/2500 2.5 MW wind turbines are proposed for the Project. Shadow flicker resulting from the operation of these 12 wind turbines was calculated at 37 discrete modeling points, and isolines were generated from a grid encompassing the area surrounding the wind turbines using the preferred Layout 1 and alternate Layout 2, individually. This analysis only included shadow flicker due to the operation of the proposed wind turbines; cumulative shadow flicker due to operation of adjacent wind energy facilities was not studied as older, shorter turbines are being removed and other larger, similarly sized turbines are greater than 1,210 meters from the receptors potentially experiencing effects from the Project.

Layout 1 (Preferred) produced a maximum expected annual duration of shadow flicker at a sensitive receptor of 85 hours, 56 minutes and a maximum worst-case daily duration of 1 hour, 59 minutes. Layout 2 (Alternate) produced a maximum expected annual duration of shadow flicker at a sensitive receptor of 16 hours, 26 minutes and a maximum worst-case daily duration of 0 hours, 41 minutes. This analysis is conservative in that modeling locations were treated as "greenhouses" and obstacles such as structures and vegetation were not included. However, applying an appropriate mitigation methodology, as set forth in this report, will reduce modeled annual and daily shadow flicker durations in exceedance of the respective limits of 30 hours per year and 30 minutes per day to acceptable amounts.

Appendix A

Shadow Flicker Modeling Results: Discrete Points

Appendix A

Table A-1: Shadow Flicker Modeling Results at Discrete Points - Layout 1 (Preferred)

Modeling ID	UTM NAD83 Zone 10 Coordinates (meters)		Worst-Case Shadow Flicker Hours per Day (HH:MM)/day	Expected Shadow Flicker Hours per Year (HH:MM)/year
	X (Easting)	Y (Northing)		
R1	622989.82	4178326.46	1:59	85:56
R2	623591.15	4178579.52	0:43	20:22
R3	624958.97	4181403.96	0:45	3:53
R4	625341.32	4178943.22	0:00	0:00
R5	626381.07	4177349.6	0:00	0:00
6	625035.29	4179649.11	0:00	0:00
7	625514.01	4179594.47	0:00	0:00
8	625433.33	4179533.83	0:00	0:00
9	625385.75	4179452.37	0:00	0:00
10	625402.99	4178742.79	0:00	0:00
11	625584.01	4178841.84	0:00	0:00
12	625472.43	4178897.61	0:00	0:00
13	625656.92	4178628.9	0:00	0:00
14	625319.22	4178569.91	0:00	0:00
15	625110.85	4178286.47	0:00	0:00
16	625212.42	4178367.52	0:00	0:00
17	625038.14	4178412.62	0:00	0:00
18	625673.53	4178403.13	0:00	0:00
19	625685.47	4178491.31	0:00	0:00
20	625914.78	4178617.27	0:00	0:00
21	625870.28	4178480.05	0:00	0:00
22	625924.27	4178519.6	0:00	0:00
23	626034.06	4178491.31	0:00	0:00
24	626015.97	4178613.62	0:00	0:00
25	625784.88	4178039.74	0:00	0:00
26	625717.82	4178024.05	0:00	0:00
27	625615.09	4178020.91	0:00	0:00
28	625934.28	4178022.69	0:00	0:00
29	625990.73	4178049.21	0:00	0:00
30	625940.66	4177917.67	0:00	0:00
31	625876.05	4177676.49	0:00	0:00
32	625859.53	4177730.04	0:00	0:00
33	625803.56	4177860.73	0:00	0:00
34	626116.42	4177933	0:00	0:00
35	626084.48	4177806.31	0:00	0:00
36	626108.5	4177664.92	0:00	0:00
37	625984.9	4177670.35	0:00	0:00

Table A-2: Shadow Flicker Modeling Results at Discrete Points - Layout 2 (Alternate)

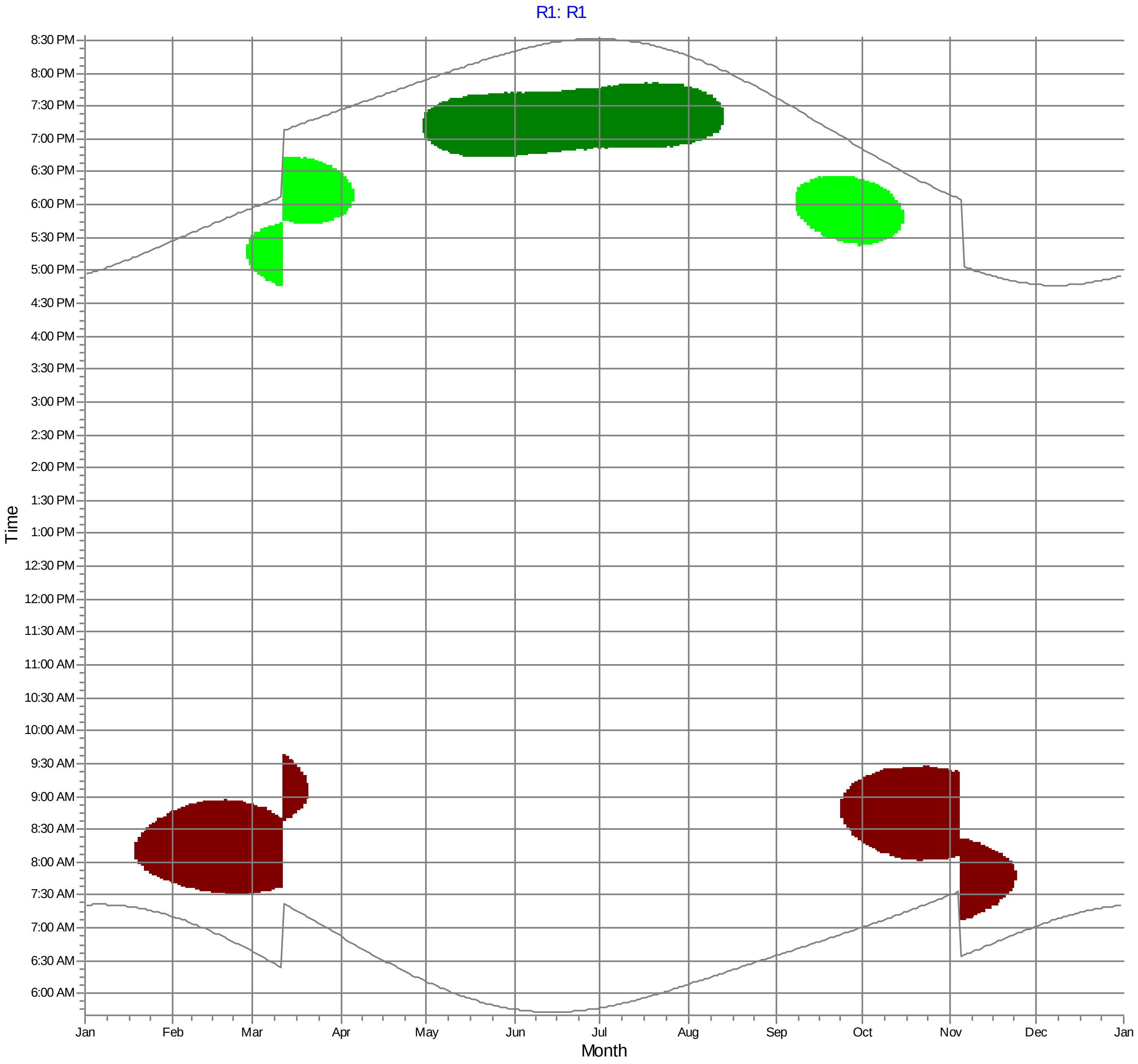
Modeling ID	UTM NAD83 Zone 10 Coordinates (meters)		Worst-Case Shadow Flicker Hours per Day (HH:MM)/day	Expected Shadow Flicker Hours per Year (HH:MM)/year
	X (Easting)	Y (Northing)		
R1	622989.82	4178326.46	0:41	12:32
R2	623591.15	4178579.52	0:31	16:26
R3	624958.97	4181403.96	0:00	0:00
R4	625341.32	4178943.22	0:00	0:00
R5	626381.07	4177349.6	0:00	0:00
6	625035.29	4179649.11	0:00	0:00
7	625514.01	4179594.47	0:00	0:00
8	625433.33	4179533.83	0:00	0:00
9	625385.75	4179452.37	0:00	0:00
10	625402.99	4178742.79	0:00	0:00
11	625584.01	4178841.84	0:00	0:00
12	625472.43	4178897.61	0:00	0:00
13	625656.92	4178628.9	0:00	0:00
14	625319.22	4178569.91	0:00	0:00
15	625110.85	4178286.47	0:00	0:00
16	625212.42	4178367.52	0:00	0:00
17	625038.14	4178412.62	0:00	0:00
18	625673.53	4178403.13	0:00	0:00
19	625685.47	4178491.31	0:00	0:00
20	625914.78	4178617.27	0:00	0:00
21	625870.28	4178480.05	0:00	0:00
22	625924.27	4178519.6	0:00	0:00
23	626034.06	4178491.31	0:00	0:00
24	626015.97	4178613.62	0:00	0:00
25	625784.88	4178039.74	0:00	0:00
26	625717.82	4178024.05	0:00	0:00
27	625615.09	4178020.91	0:00	0:00
28	625934.28	4178022.69	0:00	0:00
29	625990.73	4178049.21	0:00	0:00
30	625940.66	4177917.67	0:00	0:00
31	625876.05	4177676.49	0:00	0:00
32	625859.53	4177730.04	0:00	0:00
33	625803.56	4177860.73	0:00	0:00
34	626116.42	4177933	0:00	0:00
35	626084.48	4177806.31	0:00	0:00
36	626108.5	4177664.92	0:00	0:00
37	625984.9	4177670.35	0:00	0:00

Appendix B-1

Shadow Flicker Modeling Results: Graphical Calendars – Layout 1 (Preferred)

SHADOW - Calendar, graphical

Calculation: Points & Map - Layout 1



WTGs

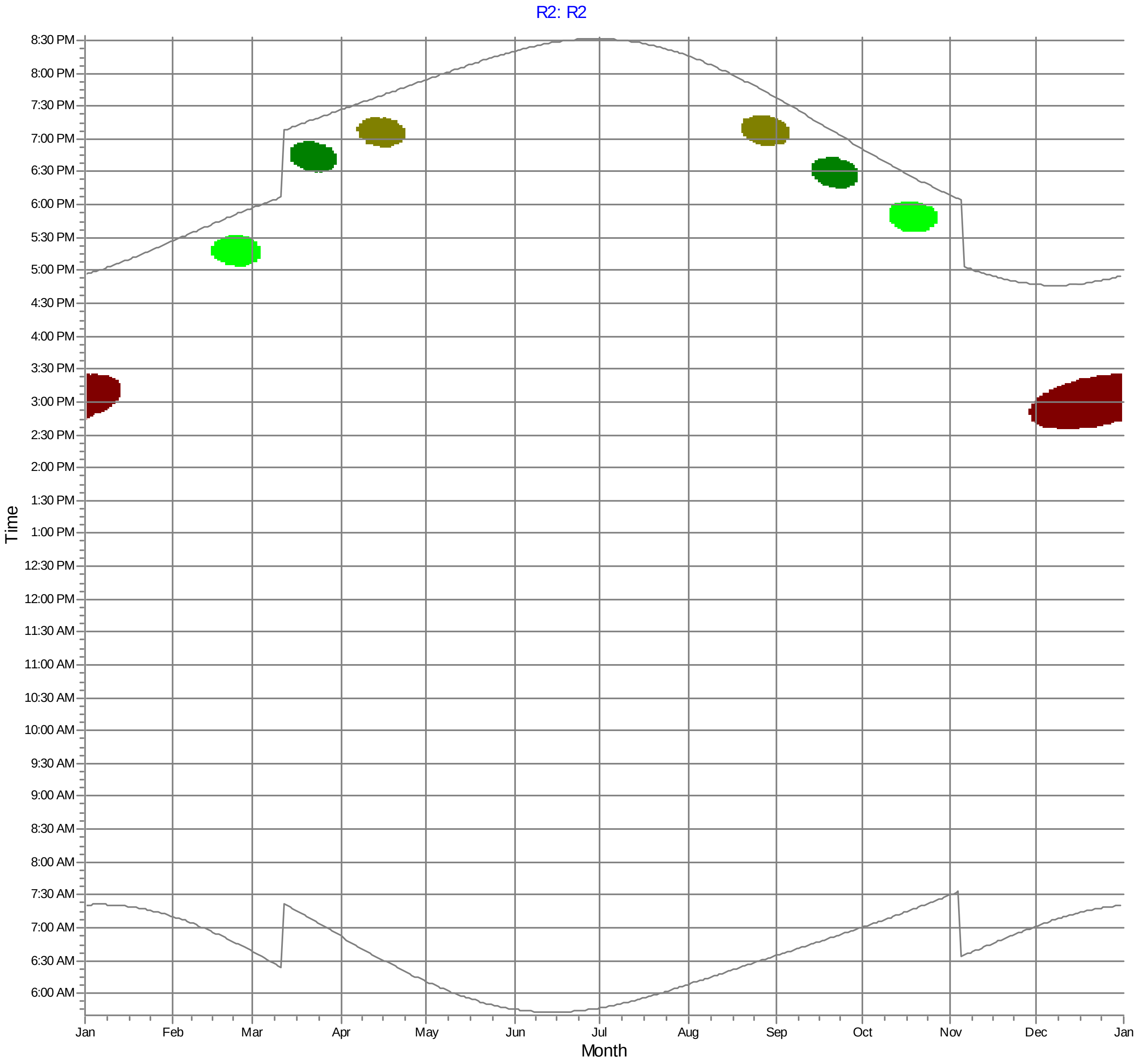
🟩 4A: 4A

🟥 7A: 7A

🟩 5A: 5A

SHADOW - Calendar, graphical

Calculation: Points & Map - Layout 1**Shadow receptor:** R2 - R2



WTGs

🟩 4A: 4A

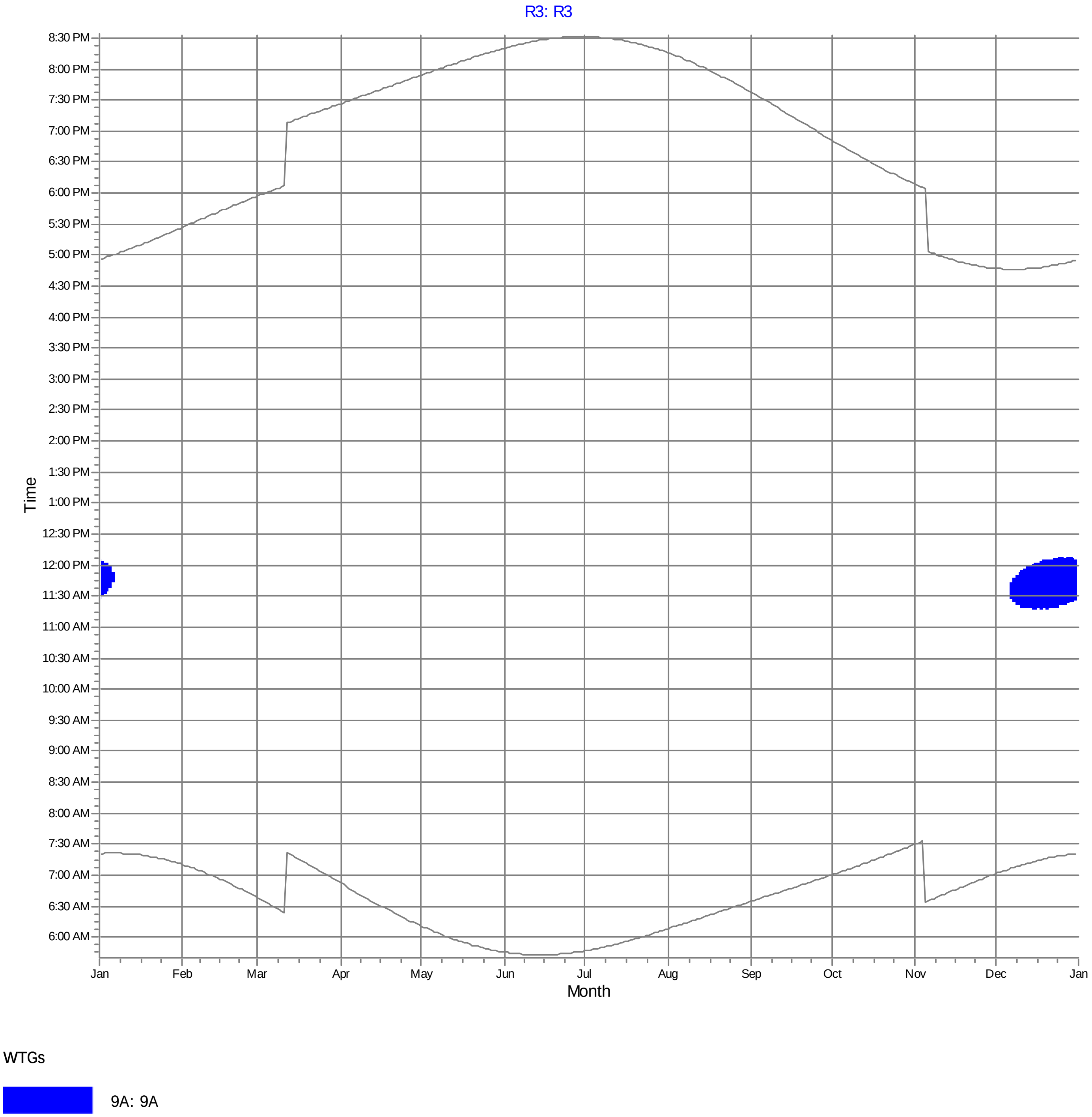
🟥 7A: 7A

🟩 5A: 5A

🟨 3A: 3A

SHADOW - Calendar, graphical

Calculation: Points & Map - Layout 1**Shadow receptor:** R3 - R3

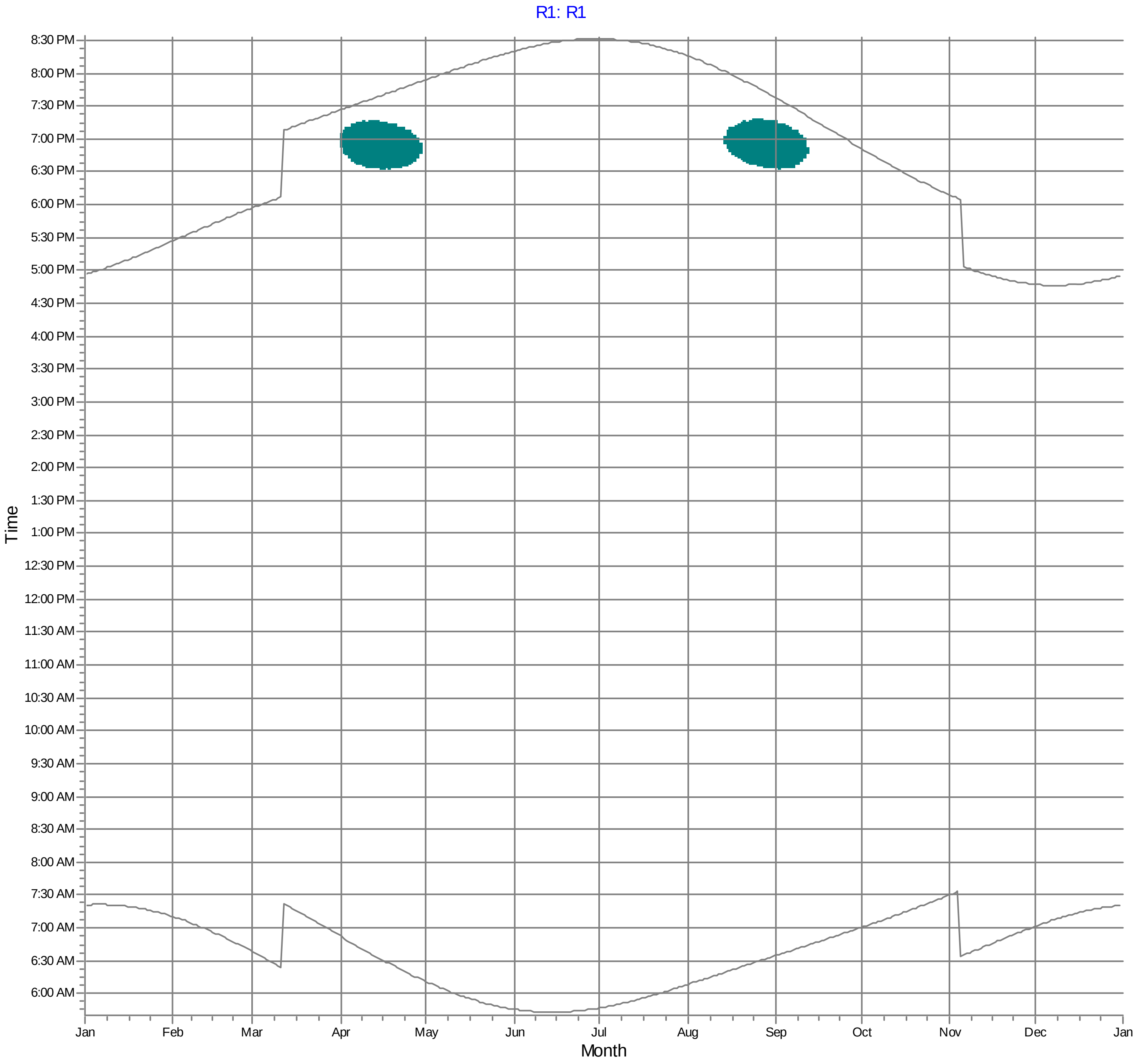


Appendix B-2

Shadow Flicker Modeling Results: Graphical Calendars – Layout 2 (Alternate)

SHADOW - Calendar, graphical

Calculation: Points & Map - Layout 2

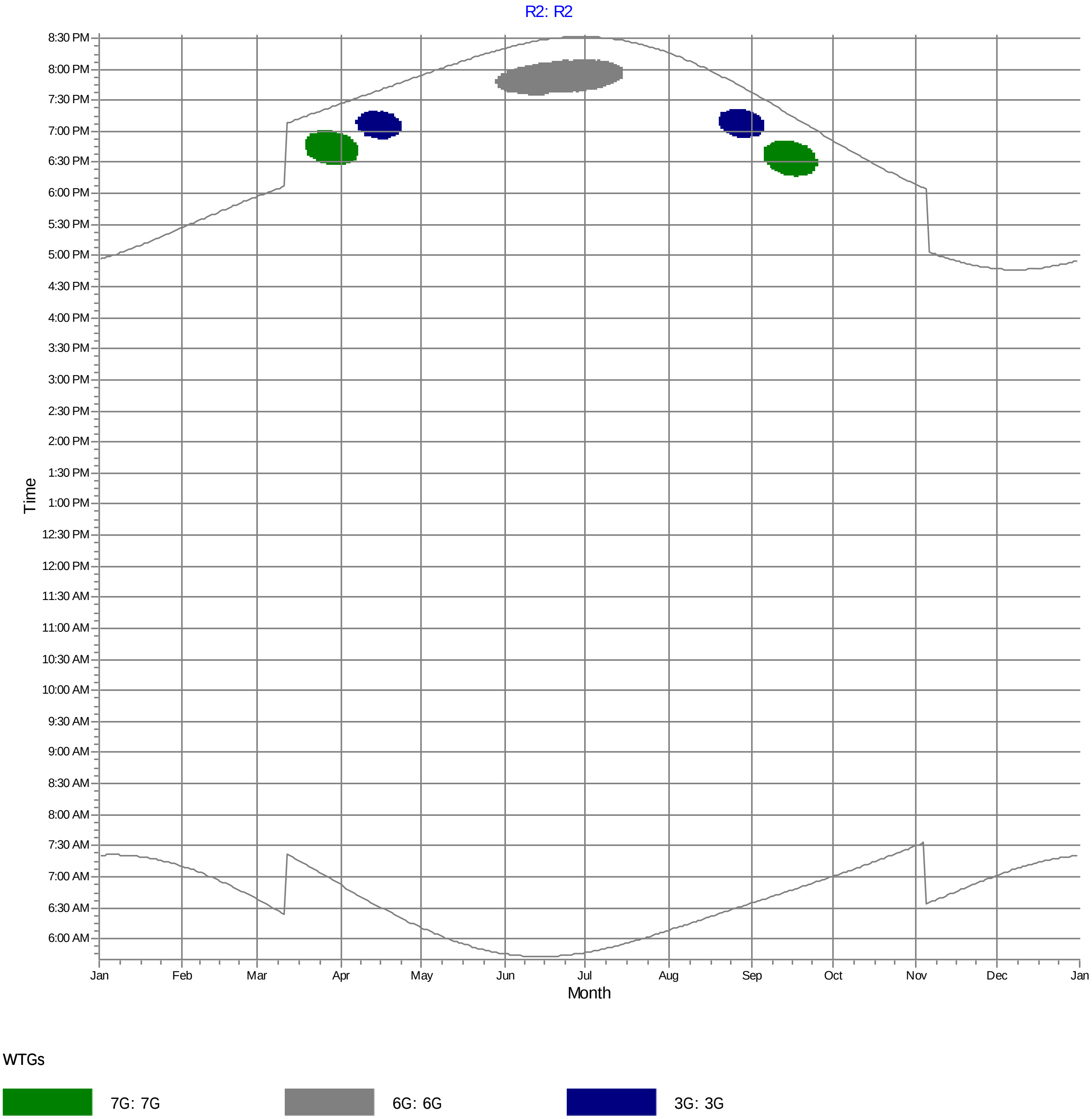


WTGs

🟩 4G: 4G

SHADOW - Calendar, graphical

Calculation: Points & Map - Layout 2**Shadow receptor:** R2 - R2



Appendix C-1

Shadow Flicker Modeling Results: Calendars – Layout 1 (Preferred)

Project:

4385 Sand Hill Wind - Flicker Model - Layout 1 (Preferred)

Licensed user:

Epsilon Associates, Inc
3 Clock Tower Place, Suite 250
US-MAYNARD MA 01754
978 897 7100

Calculated:

2/2/2016 1:23 PM/3.0.639

SHADOW - Calendar

Calculation: Points & Map - Layout 1**Shadow receptor:** R1 - R1

Assumptions for shadow calculations

Reference year for calendar	2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

```
                    |January                  |February                 |March                    |April                    |May                      |June

                  1 | 07:20                   | 07:10        07:42 (7A) | 06:38        07:32 (7A) | 06:52        17:51 (5A) | 06:10        19:02 (4A) | 05:45        18:45 (4A)
                    | 16:56                   | 17:27    63  08:45 (7A) | 17:57   107  17:30 (5A) | 19:26    36  18:27 (5A) | 19:54    20  19:22 (4A) | 20:20    55  19:40 (4A)
                  2 | 07:20                   | 07:09        07:41 (7A) | 06:36        07:33 (7A) | 06:50        17:53 (5A) | 06:09        18:59 (4A) | 05:45        18:46 (4A)
                    | 16:56                   | 17:28    65  08:46 (7A) | 17:58   110  17:33 (5A) | 19:27    31  18:24 (5A) | 19:55    26  19:25 (4A) | 20:21    55  19:41 (4A)
                  3 | 07:21                   | 07:08        07:40 (7A) | 06:35        07:33 (7A) | 06:49        17:55 (5A) | 06:08        18:57 (4A) | 05:44        18:46 (4A)
                    | 16:57                   | 17:29    67  08:47 (7A) | 17:59   113  17:34 (5A) | 19:28    27  18:22 (5A) | 19:55    30  19:27 (4A) | 20:21    55  19:41 (4A)
                  4 | 07:21                   | 07:07        07:39 (7A) | 06:33        07:34 (7A) | 06:47        17:58 (5A) | 06:07        18:55 (4A) | 05:44        18:46 (4A)
                    | 16:58                   | 17:30    69  08:48 (7A) | 18:00   114  17:36 (5A) | 19:29    20  18:18 (5A) | 19:56    34  19:29 (4A) | 20:22    54  19:40 (4A)
                  5 | 07:21                   | 07:06        07:39 (7A) | 06:32        07:34 (7A) | 06:46        18:04 (5A) | 06:06        18:54 (4A) | 05:44        18:46 (4A)
                    | 16:59                   | 17:31    70  08:49 (7A) | 18:01   118  17:38 (5A) | 19:30     9  18:13 (5A) | 19:57    36  19:30 (4A) | 20:23    55  19:41 (4A)
                  6 | 07:21                   | 07:05        07:38 (7A) | 06:31        07:34 (7A) | 06:44                   | 06:05        18:52 (4A) | 05:44        18:47 (4A)
                    | 17:00                   | 17:32    72  08:50 (7A) | 18:02   118  17:38 (5A) | 19:31                   | 19:58    39  19:31 (4A) | 20:23    54  19:41 (4A)
                  7 | 07:21                   | 07:04        07:37 (7A) | 06:29        07:35 (7A) | 06:43                   | 06:04        18:51 (4A) | 05:43        18:47 (4A)
                    | 17:01                   | 17:33    74  08:51 (7A) | 18:03   119  17:40 (5A) | 19:32                   | 19:59    41  19:32 (4A) | 20:24    54  19:41 (4A)
                  8 | 07:21                   | 07:03        07:37 (7A) | 06:28        07:36 (7A) | 06:41                   | 06:03        18:50 (4A) | 05:43        18:48 (4A)
                    | 17:01                   | 17:34    74  08:51 (7A) | 18:04   117  17:40 (5A) | 19:33                   | 20:00    43  19:33 (4A) | 20:24    53  19:41 (4A)
                  9 | 07:21                   | 07:02        07:36 (7A) | 06:26        07:37 (7A) | 06:40                   | 06:02        18:49 (4A) | 05:43        18:48 (4A)
                    | 17:02                   | 17:36    76  08:52 (7A) | 18:05   117  17:41 (5A) | 19:33                   | 20:01    45  19:34 (4A) | 20:25    54  19:42 (4A)
                 10 | 07:20                   | 07:01        07:36 (7A) | 06:25        07:37 (7A) | 06:38                   | 06:01        18:48 (4A) | 05:43        18:48 (4A)
                    | 17:03                   | 17:37    77  08:53 (7A) | 18:06   117  17:41 (5A) | 19:34                   | 20:02    47  19:35 (4A) | 20:25    53  19:41 (4A)
                 11 | 07:20                   | 07:00        07:35 (7A) | 06:23        07:38 (7A) | 06:37                   | 06:00        18:47 (4A) | 05:43        18:48 (4A)
                    | 17:04                   | 17:38    78  08:53 (7A) | 18:07   116  17:42 (5A) | 19:35                   | 20:03    48  19:35 (4A) | 20:26    53  19:41 (4A)
                 12 | 07:20                   | 06:59        07:35 (7A) | 07:22        08:39 (7A) | 06:35                   | 05:59        18:47 (4A) | 05:43        18:48 (4A)
                    | 17:05                   | 17:39    79  08:54 (7A) | 19:08   114  18:42 (5A) | 19:36                   | 20:04    49  19:36 (4A) | 20:26    53  19:41 (4A)
                 13 | 07:20                   | 06:58        07:35 (7A) | 07:20        08:41 (7A) | 06:34                   | 05:58        18:46 (4A) | 05:43        18:49 (4A)
                    | 17:06                   | 17:40    79  08:54 (7A) | 19:09   110  18:42 (5A) | 19:37                   | 20:05    50  19:36 (4A) | 20:27    52  19:41 (4A)
                 14 | 07:20                   | 06:57        07:34 (7A) | 07:19        08:42 (7A) | 06:33                   | 05:57        18:45 (4A) | 05:43        18:49 (4A)
                    | 17:07                   | 17:41    81  08:55 (7A) | 19:10   107  18:42 (5A) | 19:38                   | 20:05    52  19:37 (4A) | 20:27    52  19:41 (4A)
                 15 | 07:19                   | 06:56        07:33 (7A) | 07:17        08:44 (7A) | 06:31                   | 05:56        18:45 (4A) | 05:43        18:49 (4A)
                    | 17:08                   | 17:42    81  08:54 (7A) | 19:10   104  18:42 (5A) | 19:39                   | 20:06    52  19:37 (4A) | 20:28    53  19:42 (4A)
                 16 | 07:19                   | 06:54        07:33 (7A) | 07:16        08:45 (7A) | 06:30                   | 05:55        18:45 (4A) | 05:43        18:49 (4A)
                    | 17:09                   | 17:43    82  08:55 (7A) | 19:11   101  18:42 (5A) | 19:40                   | 20:07    53  19:38 (4A) | 20:28    53  19:42 (4A)
                 17 | 07:19                   | 06:53        07:33 (7A) | 07:14        08:48 (7A) | 06:28                   | 05:54        18:45 (4A) | 05:43        18:49 (4A)
                    | 17:10                   | 17:44    82  08:55 (7A) | 19:12    95  18:42 (5A) | 19:41                   | 20:08    53  19:38 (4A) | 20:28    53  19:42 (4A)
                 18 | 07:18                   | 06:52        07:33 (7A) | 07:13        08:50 (7A) | 06:27                   | 05:53        18:44 (4A) | 05:43        18:51 (4A)
                    | 17:11                   | 17:45    82  08:55 (7A) | 19:13    89  18:41 (5A) | 19:42                   | 20:09    54  19:38 (4A) | 20:29    52  19:43 (4A)
                 19 | 07:18        08:03 (7A) | 06:51        07:33 (7A) | 07:11        08:54 (7A) | 06:26                   | 05:53        18:44 (4A) | 05:43        18:51 (4A)
                    | 17:12    14  08:17 (7A) | 17:46    83  08:56 (7A) | 19:14    81  18:42 (5A) | 19:43                   | 20:10    54  19:38 (4A) | 20:29    52  19:43 (4A)
                 20 | 07:17        07:59 (7A) | 06:50        07:32 (7A) | 07:10        08:59 (7A) | 06:24                   | 05:52        18:44 (4A) | 05:43        18:51 (4A)
                    | 17:13    22  08:21 (7A) | 17:47    83  08:55 (7A) | 19:15    69  18:41 (5A) | 19:44                   | 20:11    55  19:39 (4A) | 20:29    52  19:43 (4A)
                 21 | 07:17        07:57 (7A) | 06:48        07:32 (7A) | 07:08        17:44 (5A) | 06:23                   | 05:51        18:44 (4A) | 05:43        18:51 (4A)
                    | 17:15    28  08:25 (7A) | 17:49    83  08:55 (7A) | 19:16    57  18:41 (5A) | 19:44                   | 20:11    55  19:39 (4A) | 20:30    52  19:43 (4A)
                 22 | 07:16        07:54 (7A) | 06:47        07:32 (7A) | 07:07        17:44 (5A) | 06:22                   | 05:50        18:44 (4A) | 05:43        18:51 (4A)
                    | 17:16    33  08:27 (7A) | 17:50    83  08:55 (7A) | 19:17    56  18:40 (5A) | 19:45                   | 20:12    55  19:39 (4A) | 20:30    52  19:43 (4A)
                 23 | 07:16        07:53 (7A) | 06:46        07:32 (7A) | 07:05        17:44 (5A) | 06:20                   | 05:50        18:44 (4A) | 05:44        18:52 (4A)
                    | 17:17    37  08:30 (7A) | 17:51    82  08:54 (7A) | 19:18    55  18:39 (5A) | 19:46                   | 20:13    56  19:40 (4A) | 20:30    52  19:44 (4A)
                 24 | 07:15        07:51 (7A) | 06:44        07:32 (7A) | 07:04        17:44 (5A) | 06:19                   | 05:49        18:44 (4A) | 05:44        18:52 (4A)
                    | 17:18    41  08:32 (7A) | 17:52    82  08:54 (7A) | 19:19    54  18:38 (5A) | 19:47                   | 20:14    56  19:40 (4A) | 20:30    52  19:44 (4A)
                 25 | 07:15        07:49 (7A) | 06:43        07:32 (7A) | 07:02        17:44 (5A) | 06:18                   | 05:49        18:45 (4A) | 05:44        18:52 (4A)
                    | 17:19    45  08:34 (7A) | 17:53    82  08:54 (7A) | 19:20    53  18:37 (5A) | 19:48                   | 20:15    55  19:40 (4A) | 20:30    52  19:44 (4A)
                 26 | 07:14        07:49 (7A) | 06:42        07:32 (7A) | 07:01        17:45 (5A) | 06:16                   | 05:48        18:44 (4A) | 05:44        18:51 (4A)
                    | 17:20    47  08:36 (7A) | 17:54    81  08:53 (7A) | 19:21    51  18:36 (5A) | 19:49                   | 20:15    56  19:40 (4A) | 20:31    53  19:44 (4A)
                 27 | 07:13        07:47 (7A) | 06:40        07:32 (7A) | 06:59        17:45 (5A) | 06:15                   | 05:47        18:44 (4A) | 05:45        18:52 (4A)
                    | 17:21    51  08:38 (7A) | 17:55    90  17:22 (5A) | 19:22    49  18:34 (5A) | 19:50                   | 20:16    56  19:40 (4A) | 20:31    53  19:45 (4A)
                 28 | 07:13        07:46 (7A) | 06:39        07:33 (7A) | 06:58        17:47 (5A) | 06:14                   | 05:47        18:44 (4A) | 05:45        18:52 (4A)
                    | 17:22    53  08:39 (7A) | 17:56   100  17:27 (5A) | 19:23    47  18:34 (5A) | 19:51                   | 20:17    56  19:40 (4A) | 20:31    53  19:45 (4A)
                 29 | 07:12        07:45 (7A) |                         | 06:56        17:47 (5A) | 06:13                   | 05:46        18:45 (4A) | 05:46        18:53 (4A)
                    | 17:23    55  08:40 (7A) |                         | 19:23    45  18:32 (5A) | 19:52                   | 20:18    56  19:41 (4A) | 20:31    52  19:45 (4A)
                 30 | 07:11        07:44 (7A) |                         | 06:55        17:49 (5A) | 06:11        19:07 (4A) | 05:46        18:45 (4A) | 05:46        18:53 (4A)
                    | 17:24    59  08:43 (7A) |                         | 19:24    42  18:31 (5A) | 19:53    10  19:17 (4A) | 20:18    55  19:40 (4A) | 20:31    52  19:45 (4A)
                 31 | 07:10        07:43 (7A) |                         | 06:53        17:49 (5A) |                         | 05:46        18:45 (4A) |
                    | 17:26    61  08:44 (7A) |                         | 19:25    39  18:28 (5A) |                         | 20:19    56  19:41 (4A) |
Potential sun hours | 306                     | 301                     | 370                     | 394                     | 440                     | 442
  Total, worst case |         546             |        2200             |        2684             |         133             |        1493             |        1590
      Sun reduction |        0.45             |        0.62             |        0.73             |        0.82             |        0.92             |        0.94
    Oper. time red. |        0.71             |        0.71             |        0.71             |        0.71             |        0.71             |        0.71
     Wind dir. red. |        0.47             |        0.48             |        0.62             |        0.72             |        0.54             |        0.54
    Total reduction |        0.15             |        0.21             |        0.32             |        0.41             |        0.35             |        0.36
        Total, real |          82             |         458             |         859             |          55             |         527             |         574
```

Table layout: For each day in each month the following matrix apply

```
Day in month    Sun rise (hh:mm)                            First time (hh:mm) with flicker    (WTG causing flicker first time)
                Sun set (hh:mm)      Minutes with flicker   Last time (hh:mm) with flicker     (WTG causing flicker last time)
```

SHADOW - Calendar

Calculation: Points & Map - Layout 1**Shadow receptor:** R1 - R1

Assumptions for shadow calculations

Reference year for calendar	2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

	July			August			September			October			November			December		
1	05:46		18:52 (4A)	06:08		18:57 (4A)	06:34			07:00		08:19 (7A)	07:29		08:05 (7A)	07:01		
	20:31	53	19:45 (4A)	20:15	49	19:46 (4A)	19:37			18:51	111	18:21 (5A)	18:08	77	09:22 (7A)	16:47		
2	05:47		18:53 (4A)	06:09		18:57 (4A)	06:35			07:01		08:18 (7A)	07:30		08:05 (7A)	07:02		
	20:31	53	19:46 (4A)	20:14	49	19:46 (4A)	19:35			18:49	113	18:20 (5A)	18:07	76	09:21 (7A)	16:47		
3	05:47		18:52 (4A)	06:09		18:58 (4A)	06:36			07:02		08:16 (7A)	07:31		08:07 (7A)	07:03		
	20:31	54	19:46 (4A)	20:13	47	19:45 (4A)	19:34			18:48	116	18:20 (5A)	18:06	75	09:22 (7A)	16:46		
4	05:48		18:53 (4A)	06:10		18:59 (4A)	06:37			07:02		08:15 (7A)	07:33		08:07 (7A)	07:03		
	20:31	54	19:47 (4A)	20:12	45	19:44 (4A)	19:32			18:46	117	18:19 (5A)	18:05	74	09:21 (7A)	16:46		
5	05:48		18:53 (4A)	06:11		18:59 (4A)	06:38			07:03		08:14 (7A)	06:34		07:08 (7A)	07:04		
	20:30	53	19:46 (4A)	20:11	44	19:43 (4A)	19:31			18:45	117	18:18 (5A)	18:04	72	08:20 (7A)	16:46		
6	05:49		18:53 (4A)	06:12		19:00 (4A)	06:38			07:04		08:12 (7A)	06:35		07:09 (7A)	07:05		
	20:30	54	19:47 (4A)	20:10	42	19:42 (4A)	19:29			18:43	119	18:17 (5A)	17:03	70	08:19 (7A)	16:46		
7	05:49		18:53 (4A)	06:13		19:01 (4A)	06:39			07:05		08:11 (7A)	06:36		07:10 (7A)	07:06		
	20:30	54	19:47 (4A)	20:09	40	19:41 (4A)	19:28			18:42	118	18:15 (5A)	17:02	69	08:19 (7A)	16:46		
8	05:50		18:53 (4A)	06:14		19:03 (4A)	06:40		17:55 (5A)	07:06		08:10 (7A)	06:37		07:10 (7A)	07:07		
	20:30	55	19:48 (4A)	20:08	36	19:39 (4A)	19:26	15	18:10 (5A)	18:40	118	18:14 (5A)	17:01	68	08:18 (7A)	16:46		
9	05:51		18:54 (4A)	06:15		19:04 (4A)	06:41		17:51 (5A)	07:07		08:09 (7A)	06:38		07:11 (7A)	07:08		
	20:30	54	19:48 (4A)	20:07	34	19:38 (4A)	19:25	23	18:14 (5A)	18:39	118	18:13 (5A)	17:00	66	08:17 (7A)	16:46		
10	05:51		18:53 (4A)	06:15		19:06 (4A)	06:42		17:48 (5A)	07:08		08:09 (7A)	06:39		07:12 (7A)	07:09		
	20:29	55	19:48 (4A)	20:06	30	19:36 (4A)	19:23	29	18:17 (5A)	18:37	114	18:11 (5A)	16:59	64	08:16 (7A)	16:46		
11	05:52		18:53 (4A)	06:16		19:07 (4A)	06:43		17:45 (5A)	07:09		08:07 (7A)	06:40		07:14 (7A)	07:09		
	20:29	56	19:49 (4A)	20:05	26	19:33 (4A)	19:22	34	18:19 (5A)	18:36	113	18:08 (5A)	16:58	62	08:16 (7A)	16:46		
12	05:52		18:53 (4A)	06:17		19:10 (4A)	06:44		17:42 (5A)	07:10		08:06 (7A)	06:41		07:15 (7A)	07:10		
	20:29	55	19:48 (4A)	20:04	21	19:31 (4A)	19:20	37	18:19 (5A)	18:34	110	18:06 (5A)	16:57	59	08:14 (7A)	16:46		
13	05:53		18:53 (4A)	06:18		19:14 (4A)	06:44		17:40 (5A)	07:11		08:05 (7A)	06:42		07:16 (7A)	07:11		
	20:28	56	19:49 (4A)	20:02	13	19:27 (4A)	19:19	41	18:21 (5A)	18:33	107	18:03 (5A)	16:57	57	08:13 (7A)	16:46		
14	05:54		18:54 (4A)	06:19			06:45		17:39 (5A)	07:12		08:05 (7A)	06:43		07:18 (7A)	07:12		
	20:28	55	19:49 (4A)	20:01			19:17	43	18:22 (5A)	18:32	101	18:00 (5A)	16:56	54	08:12 (7A)	16:47		
15	05:54		18:53 (4A)	06:20			06:46		17:37 (5A)	07:12		08:04 (7A)	06:44		07:19 (7A)	07:12		
	20:27	56	19:49 (4A)	20:00			19:16	46	18:23 (5A)	18:30	91	17:54 (5A)	16:55	52	08:11 (7A)	16:47		
16	05:55		18:53 (4A)	06:21			06:47		17:36 (5A)	07:13		08:04 (7A)	06:45		07:21 (7A)	07:13		
	20:27	56	19:49 (4A)	19:59			19:14	48	18:24 (5A)	18:29	81	09:25 (7A)	16:54	48	08:09 (7A)	16:47		
17	05:56		18:54 (4A)	06:21			06:48		17:34 (5A)	07:14		08:03 (7A)	06:46		07:22 (7A)	07:14		
	20:26	56	19:50 (4A)	19:57			19:13	49	18:23 (5A)	18:27	82	09:25 (7A)	16:54	46	08:08 (7A)	16:47		
18	05:57		18:53 (4A)	06:22			06:49		17:32 (5A)	07:15		08:03 (7A)	06:47		07:25 (7A)	07:14		
	20:26	56	19:49 (4A)	19:56			19:11	52	18:24 (5A)	18:26	82	09:25 (7A)	16:53	42	08:07 (7A)	16:48		
19	05:57		18:54 (4A)	06:23			06:49		17:31 (5A)	07:16		08:03 (7A)	06:48		07:27 (7A)	07:15		
	20:25	55	19:49 (4A)	19:55			19:09	53	18:24 (5A)	18:25	82	09:25 (7A)	16:52	39	08:06 (7A)	16:48		
20	05:58		18:54 (4A)	06:24			06:50		17:31 (5A)	07:17		08:03 (7A)	06:50		07:29 (7A)	07:16		
	20:25	56	19:50 (4A)	19:54			19:08	54	18:25 (5A)	18:23	82	09:25 (7A)	16:52	35	08:04 (7A)	16:48		
21	05:59		18:54 (4A)	06:25			06:51		17:30 (5A)	07:18		08:02 (7A)	06:51		07:31 (7A)	07:16		
	20:24	56	19:50 (4A)	19:52			19:06	55	18:25 (5A)	18:22	83	09:25 (7A)	16:51	31	08:02 (7A)	16:49		
22	06:00		18:54 (4A)	06:26			06:52		17:29 (5A)	07:19		08:02 (7A)	06:52		07:34 (7A)	07:17		
	20:23	55	19:49 (4A)	19:51			19:05	56	18:25 (5A)	18:21	83	09:25 (7A)	16:50	25	07:59 (7A)	16:49		
23	06:00		18:54 (4A)	06:27			06:53		17:27 (5A)	07:20		08:03 (7A)	06:53		07:38 (7A)	07:17		
	20:23	55	19:49 (4A)	19:50			19:03	57	18:24 (5A)	18:19	83	09:26 (7A)	16:50	18	07:56 (7A)	16:50		
24	06:01		18:54 (4A)	06:27			06:54		08:41 (7A)	07:21		08:03 (7A)	06:54		07:44 (7A)	07:18		
	20:22	55	19:49 (4A)	19:48			19:02	72	18:24 (5A)	18:18	83	09:26 (7A)	16:49	6	07:50 (7A)	16:50		
25	06:02		18:55 (4A)	06:28			06:55		08:35 (7A)	07:22		08:03 (7A)	06:55			07:18		
	20:21	54	19:49 (4A)	19:47			19:00	84	18:24 (5A)	18:17	82	09:25 (7A)	16:49			16:51		
26	06:03		18:54 (4A)	06:29			06:55		08:32 (7A)	07:23		08:03 (7A)	06:56			07:18		
	20:20	54	19:48 (4A)	19:45			18:59	91	18:24 (5A)	18:16	82	09:25 (7A)	16:48			16:51		
27	06:04		18:55 (4A)	06:30			06:56		08:29 (7A)	07:24		08:03 (7A)	06:57			07:19		
	20:20	53	19:48 (4A)	19:44			18:57	96	18:24 (5A)	18:14	82	09:25 (7A)	16:48			16:52		
28	06:04		18:55 (4A)	06:31			06:57		08:26 (7A)	07:25		08:04 (7A)	06:58			07:19		
	20:19	53	19:48 (4A)	19:43			18:55	102	18:24 (5A)	18:13	80	09:24 (7A)	16:48			16:53		
29	06:05		18:56 (4A)	06:32			06:58		08:24 (7A)	07:26		08:04 (7A)	06:59			07:19		
	20:18	52	19:48 (4A)	19:41			18:54	105	18:23 (5A)	18:12	80	09:24 (7A)	16:47			16:53		
30	06:06		18:56 (4A)	06:33			06:59		08:21 (7A)	07:27		08:04 (7A)	07:00			07:20		
	20:17	52	19:48 (4A)	19:40			18:52	110	18:22 (5A)	18:11	79	09:23 (7A)	16:47			16:54		
31	06:07		18:56 (4A)	06:33						07:28		08:04 (7A)				07:20		
	20:16	50	19:46 (4A)	19:38						18:10	79	09:23 (7A)				16:55		
Potential sun hours	449			422			374			349			306			298		
Total, worst case		1685			476			1352			2988			1285				
Sun reduction		0.97			0.96			0.93			0.84			0.61				
Oper. time red.		0.71			0.71			0.71			0.71			0.71				
Wind dir. red.		0.54			0.54			0.68			0.53			0.47				
Total reduction		0.37			0.37			0.45			0.31			0.20				
Total, real		627			175			605			933			261				

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

SHADOW - Calendar

Calculation: Points & Map - Layout 1**Shadow receptor:** R2 - R2

Assumptions for shadow calculations

Reference year for calendar 2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

	January			February			March			April			May	June
1	07:20		14:45 (7A)	07:10			06:38		17:08 (5A)	06:52			06:10	05:45
	16:56	39	15:24 (7A)	17:27			17:57	18	17:26 (5A)	19:26			19:54	20:20
2	07:20		14:46 (7A)	07:09			06:36		17:09 (5A)	06:50			06:09	05:45
	16:56	38	15:24 (7A)	17:28			17:58	16	17:25 (5A)	19:27			19:55	20:21
3	07:21		14:47 (7A)	07:08			06:35		17:11 (5A)	06:49			06:08	05:44
	16:57	36	15:23 (7A)	17:29			17:59	10	17:21 (5A)	19:28			19:55	20:21
4	07:21		14:49 (7A)	07:07			06:33			06:47			06:07	05:44
	16:58	35	15:24 (7A)	17:30			18:00			19:29			19:56	20:22
5	07:21		14:50 (7A)	07:06			06:32			06:46			06:06	05:44
	16:59	34	15:24 (7A)	17:31			18:01			19:30			19:57	20:22
6	07:21		14:50 (7A)	07:05			06:31			06:44			06:05	05:43
	17:00	33	15:23 (7A)	17:32			18:02			19:31			19:58	20:23
7	07:21		14:52 (7A)	07:04			06:29			06:43		19:08 (3A)	06:04	05:43
	17:01	31	15:23 (7A)	17:33			18:03			19:32	1	19:09 (3A)	19:59	20:24
8	07:21		14:53 (7A)	07:03			06:28			06:41		19:02 (3A)	06:03	05:43
	17:01	29	15:22 (7A)	17:34			18:04			19:33	11	19:13 (3A)	20:00	20:24
9	07:21		14:55 (7A)	07:02			06:26			06:40		19:00 (3A)	06:02	05:43
	17:02	27	15:22 (7A)	17:36			18:05			19:33	15	19:15 (3A)	20:01	20:25
10	07:20		14:57 (7A)	07:01			06:25			06:38		18:57 (3A)	06:01	05:43
	17:03	24	15:21 (7A)	17:37			18:06			19:34	19	19:16 (3A)	20:02	20:25
11	07:20		14:59 (7A)	07:00			06:23			06:37		18:57 (3A)	06:00	05:43
	17:04	21	15:20 (7A)	17:38			18:07			19:35	20	19:17 (3A)	20:03	20:26
12	07:20		15:02 (7A)	06:59			07:22			06:35		18:56 (3A)	05:59	05:43
	17:05	16	15:18 (7A)	17:39			19:08			19:36	22	19:18 (3A)	20:04	20:26
13	07:20		15:05 (7A)	06:58			07:20			06:34		18:55 (3A)	05:58	05:42
	17:06	10	15:15 (7A)	17:40			19:09			19:37	23	19:18 (3A)	20:04	20:27
14	07:20			06:57			07:19			06:32		18:55 (3A)	05:57	05:42
	17:07			17:41			19:09			19:38	23	19:18 (3A)	20:05	20:27
15	07:19			06:56		17:14 (5A)	07:17		18:40 (4A)	06:31		18:54 (3A)	05:56	05:42
	17:08			17:42	7	17:21 (5A)	19:10	11	18:51 (4A)	19:39	23	19:17 (3A)	20:06	20:28
16	07:19			06:54		17:11 (5A)	07:16		18:37 (4A)	06:30		18:54 (3A)	05:55	05:43
	17:09			17:43	13	17:24 (5A)	19:11	16	18:53 (4A)	19:40	24	19:18 (3A)	20:07	20:28
17	07:19			06:53		17:10 (5A)	07:14		18:36 (4A)	06:28		18:54 (3A)	05:54	05:43
	17:10			17:44	16	17:26 (5A)	19:12	19	18:55 (4A)	19:41	23	19:17 (3A)	20:08	20:28
18	07:18			06:52		17:08 (5A)	07:13		18:34 (4A)	06:27		18:54 (3A)	05:53	05:43
	17:11			17:45	19	17:27 (5A)	19:13	21	18:55 (4A)	19:42	22	19:16 (3A)	20:09	20:29
19	07:18			06:51		17:08 (5A)	07:11		18:33 (4A)	06:26		18:55 (3A)	05:53	05:43
	17:12			17:46	20	17:28 (5A)	19:14	23	18:56 (4A)	19:43	20	19:15 (3A)	20:10	20:29
20	07:17			06:50		17:06 (5A)	07:10		18:32 (4A)	06:24		18:56 (3A)	05:52	05:43
	17:13			17:47	23	17:29 (5A)	19:15	24	18:56 (4A)	19:43	19	19:15 (3A)	20:11	20:29
21	07:17			06:48		17:06 (5A)	07:08		18:32 (4A)	06:23		18:56 (3A)	05:51	05:43
	17:14			17:48	24	17:30 (5A)	19:16	24	18:56 (4A)	19:44	17	19:13 (3A)	20:11	20:30
22	07:16			06:47		17:06 (5A)	07:07		18:31 (4A)	06:22		18:58 (3A)	05:50	05:43
	17:16			17:50	25	17:31 (5A)	19:17	25	18:56 (4A)	19:45	13	19:11 (3A)	20:12	20:30
23	07:16			06:46		17:05 (5A)	07:05		18:30 (4A)	06:20		19:01 (3A)	05:50	05:44
	17:17			17:51	25	17:30 (5A)	19:18	25	18:55 (4A)	19:46	7	19:08 (3A)	20:13	20:30
24	07:15			06:44		17:05 (5A)	07:04		18:31 (4A)	06:19			05:49	05:44
	17:18			17:52	25	17:30 (5A)	19:19	24	18:55 (4A)	19:47			20:14	20:30
25	07:15			06:43		17:05 (5A)	07:02		18:30 (4A)	06:18			05:49	05:44
	17:19			17:53	25	17:30 (5A)	19:20	24	18:54 (4A)	19:48			20:15	20:30
26	07:14			06:42		17:05 (5A)	07:01		18:31 (4A)	06:16			05:48	05:44
	17:20			17:54	24	17:29 (5A)	19:21	22	18:53 (4A)	19:49			20:15	20:31
27	07:13			06:40		17:06 (5A)	06:59		18:31 (4A)	06:15			05:47	05:45
	17:21			17:55	23	17:29 (5A)	19:22	20	18:51 (4A)	19:50			20:16	20:31
28	07:13			06:39		17:07 (5A)	06:58		18:33 (4A)	06:14			05:47	05:45
	17:22			17:56	21	17:28 (5A)	19:23	17	18:50 (4A)	19:51			20:17	20:31
29	07:12						06:56		18:34 (4A)	06:13			05:46	05:46
	17:23						19:23	14	18:48 (4A)	19:52			20:18	20:31
30	07:11						06:55		18:38 (4A)	06:11			05:46	05:46
	17:24						19:24	6	18:44 (4A)	19:53			20:18	20:31
31	07:10						06:53						05:45	
	17:25						19:25						20:19	
Potential sun hours	306			301			370			394			440	442
Total, worst case		373			290			359			302			
Sun reduction		0.45			0.62			0.73			0.82			
Oper. time red.		0.71			0.71			0.71			0.71			
Wind dir. red.		0.81			0.76			0.71			0.63			
Total reduction		0.27			0.34			0.38			0.37			
Total, real		99			100			135			113			

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:

4385 Sand Hill Wind - Flicker Model - Layout 1 (Preferred)

Licensed user:
Epsilon Associates, Inc
3 Clock Tower Place, Suite 250
US-MAYNARD MA 01754
978 897 7100

Calculated:
2/2/2016 1:23 PM/3.0.639

SHADOW - Calendar

Calculation: Points & Map - Layout 1**Shadow receptor:** R2 - R2

Assumptions for shadow calculations

Reference year for calendar	2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

	July	August			September			October			November			December		
1	05:46	06:08			06:34		18:56 (3A)	07:00			07:29			07:01		14:42 (7A)
	20:31	20:15			19:37	21	19:17 (3A)	18:51			18:08			16:47	18	15:00 (7A)
2	05:47	06:09			06:35		18:56 (3A)	07:01			07:30			07:02		14:40 (7A)
	20:31	20:14			19:35	19	19:15 (3A)	18:49			18:07			16:47	22	15:02 (7A)
3	05:47	06:09			06:36		18:57 (3A)	07:01			07:31			07:03		14:39 (7A)
	20:31	20:13			19:34	17	19:14 (3A)	18:48			18:06			16:46	25	15:04 (7A)
4	05:48	06:10			06:37		18:58 (3A)	07:02			07:32			07:03		14:38 (7A)
	20:31	20:12			19:32	14	19:12 (3A)	18:46			18:05			16:46	28	15:06 (7A)
5	05:48	06:11			06:38		19:01 (3A)	07:03			06:34			07:04		14:38 (7A)
	20:30	20:11			19:31	8	19:09 (3A)	18:45			18:04			16:46	29	15:07 (7A)
6	05:49	06:12			06:38			07:04			06:35			07:05		14:37 (7A)
	20:30	20:10			19:29			18:43			17:03			16:46	32	15:09 (7A)
7	05:49	06:13			06:39			07:05			06:36			07:06		14:37 (7A)
	20:30	20:09			19:28			18:42			17:02			16:46	33	15:10 (7A)
8	05:50	06:14			06:40			07:06			06:37			07:07		14:37 (7A)
	20:30	20:08			19:26			18:40			17:01			16:46	34	15:11 (7A)
9	05:51	06:15			06:41			07:07			06:38			07:08		14:36 (7A)
	20:30	20:07			19:25			18:39			17:00			16:46	36	15:12 (7A)
10	05:51	06:15			06:42			07:08			06:39			07:09		14:36 (7A)
	20:29	20:06			19:23			18:37			16:59			16:46	37	15:13 (7A)
11	05:52	06:16			06:43			07:09		17:45 (5A)	06:40			07:09		14:36 (7A)
	20:29	20:05			19:22			18:36	10	17:55 (5A)	16:58			16:46	38	15:14 (7A)
12	05:52	06:17			06:43			07:10		17:43 (5A)	06:41			07:10		14:36 (7A)
	20:29	20:04			19:20			18:34	15	17:58 (5A)	16:57			16:46	39	15:15 (7A)
13	05:53	06:18			06:44			07:11		17:41 (5A)	06:42			07:11		14:36 (7A)
	20:28	20:02			19:19			18:33	18	17:59 (5A)	16:57			16:46	40	15:16 (7A)
14	05:54	06:19			06:45		18:27 (4A)	07:12		17:39 (5A)	06:43			07:12		14:36 (7A)
	20:28	20:01			19:17	9	18:36 (4A)	18:32	21	18:00 (5A)	16:56			16:46	41	15:17 (7A)
15	05:54	06:20			06:46		18:24 (4A)	07:12		17:38 (5A)	06:44			07:12		14:36 (7A)
	20:27	20:00			19:16	15	18:39 (4A)	18:30	23	18:01 (5A)	16:55			16:47	41	15:17 (7A)
16	05:55	06:21			06:47		18:22 (4A)	07:13		17:37 (5A)	06:45			07:13		14:36 (7A)
	20:27	19:59			19:14	18	18:40 (4A)	18:29	24	18:01 (5A)	16:54			16:47	42	15:18 (7A)
17	05:56	06:21			06:48		18:20 (4A)	07:14		17:37 (5A)	06:46			07:14		14:37 (7A)
	20:26	19:57			19:13	20	18:40 (4A)	18:27	24	18:01 (5A)	16:54			16:47	42	15:19 (7A)
18	05:57	06:22			06:49		18:19 (4A)	07:15		17:36 (5A)	06:47			07:14		14:37 (7A)
	20:26	19:56			19:11	22	18:41 (4A)	18:26	25	18:01 (5A)	16:53			16:48	42	15:19 (7A)
19	05:57	06:23			06:49		18:18 (4A)	07:16		17:36 (5A)	06:48			07:15		14:37 (7A)
	20:25	19:55			19:09	24	18:42 (4A)	18:25	25	18:01 (5A)	16:52			16:48	43	15:20 (7A)
20	05:58	06:24		19:07 (3A)	06:50		18:17 (4A)	07:17		17:36 (5A)	06:49			07:16		14:37 (7A)
	20:25	19:54	5	19:12 (3A)	19:08	25	18:42 (4A)	18:23	25	18:01 (5A)	16:52			16:48	43	15:20 (7A)
21	05:59	06:25		19:04 (3A)	06:51		18:17 (4A)	07:18		17:36 (5A)	06:51			07:16		14:38 (7A)
	20:24	19:52	12	19:16 (3A)	19:06	25	18:42 (4A)	18:22	24	18:00 (5A)	16:51			16:49	43	15:21 (7A)
22	06:00	06:26		19:01 (3A)	06:52		18:16 (4A)	07:19		17:36 (5A)	06:52			07:17		14:38 (7A)
	20:23	19:51	15	19:16 (3A)	19:05	26	18:42 (4A)	18:21	23	17:59 (5A)	16:50			16:49	43	15:21 (7A)
23	06:00	06:27		18:59 (3A)	06:53		18:15 (4A)	07:20		17:37 (5A)	06:53			07:17		14:39 (7A)
	20:23	19:50	19	19:18 (3A)	19:03	25	18:40 (4A)	18:19	21	17:58 (5A)	16:50			16:50	43	15:22 (7A)
24	06:01	06:27		18:58 (3A)	06:54		18:16 (4A)	07:21		17:38 (5A)	06:54			07:18		14:39 (7A)
	20:22	19:48	21	19:19 (3A)	19:02	23	18:39 (4A)	18:18	19	17:57 (5A)	16:49			16:50	43	15:22 (7A)
25	06:02	06:28		18:57 (3A)	06:55		18:16 (4A)	07:22		17:40 (5A)	06:55			07:18		14:40 (7A)
	20:21	19:47	22	19:19 (3A)	19:00	23	18:39 (4A)	18:17	16	17:56 (5A)	16:49			16:51	43	15:23 (7A)
26	06:03	06:29		18:57 (3A)	06:55		18:17 (4A)	07:23		17:41 (5A)	06:56			07:18		14:41 (7A)
	20:20	19:45	23	19:20 (3A)	18:59	21	18:38 (4A)	18:15	14	17:55 (5A)	16:48			16:51	42	15:23 (7A)
27	06:04	06:30		18:55 (3A)	06:56		18:18 (4A)	07:24		17:44 (5A)	06:57			07:19		14:41 (7A)
	20:20	19:44	24	19:19 (3A)	18:57	18	18:36 (4A)	18:14	9	17:53 (5A)	16:48			16:52	42	15:23 (7A)
28	06:04	06:31		18:55 (3A)	06:57		18:19 (4A)	07:25			06:58			07:19		14:42 (7A)
	20:19	19:43	24	19:19 (3A)	18:55	15	18:34 (4A)	18:13			16:48			16:53	42	15:24 (7A)
29	06:05	06:32		18:55 (3A)	06:58		18:22 (4A)	07:26			06:59		14:49 (7A)	07:19		14:43 (7A)
	20:18	19:41	24	19:19 (3A)	18:54	9	18:31 (4A)	18:12			16:47	3	14:52 (7A)	16:53	41	15:24 (7A)
30	06:06	06:33		18:55 (3A)	06:59			07:27			07:00		14:44 (7A)	07:20		14:43 (7A)
	20:17	19:40	23	19:18 (3A)	18:52			18:11			16:47	13	14:57 (7A)	16:54	41	15:24 (7A)
31	06:07	06:33		18:55 (3A)				07:28						07:20		14:44 (7A)
	20:16	19:38	23	19:18 (3A)				18:10						16:55	40	15:24 (7A)
Potential sun hours	449	422			374			349			306			298		
Total, worst case			235			397			336			16			1168	
Sun reduction			0.96			0.93			0.84			0.61			0.47	
Oper. time red.			0.71			0.71			0.71			0.71			0.71	
Wind dir. red.			0.63			0.69			0.76			0.81			0.81	
Total reduction			0.44			0.47			0.47			0.36			0.28	
Total, real			103			185			157			6			325	

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:

4385 Sand Hill Wind - Flicker Model - Layout 1 (Preferred)

Licensed user:

Epsilon Associates, Inc
3 Clock Tower Place, Suite 250
US-MAYNARD MA 01754
978 897 7100

Calculated:
2/2/2016 1:23 PM/3.0.639

SHADOW - Calendar

Calculation: Points & Map - Layout 1**Shadow receptor:** R3 - R3

Assumptions for shadow calculations

Reference year for calendar 2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

	January			February	March	April	May	June	July	August	September	October	November	December		
1	07:20		11:29 (9A)	07:10	06:38	06:52	06:10	05:45	05:46	06:08	06:34	07:00	07:29	07:01		
	16:55	34	12:03 (9A)	17:26	17:57	19:26	19:54	20:20	20:31	20:15	19:37	18:51	18:08	16:47		
2	07:20		11:31 (9A)	07:09	06:36	06:50	06:09	05:45	05:47	06:08	06:35	07:01	07:30	07:02		
	16:56	31	12:02 (9A)	17:28	17:58	19:27	19:55	20:21	20:31	20:14	19:35	18:49	18:07	16:46		
3	07:21		11:33 (9A)	07:08	06:35	06:48	06:08	05:44	05:47	06:09	06:36	07:01	07:31	07:03		
	16:57	28	12:01 (9A)	17:29	17:59	19:28	19:55	20:21	20:31	20:13	19:34	18:48	18:06	16:46		
4	07:21		11:36 (9A)	07:07	06:33	06:47	06:07	05:44	05:48	06:10	06:37	07:02	07:32	07:03		
	16:58	24	12:00 (9A)	17:30	18:00	19:29	19:56	20:22	20:31	20:12	19:32	18:46	18:05	16:46		
5	07:21		11:39 (9A)	07:06	06:32	06:46	06:06	05:44	05:48	06:11	06:38	07:03	06:34	07:04		
	16:59	18	11:57 (9A)	17:31	18:01	19:30	19:57	20:22	20:30	20:11	19:31	18:45	18:04	16:46		
6	07:21		11:44 (9A)	07:05	06:31	06:44	06:05	05:43	05:49	06:12	06:38	07:04	06:35	07:05		
	17:00	7	11:51 (9A)	17:32	18:02	19:31	19:58	20:23	20:30	20:10	19:29	18:43	17:03	16:46		
7	07:21			07:04	06:29	06:43	06:03	05:43	05:49	06:13	06:39	07:05	06:36	07:06		11:28 (9A)
	17:00			17:33	18:03	19:32	19:59	20:24	20:30	20:09	19:28	18:42	17:02	16:46	13	11:41 (9A)
8	07:21			07:03	06:28	06:41	06:02	05:43	05:50	06:14	06:40	07:06	06:37	07:07		11:25 (9A)
	17:01			17:34	18:04	19:32	20:00	20:24	20:30	20:08	19:26	18:40	17:01	16:46	21	11:46 (9A)
9	07:21			07:02	06:26	06:40	06:01	05:43	05:50	06:14	06:41	07:07	06:38	07:08		11:23 (9A)
	17:02			17:35	18:05	19:33	20:01	20:25	20:30	20:07	19:25	18:39	17:00	16:46	26	11:49 (9A)
10	07:20			07:01	06:25	06:38	06:00	05:43	05:51	06:15	06:42	07:08	06:39	07:09		11:22 (9A)
	17:03			17:37	18:06	19:34	20:02	20:25	20:29	20:06	19:23	18:37	16:59	16:46	30	11:52 (9A)
11	07:20			07:00	06:23	06:37	05:59	05:42	05:52	06:16	06:43	07:09	06:40	07:09		11:20 (9A)
	17:04			17:38	18:07	19:35	20:03	20:26	20:29	20:05	19:22	18:36	16:58	16:46	33	11:53 (9A)
12	07:20			06:59	07:22	06:35	05:58	05:42	05:52	06:17	06:43	07:10	06:41	07:10		11:19 (9A)
	17:05			17:39	19:08	19:36	20:04	20:26	20:29	20:04	19:20	18:34	16:57	16:46	36	11:55 (9A)
13	07:20			06:58	07:20	06:34	05:58	05:42	05:53	06:18	06:44	07:11	06:42	07:11		11:19 (9A)
	17:06			17:40	19:08	19:37	20:04	20:27	20:28	20:02	19:19	18:33	16:56	16:46	38	11:57 (9A)
14	07:20			06:57	07:19	06:32	05:57	05:42	05:54	06:19	06:45	07:11	06:43	07:12		11:19 (9A)
	17:07			17:41	19:09	19:38	20:05	20:27	20:28	20:01	19:17	18:31	16:56	16:46	39	11:58 (9A)
15	07:19			06:56	07:17	06:31	05:56	05:42	05:54	06:20	06:46	07:12	06:44	07:12		11:18 (9A)
	17:08			17:42	19:10	19:39	20:06	20:28	20:27	20:00	19:16	18:30	16:55	16:47	41	11:59 (9A)
16	07:19			06:54	07:16	06:30	05:55	05:42	05:55	06:20	06:47	07:13	06:45	07:13		11:18 (9A)
	17:09			17:43	19:11	19:40	20:07	20:28	20:27	19:59	19:14	18:29	16:54	16:47	42	12:00 (9A)
17	07:19			06:53	07:14	06:28	05:54	05:42	05:56	06:21	06:48	07:14	06:46	07:14		11:19 (9A)
	17:10			17:44	19:12	19:41	20:08	20:28	20:26	19:57	19:12	18:27	16:53	16:47	42	12:01 (9A)
18	07:18			06:52	07:13	06:27	05:53	05:43	05:56	06:22	06:48	07:15	06:47	07:14		11:18 (9A)
	17:11			17:45	19:13	19:42	20:09	20:29	20:26	19:56	19:11	18:26	16:53	16:47	44	12:02 (9A)
19	07:18			06:51	07:11	06:25	05:52	05:43	05:57	06:23	06:49	07:16	06:48	07:15		11:19 (9A)
	17:12			17:46	19:14	19:43	20:10	20:29	20:25	19:55	19:09	18:24	16:52	16:48	44	12:03 (9A)
20	07:17			06:49	07:10	06:24	05:52	05:43	05:58	06:24	06:50	07:17	06:49	07:16		11:18 (9A)
	17:13			17:47	19:15	19:43	20:11	20:29	20:25	19:54	19:08	18:23	16:51	16:48	45	12:03 (9A)
21	07:17			06:48	07:08	06:23	05:51	05:43	05:59	06:25	06:51	07:18	06:51	07:16		11:19 (9A)
	17:14			17:48	19:16	19:44	20:11	20:30	20:24	19:52	19:06	18:22	16:51	16:49	45	12:04 (9A)
22	07:16			06:47	07:07	06:21	05:50	05:43	05:59	06:26	06:52	07:19	06:52	07:17		11:19 (9A)
	17:15			17:49	19:17	19:45	20:12	20:30	20:23	19:51	19:05	18:20	16:50	16:49	45	12:04 (9A)
23	07:16			06:46	07:05	06:20	05:50	05:43	06:00	06:26	06:53	07:20	06:53	07:17		11:20 (9A)
	17:17			17:50	19:18	19:46	20:13	20:30	20:23	19:50	19:03	18:19	16:50	16:50	45	12:05 (9A)
24	07:15			06:44	07:04	06:19	05:49	05:44	06:01	06:27	06:54	07:21	06:54	07:18		11:20 (9A)
	17:18			17:52	19:19	19:47	20:14	20:30	20:22	19:48	19:02	18:18	16:49	16:50	45	12:05 (9A)
25	07:15			06:43	07:02	06:18	05:48	05:44	06:02	06:28	06:54	07:22	06:55	07:18		11:22 (9A)
	17:19			17:53	19:20	19:48	20:15	20:30	20:21	19:47	19:00	18:17	16:49	16:51	44	12:06 (9A)
26	07:14			06:42	07:01	06:16	05:48	05:44	06:03	06:29	06:55	07:23	06:56	07:18		11:22 (9A)
	17:20			17:54	19:21	19:49	20:15	20:31	20:20	19:45	18:58	18:15	16:48	16:51	44	12:06 (9A)
27	07:13			06:40	06:59	06:15	05:47	05:45	06:03	06:30	06:56	07:24	06:57	07:19		11:23 (9A)
	17:21			17:55	19:22	19:50	20:16	20:31	20:20	19:44	18:57	18:14	16:48	16:52	42	12:05 (9A)
28	07:13			06:39	06:58	06:14	05:47	05:45	06:04	06:31	06:57	07:25	06:58	07:19		11:24 (9A)
	17:22			17:56	19:22	19:51	20:17	20:31	20:19	19:43	18:55	18:13	16:48	16:52	42	12:06 (9A)
29	07:12				06:56	06:13	05:46	05:45	06:05	06:32	06:58	07:26	06:59	07:19		11:25 (9A)
	17:23				19:23	19:52	20:18	20:31	20:18	19:41	18:54	18:12	16:47	16:53	41	12:06 (9A)
30	07:11				06:55	06:11	05:46	05:46	06:06	06:32	06:59	07:27	07:00	07:20		11:26 (9A)
	17:24				19:24	19:53	20:18	20:31	20:17	19:40	18:52	18:11	16:47	16:54	39	12:05 (9A)
31	07:10				06:53		05:45		06:07	06:33		07:28		07:20		11:27 (9A)
	17:25				19:25		20:19		20:16	19:38		18:09		16:54	37	12:04 (9A)
Potential sun hours	306			301	370	394	440	442	450	422	374	349	305	298		
Total, worst case		142													963	
Sun reduction		0.45													0.47	
Oper. time red.		0.71													0.71	
Wind dir. red.		0.63													0.63	
Total reduction		0.20													0.21	
Total, real		29													204	

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Appendix C-2

Shadow Flicker Modeling Results: Calendars – Layout 2 (Alternate)

Licensed user:
Epsilon Associates, Inc
3 Clock Tower Place, Suite 250
US-MAYNARD MA 01754
978 897 7100

Calculated:
2/2/2016 1:46 PM/3.0.639

SHADOW - Calendar

Calculation: Points & Map - Layout 2**Shadow receptor:** R1 - R1

Assumptions for shadow calculations

Reference year for calendar 2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

	January	February	March	April			May	June	July	August			September			October	November	December
1	07:20	07:10	06:38	06:52		18:53 (4G)	06:10	05:45	05:46	06:08			06:34		18:34 (4G)	07:00	07:29	07:01
	16:56	17:27	17:57	19:26	10	19:03 (4G)	19:54	20:20	20:31	20:15			19:37	41	19:15 (4G)	18:51	18:08	16:47
2	07:20	07:09	06:36	06:50		18:48 (4G)	06:09	05:45	05:47	06:09			06:35		18:33 (4G)	07:01	07:30	07:02
	16:56	17:28	17:58	19:27	18	19:06 (4G)	19:55	20:21	20:31	20:14			19:35	40	19:13 (4G)	18:49	18:07	16:47
3	07:21	07:08	06:35	06:49		18:46 (4G)	06:08	05:44	05:47	06:09			06:36		18:34 (4G)	07:02	07:31	07:03
	16:57	17:29	17:59	19:28	23	19:09 (4G)	19:55	20:21	20:31	20:13			19:34	38	19:12 (4G)	18:48	18:06	16:46
4	07:21	07:07	06:33	06:47		18:43 (4G)	06:07	05:44	05:48	06:10			06:37		18:34 (4G)	07:02	07:33	07:03
	16:58	17:30	18:00	19:29	27	19:10 (4G)	19:56	20:22	20:31	20:12			19:32	38	19:12 (4G)	18:46	18:05	16:46
5	07:21	07:06	06:32	06:46		18:41 (4G)	06:06	05:44	05:48	06:11			06:38		18:35 (4G)	07:03	06:34	07:04
	16:59	17:31	18:01	19:30	31	19:12 (4G)	19:57	20:23	20:30	20:11			19:31	36	19:11 (4G)	18:45	18:04	16:46
6	07:21	07:05	06:31	06:44		18:39 (4G)	06:05	05:44	05:49	06:12			06:38		18:35 (4G)	07:04	06:35	07:05
	17:00	17:32	18:02	19:31	33	19:12 (4G)	19:58	20:23	20:30	20:10			19:29	35	19:10 (4G)	18:43	17:03	16:46
7	07:21	07:04	06:29	06:43		18:38 (4G)	06:04	05:43	05:49	06:13			06:39		18:35 (4G)	07:05	06:36	07:06
	17:01	17:33	18:03	19:32	36	19:14 (4G)	19:59	20:24	20:30	20:09			19:28	32	19:07 (4G)	18:42	17:02	16:46
8	07:21	07:03	06:28	06:41		18:37 (4G)	06:03	05:43	05:50	06:14			06:40		18:37 (4G)	07:06	06:37	07:07
	17:01	17:34	18:04	19:33	37	19:14 (4G)	20:00	20:24	20:30	20:08			19:26	29	19:06 (4G)	18:40	17:01	16:46
9	07:21	07:02	06:26	06:40		18:36 (4G)	06:02	05:43	05:51	06:15			06:41		18:38 (4G)	07:07	06:38	07:08
	17:02	17:36	18:05	19:33	39	19:15 (4G)	20:01	20:25	20:30	20:07			19:25	26	19:04 (4G)	18:39	17:00	16:46
10	07:20	07:01	06:25	06:38		18:35 (4G)	06:01	05:43	05:51	06:15			06:42		18:40 (4G)	07:08	06:39	07:09
	17:03	17:37	18:06	19:34	39	19:14 (4G)	20:02	20:25	20:29	20:06			19:23	22	19:02 (4G)	18:37	16:59	16:46
11	07:20	07:00	06:23	06:37		18:35 (4G)	06:00	05:43	05:52	06:16			06:43		18:43 (4G)	07:09	06:40	07:09
	17:04	17:38	18:07	19:35	40	19:15 (4G)	20:03	20:26	20:29	20:05			19:22	16	18:59 (4G)	18:36	16:58	16:46
12	07:20	06:59	07:22	06:35		18:35 (4G)	05:59	05:43	05:52	06:17			06:44		18:48 (4G)	07:10	06:41	07:10
	17:05	17:39	19:08	19:36	40	19:15 (4G)	20:04	20:26	20:29	20:04			19:20	3	18:51 (4G)	18:34	16:57	16:46
13	07:20	06:58	07:20	06:34		18:34 (4G)	05:58	05:43	05:53	06:18			06:44			07:11	06:42	07:11
	17:06	17:40	19:09	19:37	41	19:15 (4G)	20:05	20:27	20:28	20:02			19:19			18:33	16:57	16:46
14	07:20	06:57	07:19	06:33		18:34 (4G)	05:57	05:43	05:54	06:19		18:57 (4G)	06:45			07:12	06:43	07:12
	17:07	17:41	19:10	19:38	41	19:15 (4G)	20:05	20:27	20:28	20:01	4	19:01 (4G)	19:17			18:32	16:56	16:47
15	07:19	06:56	07:17	06:31		18:33 (4G)	05:56	05:43	05:54	06:20		18:52 (4G)	06:46			07:12	06:44	07:12
	17:08	17:42	19:10	19:39	41	19:14 (4G)	20:06	20:28	20:27	20:00	14	19:06 (4G)	19:16			18:30	16:55	16:47
16	07:19	06:54	07:16	06:30		18:33 (4G)	05:55	05:43	05:55	06:21		18:49 (4G)	06:47			07:13	06:45	07:13
	17:09	17:43	19:11	19:40	41	19:14 (4G)	20:07	20:28	20:27	19:59	20	19:09 (4G)	19:14			18:29	16:54	16:47
17	07:19	06:53	07:14	06:28		18:34 (4G)	05:54	05:43	05:56	06:21		18:46 (4G)	06:48			07:14	06:46	07:14
	17:10	17:44	19:12	19:41	40	19:14 (4G)	20:08	20:28	20:26	19:57	24	19:10 (4G)	19:13			18:27	16:54	16:47
18	07:18	06:52	07:13	06:27		18:33 (4G)	05:53	05:43	05:57	06:22		18:44 (4G)	06:49			07:15	06:47	07:14
	17:11	17:45	19:13	19:42	40	19:13 (4G)	20:09	20:29	20:26	19:56	27	19:11 (4G)	19:11			18:26	16:53	16:48
19	07:18	06:51	07:11	06:26		18:34 (4G)	05:53	05:43	05:57	06:23		18:43 (4G)	06:49			07:16	06:48	07:15
	17:12	17:46	19:14	19:43	38	19:12 (4G)	20:10	20:29	20:25	19:55	30	19:13 (4G)	19:09			18:25	16:52	16:48
20	07:17	06:50	07:10	06:24		18:34 (4G)	05:52	05:43	05:58	06:24		18:42 (4G)	06:50			07:17	06:50	07:16
	17:13	17:47	19:15	19:44	38	19:12 (4G)	20:11	20:29	20:25	19:54	32	19:14 (4G)	19:08			18:23	16:52	16:48
21	07:17	06:48	07:08	06:23		18:34 (4G)	05:51	05:43	05:59	06:25		18:41 (4G)	06:51			07:18	06:51	07:16
	17:15	17:49	19:16	19:44	36	19:10 (4G)	20:11	20:30	20:24	19:52	34	19:15 (4G)	19:06			18:22	16:51	16:49
22	07:16	06:47	07:07	06:22		18:35 (4G)	05:50	05:43	06:00	06:26		18:39 (4G)	06:52			07:19	06:52	07:17
	17:16	17:50	19:17	19:45	35	19:10 (4G)	20:12	20:30	20:23	19:51	35	19:14 (4G)	19:05			18:21	16:50	16:49
23	07:16	06:46	07:05	06:20		18:36 (4G)	05:50	05:44	06:00	06:27		18:38 (4G)	06:53			07:20	06:53	07:17
	17:17	17:51	19:18	19:46	33	19:09 (4G)	20:13	20:30	20:23	19:50	37	19:15 (4G)	19:03			18:19	16:50	16:50
24	07:15	06:44	07:04	06:19		18:36 (4G)	05:49	05:44	06:01	06:27		18:37 (4G)	06:54			07:21	06:54	07:18
	17:18	17:52	19:19	19:47	31	19:07 (4G)	20:14	20:30	20:22	19:48	39	19:16 (4G)	19:02			18:18	16:49	16:50
25	07:15	06:43	07:02	06:18		18:38 (4G)	05:49	05:44	06:02	06:28		18:37 (4G)	06:55			07:22	06:55	07:18
	17:19	17:53	19:20	19:48	28	19:06 (4G)	20:15	20:30	20:21	19:47	39	19:16 (4G)	19:00			18:17	16:49	16:51
26	07:14	06:42	07:01	06:16		18:39 (4G)	05:48	05:44	06:03	06:29		18:36 (4G)	06:55			07:23	06:56	07:18
	17:20	17:54	19:21	19:49	25	19:04 (4G)	20:15	20:31	20:20	19:45	40	19:16 (4G)	18:59			18:16	16:48	16:51
27	07:13	06:40	06:59	06:15		18:41 (4G)	05:47	05:45	06:04	06:30		18:36 (4G)	06:56			07:24	06:57	07:19
	17:21	17:55	19:22	19:50	21	19:02 (4G)	20:16	20:31	20:20	19:44	40	19:16 (4G)	18:57			18:14	16:48	16:52
28	07:13	06:39	06:58	06:14		18:43 (4G)	05:47	05:45	06:04	06:31		18:34 (4G)	06:57			07:25	06:58	07:19
	17:22	17:56	19:23	19:51	16	18:59 (4G)	20:17	20:31	20:19	19:43	41	19:15 (4G)	18:55			18:13	16:48	16:53
29	07:12		06:56	06:13		18:47 (4G)	05:46	05:46	06:05	06:32		18:34 (4G)	06:58			07:26	06:59	07:19
	17:23		19:23	19:52	8	18:55 (4G)	20:18	20:31	20:18	19:41	41	19:15 (4G)	18:54			18:12	16:47	16:53
30	07:11		06:55	06:11			05:46	05:46	06:06	06:33		18:34 (4G)	06:59			07:27	07:00	07:20
	17:24		19:24	19:53			20:18	20:31	20:17	19:40	41	19:15 (4G)	18:52			18:11	16:47	16:54
31	07:10		06:53				05:46		06:07	06:33		18:34 (4G)				07:28		07:20
	17:26		19:25				20:19		20:16	19:38	41	19:15 (4G)				18:10		16:55
Potential sun hours	306	301	370	394			440	442	449	422			374			349	306	298
Total, worst case					926						579			356				
Sun reduction					0.82						0.96			0.93				
Oper. time red.					0.71						0.71			0.71				
Wind dir. red.					0.64						0.64			0.64				
Total reduction					0.37						0.44			0.43				
Total, real					347						254			151				

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

SHADOW - Calendar

Calculation: Points & Map - Layout 2**Shadow receptor:** R2 - R2

Assumptions for shadow calculations

Reference year for calendar 2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

	January	February	March			April			May			June		
1	07:20	07:10	06:38			06:52		18:29 (7G)	06:10			05:45		19:40 (6G)
	16:56	17:27	17:57			19:26	28	18:57 (7G)	19:54			20:20	15	19:55 (6G)
2	07:20	07:09	06:36			06:50		18:29 (7G)	06:09			05:45		19:39 (6G)
	16:56	17:28	17:58			19:27	26	18:55 (7G)	19:55			20:21	18	19:57 (6G)
3	07:21	07:08	06:35			06:49		18:30 (7G)	06:08			05:44		19:39 (6G)
	16:57	17:29	17:59			19:28	25	18:55 (7G)	19:55			20:21	19	19:58 (6G)
4	07:21	07:07	06:33			06:47		18:30 (7G)	06:07			05:44		19:38 (6G)
	16:58	17:30	18:00			19:29	23	18:53 (7G)	19:56			20:22	20	19:58 (6G)
5	07:21	07:06	06:32			06:46		18:32 (7G)	06:06			05:44		19:38 (6G)
	16:59	17:31	18:01			19:30	19	18:51 (7G)	19:57			20:22	21	19:59 (6G)
6	07:21	07:05	06:31			06:44		18:33 (7G)	06:05			05:43		19:37 (6G)
	17:00	17:32	18:02			19:31	15	18:48 (7G)	19:58			20:23	23	20:00 (6G)
7	07:21	07:04	06:29			06:43		18:37 (7G)	06:04			05:43		19:37 (6G)
	17:01	17:33	18:03			19:32	9	19:09 (3G)	19:59			20:24	24	20:01 (6G)
8	07:21	07:03	06:28			06:41		19:02 (3G)	06:03			05:43		19:37 (6G)
	17:01	17:34	18:04			19:33	11	19:13 (3G)	20:00			20:24	24	20:01 (6G)
9	07:21	07:02	06:26			06:40		19:00 (3G)	06:02			05:43		19:37 (6G)
	17:02	17:36	18:05			19:33	15	19:15 (3G)	20:01			20:25	25	20:02 (6G)
10	07:20	07:01	06:25			06:38		18:57 (3G)	06:01			05:43		19:36 (6G)
	17:03	17:37	18:06			19:34	19	19:16 (3G)	20:02			20:25	26	20:02 (6G)
11	07:20	07:00	06:23			06:37		18:57 (3G)	06:00			05:43		19:36 (6G)
	17:04	17:38	18:07			19:35	20	19:17 (3G)	20:03			20:26	26	20:02 (6G)
12	07:20	06:59	07:22			06:35		18:56 (3G)	05:59			05:43		19:36 (6G)
	17:05	17:39	19:08			19:36	22	19:18 (3G)	20:04			20:26	27	20:03 (6G)
13	07:20	06:58	07:20			06:34		18:55 (3G)	05:58			05:42		19:36 (6G)
	17:06	17:40	19:09			19:37	23	19:18 (3G)	20:04			20:27	27	20:03 (6G)
14	07:20	06:57	07:19			06:32		18:55 (3G)	05:57			05:42		19:36 (6G)
	17:07	17:41	19:09			19:38	23	19:18 (3G)	20:05			20:27	28	20:04 (6G)
15	07:19	06:56	07:17			06:31		18:54 (3G)	05:56			05:42		19:36 (6G)
	17:08	17:42	19:10			19:39	23	19:17 (3G)	20:06			20:28	28	20:04 (6G)
16	07:19	06:54	07:16			06:30		18:54 (3G)	05:55			05:43		19:37 (6G)
	17:09	17:43	19:11			19:40	24	19:18 (3G)	20:07			20:28	27	20:04 (6G)
17	07:19	06:53	07:14			06:28		18:54 (3G)	05:54			05:43		19:37 (6G)
	17:10	17:44	19:12			19:41	23	19:17 (3G)	20:08			20:28	27	20:04 (6G)
18	07:18	06:52	07:13			06:27		18:54 (3G)	05:53			05:43		19:38 (6G)
	17:11	17:45	19:13			19:42	22	19:16 (3G)	20:09			20:29	27	20:05 (6G)
19	07:18	06:51	07:11		18:43 (7G)	06:26		18:55 (3G)	05:53			05:43		19:38 (6G)
	17:12	17:46	19:14	8	18:51 (7G)	19:43	20	19:15 (3G)	20:10			20:29	28	20:06 (6G)
20	07:17	06:50	07:10		18:38 (7G)	06:24		18:56 (3G)	05:52			05:43		19:38 (6G)
	17:13	17:47	19:15	16	18:54 (7G)	19:43	19	19:15 (3G)	20:11			20:29	28	20:06 (6G)
21	07:17	06:48	07:08		18:36 (7G)	06:23		18:56 (3G)	05:51			05:43		19:38 (6G)
	17:14	17:48	19:16	20	18:56 (7G)	19:44	17	19:13 (3G)	20:11			20:30	28	20:06 (6G)
22	07:16	06:47	07:07		18:34 (7G)	06:22		18:58 (3G)	05:50			05:43		19:38 (6G)
	17:16	17:50	19:17	23	18:57 (7G)	19:45	13	19:11 (3G)	20:12			20:30	28	20:06 (6G)
23	07:16	06:46	07:05		18:32 (7G)	06:20		19:01 (3G)	05:50			05:44		19:39 (6G)
	17:17	17:51	19:18	25	18:57 (7G)	19:46	7	19:08 (3G)	20:13			20:30	28	20:07 (6G)
24	07:15	06:44	07:04		18:31 (7G)	06:19			05:49			05:44		19:39 (6G)
	17:18	17:52	19:19	28	18:59 (7G)	19:47			20:14			20:30	28	20:07 (6G)
25	07:15	06:43	07:02		18:30 (7G)	06:18			05:49			05:44		19:39 (6G)
	17:19	17:53	19:20	29	18:59 (7G)	19:48			20:15			20:30	27	20:06 (6G)
26	07:14	06:42	07:01		18:30 (7G)	06:16			05:48			05:44		19:39 (6G)
	17:20	17:54	19:21	29	18:59 (7G)	19:49			20:15			20:31	27	20:06 (6G)
27	07:13	06:40	06:59		18:28 (7G)	06:15			05:47			05:45		19:40 (6G)
	17:21	17:55	19:22	31	18:59 (7G)	19:50			20:16			20:31	27	20:07 (6G)
28	07:13	06:39	06:58		18:29 (7G)	06:14			05:47			05:45		19:39 (6G)
	17:22	17:56	19:23	30	18:59 (7G)	19:51			20:17			20:31	28	20:07 (6G)
29	07:12		06:56		18:28 (7G)	06:13			05:46		19:47 (6G)	05:46		19:40 (6G)
	17:23		19:23	30	18:58 (7G)	19:52			20:18	1	19:48 (6G)	20:31	27	20:07 (6G)
30	07:11		06:55		18:28 (7G)	06:11			05:46		19:43 (6G)	05:46		19:40 (6G)
	17:24		19:24	30	18:58 (7G)	19:53			20:18	9	19:52 (6G)	20:31	27	20:07 (6G)
31	07:10		06:53		18:28 (7G)				05:45		19:42 (6G)			
	17:25		19:25	29	18:57 (7G)				20:19	12	19:54 (6G)			
Potential sun hours	306	301	370			394			440			442		
Total, worst case				328			446			22			763	
Sun reduction				0.73			0.82			0.92			0.94	
Oper. time red.				0.71			0.71			0.71			0.71	
Wind dir. red.				0.69			0.65			0.47			0.47	
Total reduction				0.36			0.38			0.31			0.32	
Total, real				119			170			7			242	

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Project:

4385 Sand Hill Wind - Flicker Model - Layout 2 (Alternate)

Licensed user:
Epsilon Associates, Inc
3 Clock Tower Place, Suite 250
US-MAYNARD MA 01754
978 897 7100

Calculated:
2/2/2016 1:46 PM/3.0.639

SHADOW - Calendar

Calculation: Points & Map - Layout 2**Shadow receptor:** R2 - R2

Assumptions for shadow calculations

Reference year for calendar 2017

Sunshine probability S/S0 (Sun hours/Possible sun hours) []

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.45	0.62	0.73	0.82	0.92	0.94	0.97	0.96	0.93	0.84	0.61	0.47

Operational time

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Sum
262	108	40	36	61	125	147	46	32	95	2,192	1,875	366	140	178	538	6,241

Idle start wind speed: Cut in wind speed from power curve

	July			August			September			October	November	December
1	05:46		19:40 (6G)	06:08			06:34		18:56 (3G)	07:00	07:29	07:01
	20:31	27	20:07 (6G)	20:15			19:37	21	19:17 (3G)	18:51	18:08	16:47
2	05:47		19:41 (6G)	06:09			06:35		18:56 (3G)	07:01	07:30	07:02
	20:31	26	20:07 (6G)	20:14			19:35	19	19:15 (3G)	18:49	18:07	16:47
3	05:47		19:41 (6G)	06:09			06:36		18:57 (3G)	07:01	07:31	07:03
	20:31	26	20:07 (6G)	20:13			19:34	17	19:14 (3G)	18:48	18:06	16:46
4	05:48		19:42 (6G)	06:10			06:37		18:58 (3G)	07:02	07:32	07:03
	20:31	25	20:07 (6G)	20:12			19:32	14	19:12 (3G)	18:46	18:05	16:46
5	05:48		19:42 (6G)	06:11			06:38		19:01 (3G)	07:03	06:34	07:04
	20:30	24	20:06 (6G)	20:11			19:31	8	19:09 (3G)	18:45	18:04	16:46
6	05:49		19:43 (6G)	06:12			06:38		18:31 (7G)	07:04	06:35	07:05
	20:30	24	20:07 (6G)	20:10			19:29	12	18:43 (7G)	18:43	17:03	16:46
7	05:49		19:43 (6G)	06:13			06:39		18:28 (7G)	07:05	06:36	07:06
	20:30	23	20:06 (6G)	20:09			19:28	17	18:45 (7G)	18:42	17:02	16:46
8	05:50		19:45 (6G)	06:14			06:40		18:26 (7G)	07:06	06:37	07:07
	20:30	21	20:06 (6G)	20:08			19:26	20	18:46 (7G)	18:40	17:01	16:46
9	05:51		19:46 (6G)	06:15			06:41		18:24 (7G)	07:07	06:38	07:08
	20:30	20	20:06 (6G)	20:07			19:25	24	18:48 (7G)	18:39	17:00	16:46
10	05:51		19:46 (6G)	06:15			06:42		18:23 (7G)	07:08	06:39	07:09
	20:29	19	20:05 (6G)	20:06			19:23	26	18:49 (7G)	18:37	16:59	16:46
11	05:52		19:47 (6G)	06:16			06:43		18:22 (7G)	07:09	06:40	07:09
	20:29	17	20:04 (6G)	20:05			19:22	27	18:49 (7G)	18:36	16:58	16:46
12	05:52		19:48 (6G)	06:17			06:43		18:20 (7G)	07:10	06:41	07:10
	20:29	15	20:03 (6G)	20:04			19:20	29	18:49 (7G)	18:34	16:57	16:46
13	05:53		19:50 (6G)	06:18			06:44		18:19 (7G)	07:11	06:42	07:11
	20:28	12	20:02 (6G)	20:02			19:19	30	18:49 (7G)	18:33	16:57	16:46
14	05:54		19:52 (6G)	06:19			06:45		18:19 (7G)	07:12	06:43	07:12
	20:28	9	20:01 (6G)	20:01			19:17	30	18:49 (7G)	18:32	16:56	16:46
15	05:54			06:20			06:46		18:18 (7G)	07:12	06:44	07:12
	20:27			20:00			19:16	31	18:49 (7G)	18:30	16:55	16:47
16	05:55			06:21			06:47		18:18 (7G)	07:13	06:45	07:13
	20:27			19:59			19:14	31	18:49 (7G)	18:29	16:54	16:47
17	05:56			06:21			06:48		18:17 (7G)	07:14	06:46	07:14
	20:26			19:57			19:13	30	18:47 (7G)	18:27	16:54	16:47
18	05:57			06:22			06:49		18:17 (7G)	07:15	06:47	07:14
	20:26			19:56			19:11	30	18:47 (7G)	18:26	16:53	16:48
19	05:57			06:23			06:49		18:18 (7G)	07:16	06:48	07:15
	20:25			19:55			19:09	28	18:46 (7G)	18:25	16:52	16:48
20	05:58			06:24		19:07 (3G)	06:50		18:18 (7G)	07:17	06:49	07:16
	20:25			19:54	5	19:12 (3G)	19:08	27	18:45 (7G)	18:23	16:52	16:48
21	05:59			06:25		19:04 (3G)	06:51		18:19 (7G)	07:18	06:51	07:16
	20:24			19:52	12	19:16 (3G)	19:06	25	18:44 (7G)	18:22	16:51	16:49
22	06:00			06:26		19:01 (3G)	06:52		18:20 (7G)	07:19	06:52	07:17
	20:23			19:51	15	19:16 (3G)	19:05	22	18:42 (7G)	18:21	16:50	16:49
23	06:00			06:27		18:59 (3G)	06:53		18:20 (7G)	07:20	06:53	07:17
	20:23			19:50	19	19:18 (3G)	19:03	20	18:40 (7G)	18:19	16:50	16:50
24	06:01			06:27		18:58 (3G)	06:54		18:23 (7G)	07:21	06:54	07:18
	20:22			19:48	21	19:19 (3G)	19:02	14	18:37 (7G)	18:18	16:49	16:50
25	06:02			06:28		18:57 (3G)	06:55		18:27 (7G)	07:22	06:55	07:18
	20:21			19:47	22	19:19 (3G)	19:00	5	18:32 (7G)	18:17	16:49	16:51
26	06:03			06:29		18:57 (3G)	06:55			07:23	06:56	07:18
	20:20			19:45	23	19:20 (3G)	18:59			18:15	16:48	16:51
27	06:04			06:30		18:55 (3G)	06:56			07:24	06:57	07:19
	20:20			19:44	24	19:19 (3G)	18:57			18:14	16:48	16:52
28	06:04			06:31		18:55 (3G)	06:57			07:25	06:58	07:19
	20:19			19:43	24	19:19 (3G)	18:55			18:13	16:48	16:53
29	06:05			06:32		18:55 (3G)	06:58			07:26	06:59	07:19
	20:18			19:41	24	19:19 (3G)	18:54			18:12	16:47	16:53
30	06:06			06:33		18:55 (3G)	06:59			07:27	07:00	07:20
	20:17			19:40	23	19:18 (3G)	18:52			18:11	16:47	16:54
31	06:07			06:33		18:55 (3G)				07:28		07:20
	20:16			19:38	23	19:18 (3G)				18:10		16:55
Potential sun hours	449			422			374			349	306	298
Total, worst case		288			235			557				
Sun reduction		0.97			0.96			0.93				
Oper. time red.		0.71			0.71			0.71				
Wind dir. red.		0.47			0.63			0.68				
Total reduction		0.33			0.43			0.45				
Total, real		94			102			253				

Table layout: For each day in each month the following matrix apply

Day in month	Sun rise (hh:mm)		First time (hh:mm) with flicker	(WTG causing flicker first time)
	Sun set (hh:mm)	Minutes with flicker	Last time (hh:mm) with flicker	(WTG causing flicker last time)

Attachment 2
Noise Analysis

SOUND TECHNICAL REPORT FOR THE SAND HILL PROPOSED WIND PROJECT ALAMEDA COUNTY, CALIFORNIA

PREPARED FOR:

New Dimension Energy Company
221 Crescent Street, Suite 103A
Waltham, MA 02453
Contact: Charlie Karustis
781.609.4758

PREPARED BY:

ICF International
630 K Street, Suite 400
Sacramento, CA 95814
Contact: David Buehler, P.E., INCE Bd. Cert.
916.737.3000

February 2016

ICF International. 2016. *Sound Technical Report for the Sand Hill Proposed Wind Project, Alameda County, California*. February. (ICF 00716.15.) Sacramento, CA. Prepared for Ogin, Inc., Waltham, MA.

Contents

Page

Sound Technical Report for the Proposed Sand Hill Wind Project 1

- Project Description 1
- Environmental Noise Fundamentals 1
  - Sound Descriptors 1
  - Decibel Addition 4
  - Perception of Sound Level Changes 4
  - Sound Propagation 4
  - Other Factors Related to Wind Turbines 5
- Regulatory Setting 6
  - Local 6
- Existing Sound Environment 9
  - Short-Term Monitoring 9
  - Long-Term Monitoring 10
- Impact Discussion 11
  - Analysis Methods 11
- References Cited 17

Appendix A GW121-2500 Wind Turbine Sound Power Levels

List of Tables and Figures

Tables **Page**

Table 1. Typical A-Weighted Sound Levels 3
Table 2. Alameda County Exterior Noise Standards 7
Table 3. Summary of Measurements at S1 10
Table 4. Summary of Measurements at S2 10
Table 5. Summary of Measurements at S3 10
Table 6. Summary of Long-term Measurements 11
Table 7. A-Weighted Sound Power Levels 11
Table 8. Octave Band Sound Levels for Proposed Turbines 12
Table 9. Predicted Sound Levels at Various Distances from a Single Turbine 12
Table 10. Modeling Results for Layout 1 (Preferred Alternative) 12
Table 11. Modeling Results for the Layout 2 (Alternate) 13
Table 12. Summary of Measurements at M2 (July 2013) 14
Table 13. Legacy Turbines in the Project Area 14
Table 14. Sound Power Levels for Small Turbines (≤100 kW) 15
Table 15. Estimated Sound Power Levels for Legacy Turbines 15
Table 16. Calculated Sound Levels at R1 for Legacy Turbines and GW121-2500 Layouts (with measured sound level at Position M2) 16

Figure **Follows Page**

Figure 1 Proposed Locations of Layout 1 Turbines 2
Figure 2 Proposed Locations of Layout 2 Turbines 2
Figure 3. Sound Power Levels for Small Turbines .... on 16

Acronyms and Abbreviations

°F	degrees Fahrenheit
ANSI	American National Standard Institute
APWRA	Altamont Pass Wind Resource Area
AWEA	American Wind Energy Association
CNEL	Community Noise Equivalent Level
County	Alameda County
CUP	Conditional Use Permit
dB	decibels
dBA	A-weighted sound level
dBC	C-weighted sound level
Hz	Hertz
kHz	kilohertz
kW	kilowatt
L_{dn}	day-night level
L_{eq}	equivalent sound level
L_{eq}(h)	1-hour A-weighted equivalent sound level
L_{max}	maximum A-weighted sound level
L_{min}	minimum A-weighted sound level
L_{xx}	percentile-exceeded sound level
m/s	Meters per second
mPa	micro-Pascals
mph	miles per hour
MW	megawatt
NDEC	New Dimension Energy Company
NREL	National Renewable Energy Laboratory
project applicant	New Dimension Energy Company
proposed project	Sand Hill Wind Project
SLM	sound level meter
WTGS	Wind Turbine Generation Systems

Sound Technical Report for the Proposed Sand Hill Wind Project

New Dimension Energy Company (NDEC) (project applicant) has proposed a repowering program (Sand Hill Wind Project [proposed project]) that would entail the removal and replacement of existing 40–100 kilowatt (kW) wind turbines previously owned by SeaWest Power Resources on multiple parcels in the Altamont Pass Wind Resource Area (APWRA). The project applicant would replace the older, existing turbines with twelve (12) Goldwind GW121-2500 wind turbines at a 90-meter hub height. The proposed project would require a Conditional Use Permit (CUP) in accordance with the Alameda County (County) Zoning Ordinance.

This sound technical report provides an assessment of sound associated with operation of the proposed GW121-2500 wind turbines. This report discusses environmental noise fundamentals, applicable noise regulations and policies, existing noise conditions, and an evaluation of effects on sound associated with implementation of the proposed project at five (5) receptor locations.

Project Description

The project includes three separate areas where turbines will be located. Two turbine array scenarios are evaluated:

- Layout 1 – Preferred Alternative
- Layout 2 – Alternate

Under each scenario, 12 GW121/2500 2.5 megawatt (MW) turbines would be installed at a 90-meter hub height. Figures 1 and 2 illustrate the project area and the proposed locations of the Layout 1 and Layout 2 turbines, respectively. Each figure also depicts the location of nearby residences and their proximity to the proposed turbine locations.

Environmental Noise Fundamentals

Sound can be described as the mechanical energy of a vibrating object transmitted by pressure waves through a liquid or gaseous medium (e.g., air) to a hearing organ, such as a human ear. *Noise* is defined as sound that is objectionable because it is disturbing or annoying.

In the science of acoustics, the fundamental model consists of a sound (or noise) source, a receiver, and the propagation path between the two. The loudness of the noise source and obstructions or atmospheric factors affecting the propagation path to the receiver determine the sound level and characteristics of the noise perceived by the receiver.

Sound Descriptors

Continuous sound can be described by frequency (pitch) and amplitude (loudness). A low-frequency sound is perceived as low in pitch. Frequency is expressed in terms of cycles per second, or Hertz (Hz) (e.g., a frequency of 250 cycles per second is referred to as 250 Hz). High frequencies are sometimes more conveniently expressed in kilohertz (kHz), or thousands of Hz. The audible frequency range for humans is generally between 20 Hz and 20,000 Hz.

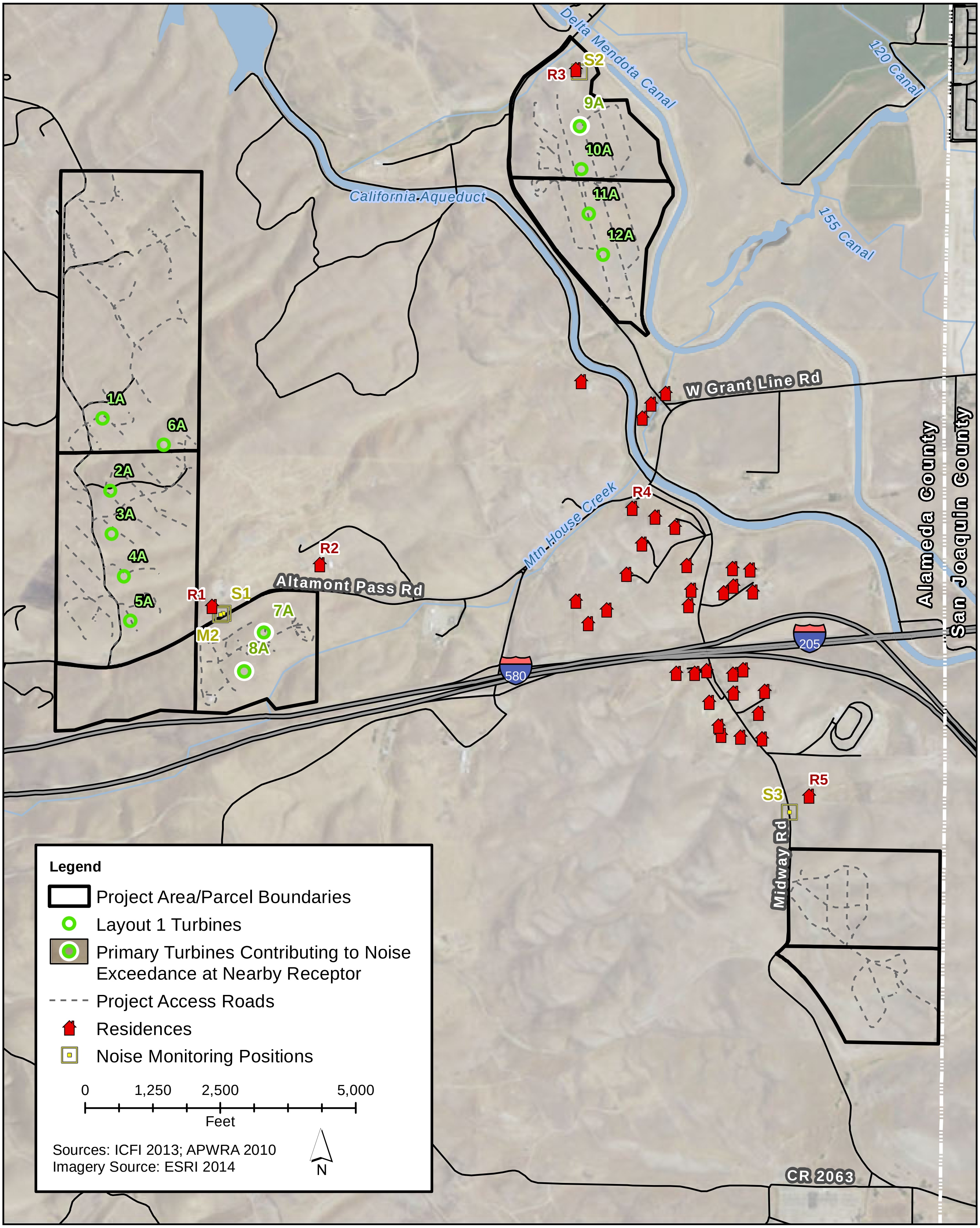
The amplitude of pressure waves generated by a sound source determines the loudness of that source. Sound pressure amplitude is measured in micro-Pascals (mPa). One mPa is approximately one hundred-billionth (0.00000000001) of normal atmospheric pressure. Sound pressure amplitudes for different kinds of noise environments can range from less than 100 to 100,000,000 mPa. Because of this huge range of values, sound is rarely expressed in terms of mPa. Instead, a logarithmic scale is used to describe *sound pressure level* (also referred to simply as *sound level*) in terms of decibels (dB). The threshold of hearing for young people is about 0 dB, which corresponds to 20 mPa.

The dB scale alone does not adequately characterize how humans perceive noise. The dominant frequencies of a sound have a substantial effect on the human response to that sound. Although the intensity (energy per unit area) of the sound is a purely physical quantity, the loudness or human response is determined by characteristics of the human ear.

Human hearing is limited in the range of audible frequencies as well as in the way it perceives the sound pressure level in that range. In general, people are most sensitive to the frequency range of 1,000–8,000 Hz and perceive sounds within that range better than sounds of the same amplitude in higher or lower frequencies. To approximate the response of the human ear, sound levels of individual frequency bands are weighted, depending on the human sensitivity to those frequencies. Then, an *A-weighted sound level* (expressed in units of dBA) can be computed based on this information.

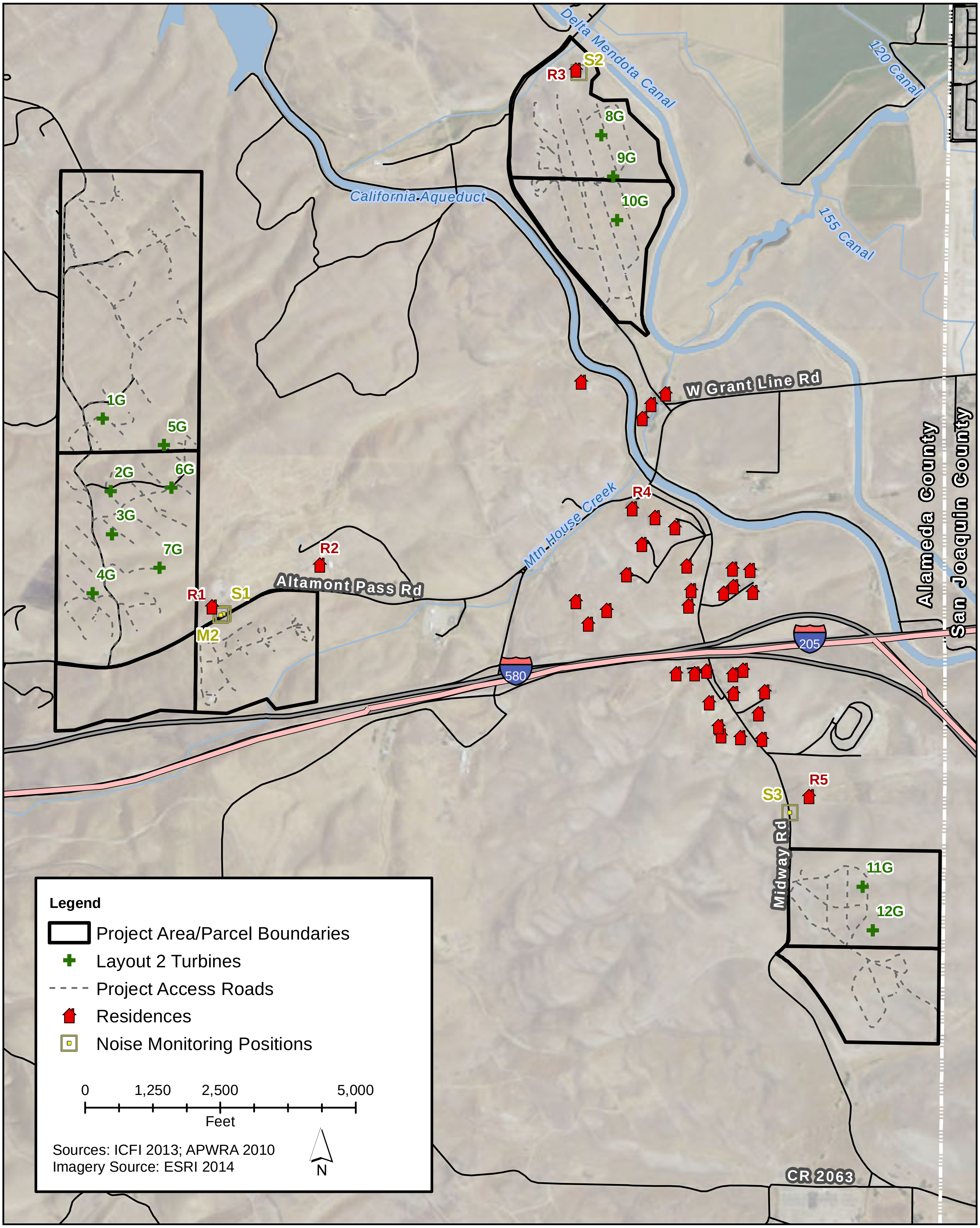
The A-weighting network approximates the frequency response of the average young ear when listening to most ordinary sounds. When people make judgments of the relative loudness or annoyance of a sound, their judgments correlate well with the A-scale sound levels of those sounds. Table 1 describes typical A-weighted sound levels for various noise sources.

Other weighting networks have been devised to address high noise levels or other special problems (e.g., B-, C-, and D-scales). C-weighted sound levels are sometimes considered for wind turbine noise analysis. The C-weighted sound level, or dBC, gives more weight to lower frequency noise. C-weighting is very close to an unweighted or *flat* response. When evaluating sounds that have varying amounts of low-frequency energy, A-weighted sound levels will not indicate the low frequency variations, but C-weighted sound levels will.



Sources: ICFI 2013; APWRA 2010
Imagery Source: ESRI 2014

Figure 1
Noise Impacts - Layout 1



Sources: ICFI 2013; APWRA 2010
Imagery Source: ESRI 2014

Figure 2
Noise Impacts - Layout 2

Table 1. Typical A-Weighted Sound Levels

Common Outdoor Activities	Sound Level (dBA)	Common Indoor Activities
	— 110 —	Rock band
Jet flying at 1,000 feet		
	— 100 —	
Gas lawn mower at 3 feet		
	— 90 —	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	— 80 —	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawn mower, 100 feet	— 70 —	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	— 60 —	
		Large business office
Quiet urban daytime	— 50 —	Dishwasher next room
Quiet urban nighttime	— 40 —	Theater, large conference room (background)
Quiet suburban nighttime		
	— 30 —	Library
Quiet rural nighttime		Bedroom at night
	— 20 —	
		Broadcast/recording studio
	— 10 —	
Lowest threshold of human hearing	— 0 —	Lowest threshold of human hearing

Source: California Department of Transportation 2013.
dBA = A-weighted sound level
mph = miles per hour

Noise in most typical environments fluctuates over time. Various noise descriptors have been developed to describe time-varying noise levels. The following are the noise descriptors most commonly used in environmental noise analysis.

- **Equivalent Sound Level (L_{eq}):** L_{eq} represents an average of the sound energy occurring over a specified period. In effect, L_{eq} is the steady-state sound level containing the same acoustical energy as the time-varying sound that actually occurs during the same period. The 1-hour A-weighted equivalent sound level (L_{eq}[h]) is the energy average of A-weighted sound levels occurring during a 1-hour period.
- **Percentile-Exceeded Sound Level (L_{xx}):** L_{xx} represents the sound level exceeded for a given percentage of a specified period (e.g., L_{10} is the sound level exceeded 10% of the time, and L_{90} is the sound level exceeded 90% of the time).
- **Minimum and Maximum Sound Level (L_{min} and L_{max}):** L_{min} is the lowest A-weighted sound level during a specified period, while L_{max} is the highest.

- **Day-Night Level (L_{dn}):** L_{dn} is the energy average of A-weighted sound levels occurring over a 24-hour period, with a 10-dB penalty added to A-weighted sound levels occurring between 10:00 p.m. and 7:00 a.m.
- **Community Noise Equivalent Level (CNEL):** Much like L_{dn}, CNEL is the energy average of the A-weighted sound levels occurring over a 24-hour period, with a 10-dB penalty added to A-weighted sound levels occurring between 10:00 p.m. and 7:00 a.m. and a 5-dB penalty added to the A-weighted sound levels occurring between 7:00 p.m. and 10:00 p.m.

Decibel Addition

Because decibels are logarithmic units, sound pressure levels cannot be added or subtracted through ordinary arithmetic. On the dB scale, a doubling of sound energy corresponds to a 3-dB increase. In other words, when two identical sources are each producing sound of the same loudness, their combined sound level at a given distance would be 3 dB higher than one source under the same conditions. For example, if one wind turbine produces a sound pressure level of 70 dBA, two wind turbines would not produce 140 dBA—rather, they would combine to produce 73 dBA. The cumulative sound level of any number of sources such as wind turbines can be determined using decibel addition.

Perception of Sound Level Changes

Under controlled conditions in an acoustical laboratory, the trained, healthy human ear is able to discern 1-dB changes in sound levels when exposed to steady, single-frequency (pure tone) signals in the mid-frequency (1,000–8,000 Hz) range. In typical noisy environments, changes in sound of 1–2 dB are generally not perceptible. However, it is widely accepted that people are able to begin to detect sound level increases of 3 dB in typical noisy environments. Further, a 5-dB increase is generally perceived as a distinctly noticeable increase, and a 10-dB increase is generally perceived as a doubling of loudness. Accordingly, a doubling of sound energy (e.g., doubling the volume of traffic on a highway) that would result in a 3-dB increase in sound would generally be barely detectable.

Sound Propagation

When sound propagates over distance, it changes in level and frequency. The manner in which sound reduces with distance depends on the factors described in the next sections.

Geometric Spreading

Sound from a stationary localized source (i.e., a point source) propagates uniformly outward in a spherical pattern. The sound level attenuates (i.e., decreases) at a rate of 6 dB for each doubling of distance from a point source. The strength of the source is often characterized by its sound power level. Sound power level is independent of the distance a receiver is from the source and is a property of the source alone. If the sound power level of an idealized source and its distance from a receiver are known, sound pressure level at the receiver point can be calculated based on geometric spreading. This approach is applied to wind turbine generators in the standard measurement techniques for determining the sound power or source level (Illingworth & Rodkin 2009).

A number of factors can modify the sound level associated with spherical spreading. The first factor is the ground, which acts as a reflecting plane. If the ground is hard, sound energy is reflected off the ground and typically increases A-weighted sound levels by 3 dB. If the ground plane is acoustically soft or absorptive (such as grassland or a plowed field), some sound energy is absorbed by the ground and the increase from reflection will be less than 3 dB.

Other Factors that Affect Propagation

Additional factors that affect sound propagation are often grouped under the term *excess attenuation*. Excess attenuation is any additional attenuation that is not attributed to simple spherical spreading. Excess attenuation includes shielding effects from barriers (e.g., hills or structures); attenuation effects associated with vegetation, trees, rain, sleet, snow, or fog; and attenuation associated with wind and temperature gradients. Excess attenuation is almost always present under outdoor propagation conditions. For sound propagating over soft ground at near grazing angles of incidence, excess attenuations of 20–30 dB can be measured as a result of the interference effect of the direct and reflected sound. However, under certain meteorological conditions, some of these excess attenuation mechanisms are reduced or eliminated, leaving spherical spreading as the primary determinant of sound level at a receiver location (Illingworth & Rodkin 2009).

Other Factors Related to Wind Turbines

Operating wind turbines can generate two types of sound: mechanical sound from components such as gearboxes, generators, yaw drives, and cooling fans; and aerodynamic sound from the flow of air over and past the rotor blades. Modern wind turbine design has greatly reduced mechanical sound, which can generally be ignored in comparison to the aerodynamic sound, which is often described as a swishing or whooshing sound.

Wind turbines produce a broadband sound (i.e., the sound covers a wide range of frequencies, including low frequencies). Low-frequency sounds are in the range of 20–100 Hz, and infrasonic sound (or infrasound) is low-frequency sound of less than 20 Hz. Low-frequency sound propagates over longer distances than higher frequency sound, is transmitted through buildings more readily, and can excite structural vibrations (e.g., rattling windows or doors). The threshold of perception, in decibels, also increases as the frequency decreases. For example, in the frequency range where humans hear best (in the low kH), the threshold of hearing is at about 0 dB, but at a frequency of only 10 Hz, the threshold of hearing is about 100 dB (Rogers et al. 2006).

Older wind turbines—particularly those in which the blades were on the downwind side of the tower—produced more low-frequency sound because their towers blocked wind flow, causing the blades to pass through more turbulent air. Modern, upwind turbines produce a broadband sound that includes low-frequency sounds, but not at significant levels. A primary cause for low-frequency sounds in modern turbines is the blade passing through the change in air flow at the front of the tower, and this can be aggravated by unusually turbulent wind conditions. This effect is generally referred to as blade amplitude modulation because the aerodynamic sound generated by the blades (i.e., the swishing sound) is modulated as the turbine blades pass through uneven air velocities. The uneven air that causes this effect may be due to interaction of other turbines, excessive wind shear, or topography (Bowdler 2008).

Wind generates sound. The amount of sound generated can vary widely depending primarily on the amount of vegetation in the area and the speed of the wind. For a given wind speed, the sound level in a desert with no trees or vegetation will be different than in a highly vegetated area. When trees are in full leaf, wind rustling through the leaves produces high frequency sound. The amount of sound generated depends on wind speed, the distance to the trees or foliage, and the approximate frontal area of the trees or foliage as seen from the observed position. Sound levels generated by wind can range from approximately 20–60 dBA for wind speeds in the range of 2–20 miles per hour (mph) (Hoover & Keith 2000).

Regulatory Setting

Federal, state, and local agencies regulate different aspects of environmental noise. Generally, the federal government establishes noise standards for transportation-related noise sources closely linked to interstate commerce. These sources include aircraft, locomotives, and heavy-duty trucks. The state government sets noise standards for transportation noise sources such as automobiles, light trucks, and motorcycles. Noise sources associated with industrial, commercial, and construction activities are generally subject to local control through noise ordinances and general plan policies. Local general plans identify general principles intended to guide and influence development plans. No federal or state regulations are directly applicable to the proposed project. The local regulatory setting is discussed below.

Local

County General Plan Noise Element

The County's General Plan Noise Element (Alameda County 1975) contains goals, objectives, and implementation programs to provide county residents with an environment that is free from excessive noise, and promotes compatibility of land uses with respect to noise. The Noise Element does not explicitly define the acceptable outdoor noise level for the backyards of single-family homes or common outdoor spaces of multifamily housing projects, but it recognizes the U.S. Environmental Protection Agency noise level standards for residential land uses. These standards are an exterior L_{dn} of 55 dBA and an interior L_{dn} of 45 dBA. (The L_{dn} measurement, which also includes a 10 dB weighting for nighttime sound, is approximately equal to the CNEL for most environmental settings.) The Noise Element also references noise and land use compatibility standards developed by an Association of Bay Area Governments–sponsored study.

East County Area Plan

The County's *East County Area Plan* (Alameda County 2000) contains a goal, policies, and implementation programs related to community noise and windfarms.

Goal: To minimize East County residents and workers exposure to excessive noise.

Policy 170: The County shall protect nearby existing uses from potential traffic, noise, dust, visual, and other impacts generated by the construction and operation of windfarm facilities.

Policy 288: The County shall endeavor to maintain acceptable noise levels throughout East County.

Policy 289: The County shall limit or appropriately mitigate new noise sensitive development in areas exposed to projected noise levels exceeding 60 dB based on the California Office of Noise Control Land Use Compatibility Guidelines.

Policy 290: The County shall require noise studies as part of development review for projects located in areas exposed to high noise levels and in areas adjacent to existing residential or other sensitive land uses. Where noise studies show that noise levels in areas of existing housing will exceed "normally acceptable" standards (as defined by the California Office of Noise Control Land Use Compatibility Guidelines), major development projects shall contribute their pro-rated share to the cost of noise mitigation measures such as those described in Program 104.

Program 74: The County shall amend the Zoning Ordinance to incorporate siting and design standards for wind turbines to mitigate biological, visual, noise, and other impacts generated by windfarm operations.

Program 104: The County shall require the use of noise reduction techniques (such as buffers, building design modifications, lot orientation, sound walls, earth berms, landscaping, building setbacks, and real estate disclosure notices) to mitigate noise impacts generated by transportation-related and stationary sources as specified in the California Office of Noise Control Land Use Compatibility Guidelines.

County General Code

Several components of the County's General Code are applicable to the proposed project. The County's Noise Ordinance (County General Code, Chapter 6.60) allows higher noise exposure levels for commercial properties than for residential uses, schools, hospitals, churches, or libraries. These standards augment the state-mandated requirements of the County Building Code, which establishes standards for interior noise levels consistent with the noise insulation standards in the California State Building Code. Table 2 shows the number of cumulative minutes that a particular external noise level is permitted, as well as the maximum noise allowed under the County General Code.

Table 2. Alameda County Exterior Noise Standards

Cumulative Number of Minutes in any 1-hour Period	Daytime (7:00 a.m. to 10:00 p.m.) (dBA)	Nighttime (10:00 p.m. to 7:00 a.m.) (dBA)
Residential uses, schools, hospitals, churches, and libraries		
30	50	45
15	55	50
5	60	55
1	65	60
Maximum (0)	70	65
Commercial uses		
30	65	60
15	70	65
5	75	70
1	80	75
Maximum (0)	85	80

dBA = A-weighted sound level

The County Zoning Ordinance (County General Code, Chapter 17) restricts noise from commercial activities by prohibiting any use that would generate a noise or vibration that is discernible without instruments beyond the property line. This performance standard does not apply to transportation activities or temporary construction work. The provisions of the zoning ordinance do not apply to noise sources associated with construction, provided the activities do not take place before 7:00 a.m. or after 7:00 p.m. on any day except Saturday or Sunday, or before 8:00 a.m. or after 5:00 p.m. on Saturday or Sunday.

County Conditional Use Permits

The County's CUPs for the continued operation of the APWRA windfarms after 2005, regulated by Resolution Number R-2005-463, identify the following specific conditions regarding noise.

21. Noise Standards: Wind turbines shall be operated so as to not exceed the County's noise standard of 55 dBA (L_{dn}) or 70 dBC (L_{dn}) as measured in both cases at the exterior of any dwelling unit. If the dwelling unit is on land under lease from the Permittee, the applicable standard shall be 65 dBA (L_{dn}) and 70 dBC (L_{dn}).

22. Noise Complaints: In the event a reasonable complaint is received by the Building Official alleging the presence of sound levels from a wind turbine or windfarm exceeding 55 dBA (L_{dn}) at a dwelling that was existing at the time this permit was issued (or 65 dBA [L_{dn}] if the dwelling is on land under lease for a windfarm), or 70 dBC (L_{dn}) as measured at the exterior of the dwelling:

    a. The Building Official shall report this matter to the Permittee and to the Planning Director and upon receipt of such report, this matter shall be brought to hearing pursuant to Section 17.54.650 and may be considered as provided by Section 17.54.030 of the Alameda County Ordinance Code; and

    b. Upon receipt of the report of the Building Official, the Planning Director shall commission a qualified firm to make a site specific study and furnish a report and recommendation on the circumstances, if any, which would render the project in conformance with all applicable noise conditions; the report shall also include a recommendation to the Board of Zoning Adjustments who will make the final determination as to whether subsection (d) shall be imposed.

    c. For a minimum 30-day period from the date of notification, at the time and place as may be agreed upon by the parties involved, Permittee shall attempt in good faith to negotiate a resolution of this matter with the party making the allegation; any such resolution shall be reported to the Planning Director in a timely manner; and

    d. Following the review period as provided under subsection (c) and until the conclusion of the revocation procedures as provided by Section 17.54.030, up to one fourth of the wind turbines authorized by this permit to be constructed or maintained that are in closest proximity to the dwelling of the party making the allegation, shall be made inoperative.

    Methods for measuring and reporting acoustic emissions from wind turbines and windfarms shall be equal to or exceed the minimum standards for precision described in American Wind Energy Association (AWEA) Standard AWEA 2.1-1989: *Procedures for the Measurement and Reporting of Acoustic Emissions from Wind Turbine Generation Systems (WTGS) Volume I: First Tier.*

    The Planning Director, in consultation with the Alameda County Environmental Health Services Agency, shall establish criteria for noise samples and measurement parameters such as the duration of data collection, time of day, wind speed, atmospheric conditions and direction as set forth in the Wyle Research Report.

23. Noise Enforcement Deposits: The Permittee shall as condition of the continued operation of the Facility as approved under this Permit maintain a $2,000.00 cash deposit for use in the

> investigation and evaluation of a noise complaint as provided in Condition 22 herein above. If all or any part of said cash deposit is depleted by such activities, the Permittee shall restore the balance of the deposit to the original $2,000.00. In the course of the review of this permit on the third anniversary of its issuance, if warranted by the record, the requirement of this $2,000.00 deposit may be deleted and funds paid by the Permittee may be returned to the Permittee.

The Resolution approving the CUPs for windfarm operations included a finding that as a land use, the wind energy use "is properly related to other land uses and transportation and service facilities in the vicinity, in that … d) Although some residents may object to the visual, noise, or other effects of the turbines, the County has determined that the wind energy projects are in compliance with the conditions of approval and are an acceptable use in the area."

Existing Sound Environment

Land around the project area is primarily agricultural land with some scattered rural residences. Sound sources in the project area include traffic on local and distant roadways, existing wind turbines, and natural sources such as birds and wind blowing through tall grass.

Short-Term Monitoring

Short-term (1–2 minute average) measurements were collected at three monitoring locations located near residences (receptors) R1, R3, and R5 and designated as S1, S2, and S3, respectively (Figures 1 and 2). ICF was not granted landowner access to the R1 and R5 properties so position S1 and S2 were located in the public right-of-way directly adjacent to Altamont Pass Road and Midway Road, respectively. ICF was granted access to the property at R2 by the land owner.

Position S1 was located approximately 150 feet southeast of receptor R1. Position S2 was located on the property near the residence. Position S3 was located approximately 375 feet southwest of receptor R3.

Monitoring was conducted at S1, S2, and S3 on Monday, January 25, 2016, at 11:21 a.m., 11:53 a.m., and 12:31 p.m., respectively, using a Larson Davis Model 831 sound level meter (SLM). This SLM is classified as Type 1 (precision-grade) instrument, as defined in American National Standard Institute (ANSI) specification S1.4-1984 and International Electrotechnical Commission publications 804 and 651. The meters were set to the "slow" time-response mode and the A-weighting filter network.

Wind speed, temperature, and relative humidity measurements were taken during the sound measurement periods with a handheld Kestrel 3000 portable weather meter. Weather conditions were generally calm with occasional gusts to 5 or 6 mph. Skies were overcast, with temperature at 53 degrees Fahrenheit (°F) and relative humidity at 75%. The sound level measurements were taken during calm, quiet periods when there were no vehicles or other obvious sources of sound. None of the existing turbines in the immediate area were operating. Tables 3 through 5 summarize the short-term sound level measurement results at each monitoring position.

Table 3. Summary of Measurements at S1

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
S1	11:21 a.m.	1 min	40.8	57.2	35.7	43.1	39.1	38.1	36.9

Latitude, Longitude Coordinates: 37.743639°, -121.603321°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

Table 4. Summary of Measurements at S2

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
S2	11:53 a.m.	2 min	34.9	44.1	27.1	38.5	34.0	32.6	28.7

Latitude, Longitude Coordinates: 37.771322°, -121.580955°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

Table 5. Summary of Measurements at S3

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
S3	12:31 a.m.	2 min	48.2	62.4	42.6	51.9	48.5	47.4	44.3

Latitude, Longitude Coordinates: 37.733864°, -121.566979°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

Long-Term Monitoring

Long-term sound level data was also collected at monitoring positions S1, S2, and S3 in 1-hour increments on Tuesday, January 26, and Wednesday, January 27, 2016 beginning at midnight and ending at midnight. Monitoring was conducted using three Piccolo SLM-P3 sound level meters, a Type 2 instrument, as defined in ANSI specification S1.4-1984 and International Electrotechnical Commission publications 804 and 651. As previously noted, positions S1 and S3 were located in the public right-of-way directly adjacent to the roadway. Accordingly, the measurements at these positions were strongly influenced by traffic and represent sound levels that are higher than at the nearby residences; the results at these positions are provided for general reference. Table 6 summarizes the measurement results.

Table 6. Summary of Long-term Measurements

Location	Tuesday January 26 (L_{dn})	Wednesday January 27 (L_{dn})
S1*	77.5	77.2
S2	50.8	49.5
S3*	67.0	65.5

*Measurement location abutting roadway and is strongly influenced by traffic. This measurement value represents a sound level higher than on the nearby residential property.

L_{dn} = day-night level

Impact Discussion

Analysis Methods

Wind Turbine Sound

The project applicant provided one-third octave band A-weighted sound power data for the GW121/2500. A copy of the data corresponding to a wind speed of 10 meters per second (m/s) is provided in Appendix A. For analysis purposes, octave band sound power levels were used and determined by summing the one-third octave band sound power levels associated with each octave band. Table 7 summarizes the resulting A-weighted octave band sound power levels and the overall A-weighted sound power level.

Table 7. A-Weighted Sound Power Levels

Overall (dBA)	Octave Bands								
	31.5	63	125	250	500	1000	2000	4000	8000
	A-Weighted Sound Power Levels								
106.8	80.1	88.2	92.4	98.7	102.4	100.8	94.1	93.5	96.0

dBA = A-weighted sound level

Sound levels at various distances are calculated on the basis of hemispherical point source attenuation using the following equation (Hoover & Keith 2000):

$$L_p = L_w - 10\log 2\pi d^2 + 10$$

Where:

L_p = sound pressure level
L_w = sound power level
d = distance from source in feet

Atmospheric molecular absorption based on “standard” day conditions (64°F and 70% humidity) was also included in the calculation (Hoover & Keith 2000). Attenuation values per 1,000 feet are summarized in Table 8.

Table 8. Octave Band Sound Levels for Proposed Turbines

Octave band	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Atmospheric absorption	0.1	0.2	0.4	0.7	1.5	3.0	7.6	13.7

Hz = Hertz
kHZ = kilohertz

Table 9 incorporates the data from Table 7 and Table 8 to provide a summary of the single turbine sound levels at various distances.

Table 9. Predicted Sound Levels at Various Distances from a Single Turbine

Distance (feet)	dBA
500	54.0
1,000	47.4
1,500	43.4
2,000	40.4
2,500	38.1
3,000	36.1
3,500	34.4
4,000	32.9

dBA = A-weighted sound level

Analysis

Each layout would involve the operation of 12 turbines. The cumulative sound level at five key receptor locations was calculated by applying geometric attenuation and atmospheric attenuation from Table 8. No other attenuation factors or safety factors were applied. Receptor locations are shown in Figures 1 and 2.

Table 10 summarizes the calculated A-weighted L_{eq} and L_{dn} sound levels at each receptor location for Layout 1 (Preferred Alternative).

Table 10. Modeling Results for Layout 1 (Preferred Alternative)

Receptor	L_{eq} (dBA)	L_{dn} (dBA)	L_{dn} (dBC)
R1	51.1	**57.5**	**71.8**
R2	45.8	52.2	67.4
R3	48.5	54.9	69.2
R4	36.7	43.1	60.6
R5	29.2	35.6	55.7

L_{eq} = equivalent sound level
L_{dn} = day-night level
dBA = A-weighted sound level
dBC = C-weighted sound level

The results show an exceedance of the County 55 L_{dn} (A) and 70 L_{dn} (C) noise standards at R1 (shown in bold in Table 10). The exceedance is primarily driven by turbines 7A and 8A, the turbines closest to R1. R3 is on land under lease with the project. As such, the applicable noise standard increases to 65 L_{dn} (A).

One approach for reducing the L_{dn} sound levels to a compliant level at R1 would be to curtail the operation of turbines 7A and 8A at night. The resulting modeled sound levels are 54.6 L_{dn} (A) and 69.2 L_{dn} (C). However, this strategy is not economically feasible given the wind speeds are typically higher during the evening and early morning hours.

Table 11 summarizes the calculated sound levels at each receptor location under Layout 2 (Alternate). The A-weighted L_{eq} and L_{dn} at each receptor location are provided.

Table 11. Modeling Results for the Layout 2 (Alternate)

Receptor	L_{eq} (dBA)	L_{dn} (dBA)	L_{dn} (dBC)
R1	48.5	54.9	69.5
R2	42.6	49.0	64.8
R3	46.6	53.0	67.5
R4	35.5	41.9	59.8
R5	42.4	48.8	63.9

L_{eq} = equivalent sound level
L_{dn} = day-night level
dBA = A-weighted sound level
dBC = C-weighted sound level

The results in Table 11 do not show an exceedance of the County 55 L_{dn} (A) and 70 L_{dn} (C) noise standards. However, the calculated L_{dn} value at receptor R1 is however within 0.5 dB of the 55 L_{dn} (A) and L_{dn} (C) noise standards.

Discussion and Conclusions

Although the calculated sound for the proposed GW121-2500 wind turbines at receptor R1 exceeds County noise standards under Layout 1, and is close to exceeding the standards under Layout 2, it is important to put these calculated sound levels in context. Large numbers of wind turbines have operated in the project area near these receptors for several decades; for purposes of this discussion, these existing turbines are referred to as legacy turbines. The following is a discussion of previous measurements and modeling that have been used to characterize sound conditions when legacy turbines were previously operating.

Measurements with Legacy Turbines Operating

ICF conducted sound level measurements near receptor R1 in July 2013 at a position designated as M2 (Figures 1 and 2) about 400 feet southwest of the residence (ICF International 2013). At that time, a number of the legacy turbines were operating. The average wind speed as measured with a handheld meter during the measurement period was approximately 12 mph (5.4 m/s). Table 12 summarizes key measurement data recorded. Sound from the legacy turbines and sound from wind blowing through the grass was audible. Measurements were taken in the absence of nearby traffic or other specific sources of sound.

Table 12. Summary of Measurements at M2 (July 2013)

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
M2	10:38 a.m.	5 min	56.1	62.6	53.6	57.6	56.0	55.5	54.3

Latitude, Longitude Coordinates: 37.743564°, -121.603492°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

The measured L_{eq} value at M2 was 56.1 dBA. The sound levels at M2 are considered to be reasonably representative of the sound levels at R1 in the absence of traffic.

Modeling of Legacy Turbines

To provide further context, a sound model was developed assuming 399 legacy turbines were operating within the project area. Table 13 summarizes the models, ratings, and number of legacy turbines.

Table 13. Legacy Turbines in the Project Area

Turbine Name	Rating (kWs)	Number of Turbines
Enertech	40	136
Micon 65 kW	65	225
Windmatic 15S	66	26
Polenki 100	100	12

kW = kilowatt

Manufacturer sound power level or octave-band data are not available for these legacy turbines. There is, however, a study conducted by the National Renewable Energy Laboratory (NREL) (National Renewable Energy Laboratory 2003) that provides measured A-weighted sound power levels associated with several types of small wind turbines that are similar in size to the legacy turbines. Table 14 lists theses turbine models along with their power ratings and sound power levels.

Table 14. Sound Power Levels for Small Turbines (≤100 kW)

Name	Rating (kW)	Sound Power (dBA) for Wind at 8 m/s
Southwest AIR 403	0.4	81.2
Southwest Whisper H40	0.9	84.9
Bergey Excel-S	10	98.4
Atlantic Orient AOC 15/50	50	101.1
NPS North Wind 100	100	93.8

Source: National Renewable Energy Laboratory 2003.
kW = kilowatt
dBA = A-weighted sound level
m/s = meters per second

To estimate the sound power of the legacy turbines, a logarithmic curve fit line was developed using the NREL measured sound power levels. The estimated sound power levels are summarized in Table 15 and plotted in Figure 3.

Table 15. Estimated Sound Power Levels for Legacy Turbines

Name	Rating (kW)	Sound Power (dBA) for Wind at 8 m/s
Enertech	40	97.1
Micon 65 kW	65	98.5
Windmatic 15S	66	98.6
Polenki 100	100	99.8

kW = kilowatt
dBA = A-weighted sound level
m/s = meters per second

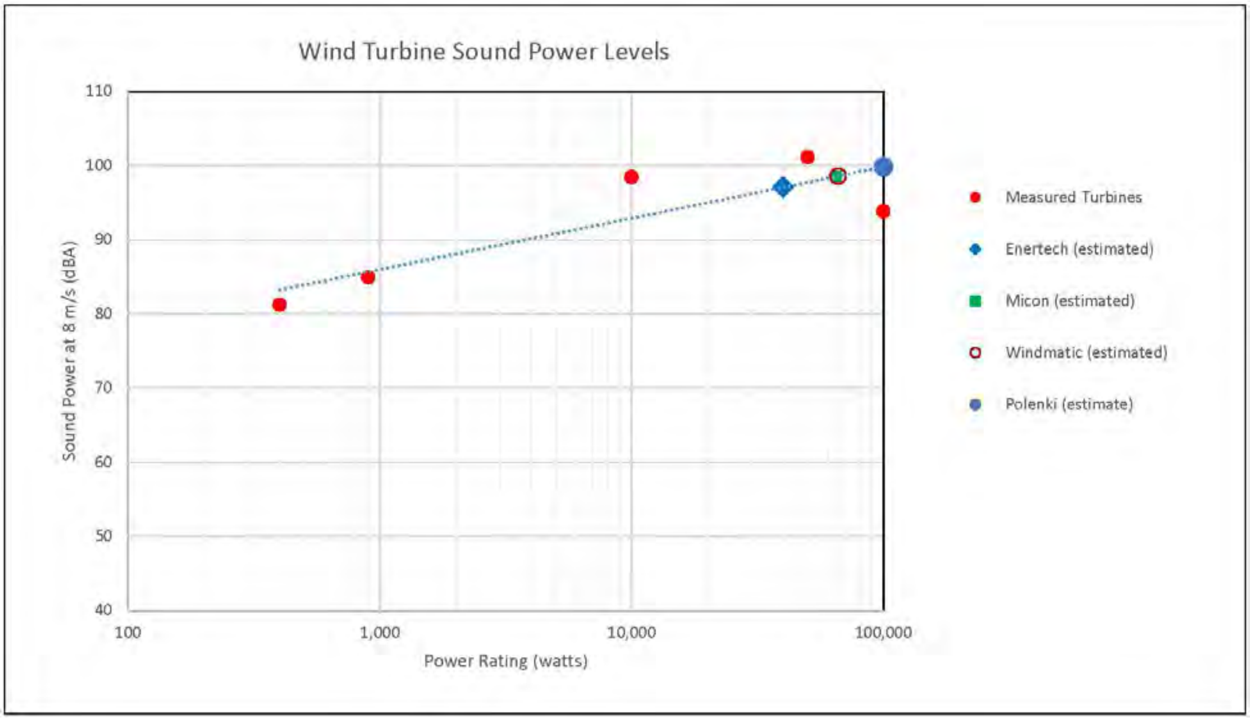


Figure 3. Sound Power Levels for Small Turbines

A legacy turbine sound model was then developed using the Table 15 results and employing the same methods as those described for the proposed GW121-2500 turbines. For comparison, Table 16 summarizes the calculated sound levels at receptor R1 for the legacy turbines, the sound level measured at position M2, and the calculated sound levels for the two GW121-2500 layouts.

Table 16. Calculated Sound Levels at R1 for Legacy Turbines and GW121-2500 Layouts (with measured sound level at Position M2)

Condition	L_{eq} (dBA)	L_{dn} (dBA)
Legacy	56.6	63.0
M2 (measured)	56.1	NA
Layout 1 – GW121-2500	51.1	57.5
Layout 2 – GW121-2500	48.5	54.9

L_{eq} = equivalent sound level
L_{dn} = day-night level
dBA = A-weighted sound level
NA = not applicable

The modeling results show that the calculated L_{eq} of 56.6 dBA for the legacy turbines is consistent with the 56.1 dBA measured at M2. Further, the result show that the calculated sound levels for receptor R1 from the operation of the two GW121-2500 layouts are likely lower than sound levels experienced at that location during the operation of the 399 legacy turbine array.

References Cited

Alameda County. 1975. *Alameda County General Plan Noise Element*.

Alameda County. 2000. *East County Area Plan*.

Bowdler, D. 2008. Amplitude Modulation of Wind Turbine Noise. A Review of the Evidence. *Institute of Acoustics Bulletin* 33:4. Available: http://docs.wind-watch.org/bowdler-amofwindturbines.pdf. Accessed: June 27, 2013. Clydebank, UK: New Acoustics.

California Department of Transportation. 2013. *Technical Noise Supplement to the Traffic Noise Analysis Protocol*. Sacramento, CA.

Hoover & Keith, Inc. 2000. *Noise Control for Buildings, Manufacturing Plants, Equipment and Products.* Lecture notes, first published 1981. Houston, TX.

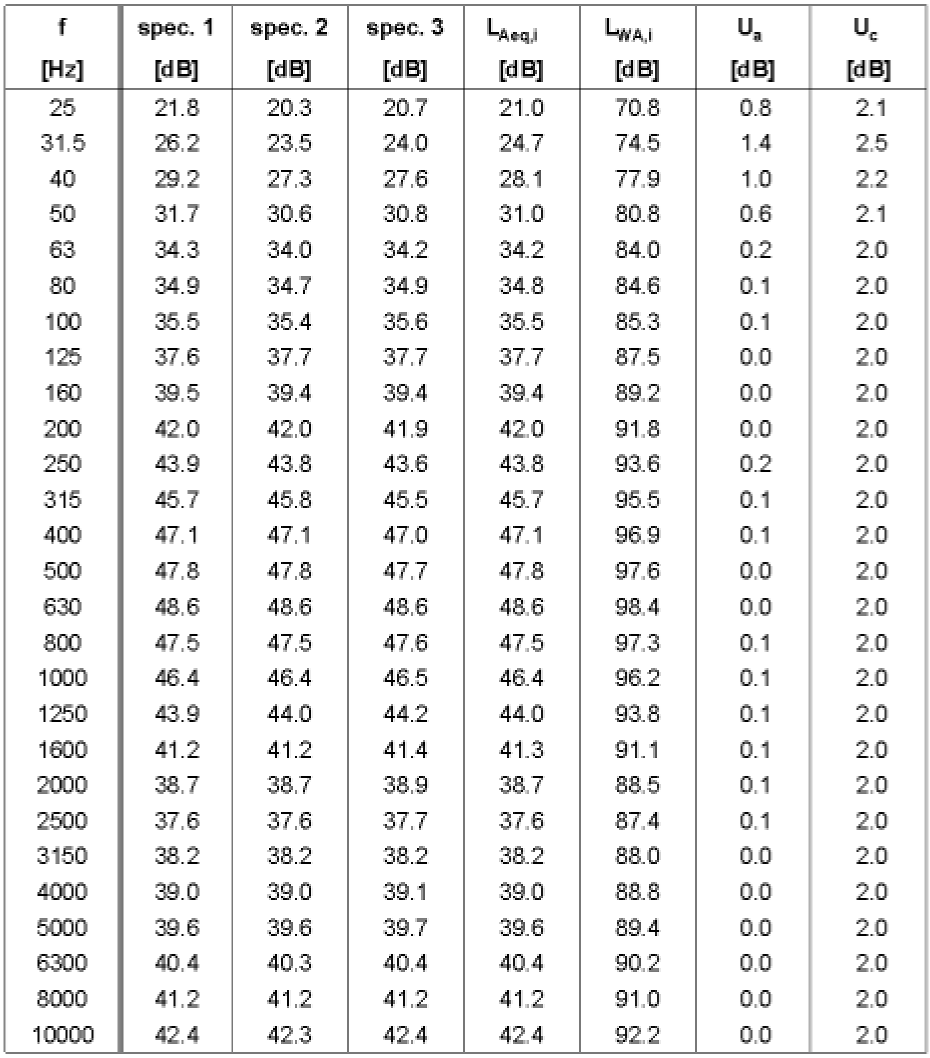
ICF International. 2013. *Sand Hill Wind Project Draft Environmental Impact Report*. November. (ICF 00151.13.) Sacramento, CA. Prepared for Alameda County, Hayward, CA.

Illingworth & Rodkin, Inc. 2009. *Shiloh III Wind Project Noise Technical Report, Solano County, California*. Petaluma, CA.

National Renewable Energy Laboratory. 2003. Acoustic tests of small wind turbines. Golden, CO.

Rogers, A. L., J. F. Manwell, and S. Wright. 2006. *Wind Turbine Acoustic Noise*. Available: http://ceere.org/rerl/publications/whitepapers/Wind_Turbine_Acoustic_Noise_Rev2006.pdf. Amherst, MA: Renewable Energy Research Laboratory, Department of Mechanical and Industrial Engineering, University of Massachusetts at Amherst. Accessed: June 27, 2013.

Appendix A
GW121-2500 Wind Turbine Sound Power Levels



f [Hz]	spec. 1 [dB]	spec. 2 [dB]	spec. 3 [dB]	$L_{Aeq,i}$ [dB]	$L_{WA,i}$ [dB]	U_a [dB]	U_c [dB]
25	21.8	20.3	20.7	21.0	70.8	0.8	2.1
31.5	26.2	23.5	24.0	24.7	74.5	1.4	2.5
40	29.2	27.3	27.6	28.1	77.9	1.0	2.2
50	31.7	30.6	30.8	31.0	80.8	0.6	2.1
63	34.3	34.0	34.2	34.2	84.0	0.2	2.0
80	34.9	34.7	34.9	34.8	84.6	0.1	2.0
100	35.5	35.4	35.6	35.5	85.3	0.1	2.0
125	37.6	37.7	37.7	37.7	87.5	0.0	2.0
160	39.5	39.4	39.4	39.4	89.2	0.0	2.0
200	42.0	42.0	41.9	42.0	91.8	0.0	2.0
250	43.9	43.8	43.6	43.8	93.6	0.2	2.0
315	45.7	45.8	45.5	45.7	95.5	0.1	2.0
400	47.1	47.1	47.0	47.1	96.9	0.1	2.0
500	47.8	47.8	47.7	47.8	97.6	0.0	2.0
630	48.6	48.6	48.6	48.6	98.4	0.0	2.0
800	47.5	47.5	47.6	47.5	97.3	0.1	2.0
1000	46.4	46.4	46.5	46.4	96.2	0.1	2.0
1250	43.9	44.0	44.2	44.0	93.8	0.1	2.0
1600	41.2	41.2	41.4	41.3	91.1	0.1	2.0
2000	38.7	38.7	38.9	38.7	88.5	0.1	2.0
2500	37.6	37.6	37.7	37.6	87.4	0.1	2.0
3150	38.2	38.2	38.2	38.2	88.0	0.0	2.0
4000	39.0	39.0	39.1	39.0	88.8	0.0	2.0
5000	39.6	39.6	39.7	39.6	89.4	0.0	2.0
6300	40.4	40.3	40.4	40.4	90.2	0.0	2.0
8000	41.2	41.2	41.2	41.2	91.0	0.0	2.0
10000	42.4	42.3	42.4	42.4	92.2	0.0	2.0

One third octave analysis result at 10 m/s (dB, A weight)

Attachment 3
Blade Throw Analysis

Epsilon
ASSOCIATES INC.

4385 Sand Hill Wind_Blade Throw Report FINAL 2-12-2016

February 12, 2016 Epsilon Ref. 4385

PRINCIPALS

Theodore A Barten, PE
Margaret B Briggs
Michael E Guski, CCM
Dale T Raczynski, PE
Cindy Schlessinger
Lester B Smith, Jr
Robert D O'Neal, CCM, INCE
Andrew D Magee
Michael D Howard, PWS
Douglas J Kelleher
AJ Jablonowski, PE
Stephen H Slocomb, PE
David E Hewett, LEED AP

Samuel G. Mygatt, LLB
1943-2010

ASSOCIATES

Dwight R Dunk. LPD
David C. Klinch, PWS, PMP

3 Clock Tower Place, Suite 250
Maynard, MA 01754
www.epsilonassociates.com

978 897 7100
FAX 978 897 0099

Mr. Chris Brungardt
Vice President
ICF International
630 K St., Suite 400
Sacramento, CA 95818

Subject: Sand Hill Wind, Alameda County, CA – Blade Throw Analysis

Dear Mr. Brungardt:

Epsilon Associates, Inc. (Epsilon) has been retained by ICF International (ICF) to conduct a blade throw analysis for the Sand Hill Wind Project in Alameda County, California expected to consist of up to twelve (12) wind turbine generators. The purpose of the analysis is to assess potential blade throw distances and determine if, in the rare event a blade is dislodged from a turbine, it could collide with a sensitive receptor (e.g. residence), or passing vehicle, transmission line, or adjacent parcel.

For this analysis, two (2) layouts were evaluated (preferred and alternate) for the Goldwind 2.5-121 wind turbine model, which is anticipated to have the following characteristics based on technical data provided by ICF:

- Hub height = 90 meters above ground level
- Rotor diameter = 121 meters
- Rotor blade length = 59.5 meters
- Max Rotor speed = 15.2 rpm (13.5 rpm rated speed)

In addition, ICF provided the locations of the residences, Project parcels, and transmission lines for evaluation in this analysis.

Calculations in the California Energy Commission's Permitting Setback Requirements for Wind Turbines in California, prepared by the California Wind Energy Collaborative, November 2006, report number CEC-500-2005-184, (the "CEC report") were used as a guide to calculate blade throw. The calculations follow the simple ballistics model prediction in Section 3.4.1 of that report, which has precedent in several permitted projects. Epsilon is unaware of any other state or local standards for blade throw analyses outside of this report. The key assumptions in the calculations are stated below, and are the same ones used in blade throw analyses for other recently approved wind projects in the Altamont Pass and Montezuma Hills Wind Resource Areas. The calculations are for the release of an entire blade at the maximum nominal rotor speed of 15.2 rpm. They do not address throw of a blade fragment or rotor overspeed conditions, both of which are less likely[1], but either of which could cause a blade throw range longer than shown in the analysis. To provide context, the likelihood of a blade fragment or overspeed failure is estimated at approximately one-third and one one-hundredth that of an entire blade failure, respectively[2].

Based on geometric design data from the turbine manufacturer, the radial position of the full rotor blade's center of gravity was provided as 18.7 meters from the root of the blade, or a distance of 19.7 meters from the center of the hub, due to the blade's taper. Aerodynamic forces, assumed to be much smaller than the rotor's weight, were not included in the model and the blade was assumed to travel and land in its original plane of rotation. A consideration of aerodynamic forces or out-of-plane projection would involve more complex computational fluid dynamics (CFD) modeling, requiring much more detailed information than is currently available (i.e., blade geometry, weight distribution, air flow, etc.) and introduce a significant amount of uncertainty. Additionally, blade throw was assumed to occur anywhere in a 360 degree direction around each wind turbine (independent of wind direction).

---

1 Rademakers & Braam, *Guidelines on the environmental risk of wind turbines in the Netherlands*, March 2004, Table 1

2 H. Braam and G.J. van Mulekom, *Analysis of Risk-Involved Incidents of Wind Turbines*. Translated by J. M. Hopemans and C.P. Van Dam and included as Attachment 1 in *Permitting Setback Requirements for Turbines in California* Prepared for the California Energy Commission (CEC) by the California Wind Energy Collaborative (CWEC), November 2006, CEC-500-2005-184, Table 6.1.

The CEC report notes that "the maximum range in a vacuum is achieved when the release angle is 45°" (page 21)[3]. However, this is only true for an object that is released and lands at the same elevation, a virtual impossibility for a utility-scale wind turbine on flat or elevated terrain, unless it is located at the bottom of a valley.

Based on elevation data for the project area derived from USGS Digital Elevation Model (DEM), the maximum elevation drop within 213 meters (700 feet) from any turbine base for either of the two layouts considered would be approximately 45 meters, or 145 feet. In other words, the potential impact site could be as much as 45 meters below the base elevation of a turbine. To account for this variation in terrain height surrounding the wind turbines, a variety of release angles were modeled.

For the preferred wind turbine layout (Layout 1), maximum range of throw for a full blade in a vacuum was calculated to occur not at 45°, but rather when the blade's "overhand" release angle is 22° from horizontal. The resulting maximum blade throw for Layout 1 is predicted to range between 176 and 193 meters (576 and 635 feet), or between 1.2 and 1.3 times the total turbine height (TTH) of 150.5 meters, depending on local terrain.

For the alternate wind turbine layout (Layout 2), maximum range of throw for a full blade in a vacuum was also calculated to occur when the blade's "overhand" release angle is 22° from horizontal. Similarly, the resulting maximum blade throw for Layout 2 is predicted to range between 174 and 193 meters (572 and 633 feet), or between 1.2 and 1.3 times the TTH of 150.5 meters, depending on local terrain.

The attached Figures 1 and 2 show the maximum calculated blade-throw radii as shaded circles around each wind turbine for Layout 1 (Preferred) and Layout 2 (Alternate), respectively, along with nearby residences, roadways, transmission lines, and property parcels. As can be seen from these figures, all identified sensitive residential receptors are beyond the maximum blade throw distances predicted by this analysis for both Layouts 1 and 2. Based on a review of the aerial photography, the maximum blade through distances for Layouts 1 and 2 will not extend to the traveled roadways in the vicinity of the Project (Altamont Pass Road,

---

[3] For both the preferred and alternate layouts proposed at this site, a release angle of 45° would result in maximum blade throw of either 165 meters (underhand release) or 150 meters (overhand release), assuming flat terrain.

Mountain House Road, Midway Road, and Interstate 580). Similarly, transmission lines in the project area are also beyond maximum blade throw distances for both Layouts 1 and 2. Finally, the maximum blade throw distances predicted for each turbine fall within the project parcel at all locations, with the exception of wind turbine 8A which extends outside to the south by approximately 3 meters (10 feet) and wind turbine 6G in Layout 2 which extends outside to the east by approximately 30 meters (100 feet). The neighboring parcel which the maximum blade throw area for wind turbine 8A extends into may be part of the Interstate ROW but as stated previously, does not extend to the traveled roadway. Based on ICF review of utility line information, it was determined that the maximum blade throw area from wind turbine 11A in Layout 1 intersects two tower footings by 2.3 meters (7.5 feet). If Sand Hill obtains the appropriate waivers and authorizations for Layout 1, wind turbine 11A will be moved to the east approximately 3 meters (10 feet) to eliminate potential blade throw intersection with the utility line tower footings.

The true probability of an impact depends on the number of blade throw events over the operational life of the project, the effect of aerodynamic forces on the blade or blade fragment governed by the principles of fluid mechanics and the laws of motion, the frequency distribution of wind speed and direction, the location, number, size, and shape of each blade or fragment, and the number of receptors likely to be located within the release area. The largest fragments would experience the highest aerodynamic drag forces and are most likely to hit the ground nearest to the base of the turbine. As a result, the probability of an impact with large fragments decreases significantly as one moves away from the turbine.

To reduce the likelihood of blade throw-related incidents, the Goldwind 2.5-121 wind turbine, like most modern wind turbine technology, is designed to shut down automatically under cut-out wind speed conditions higher than 22 m/s at hub height. Based on consultation with ICF, it is Epsilon's understanding that the selected turbine model also comes equipped with hydraulic pitch control to minimize throw and ensure safe and reliable blade pitching in all wind environments.

If you have any questions on this report, please contact me at (978) 461-6244, or by e-mail at cemil@epsilonassociates.com.

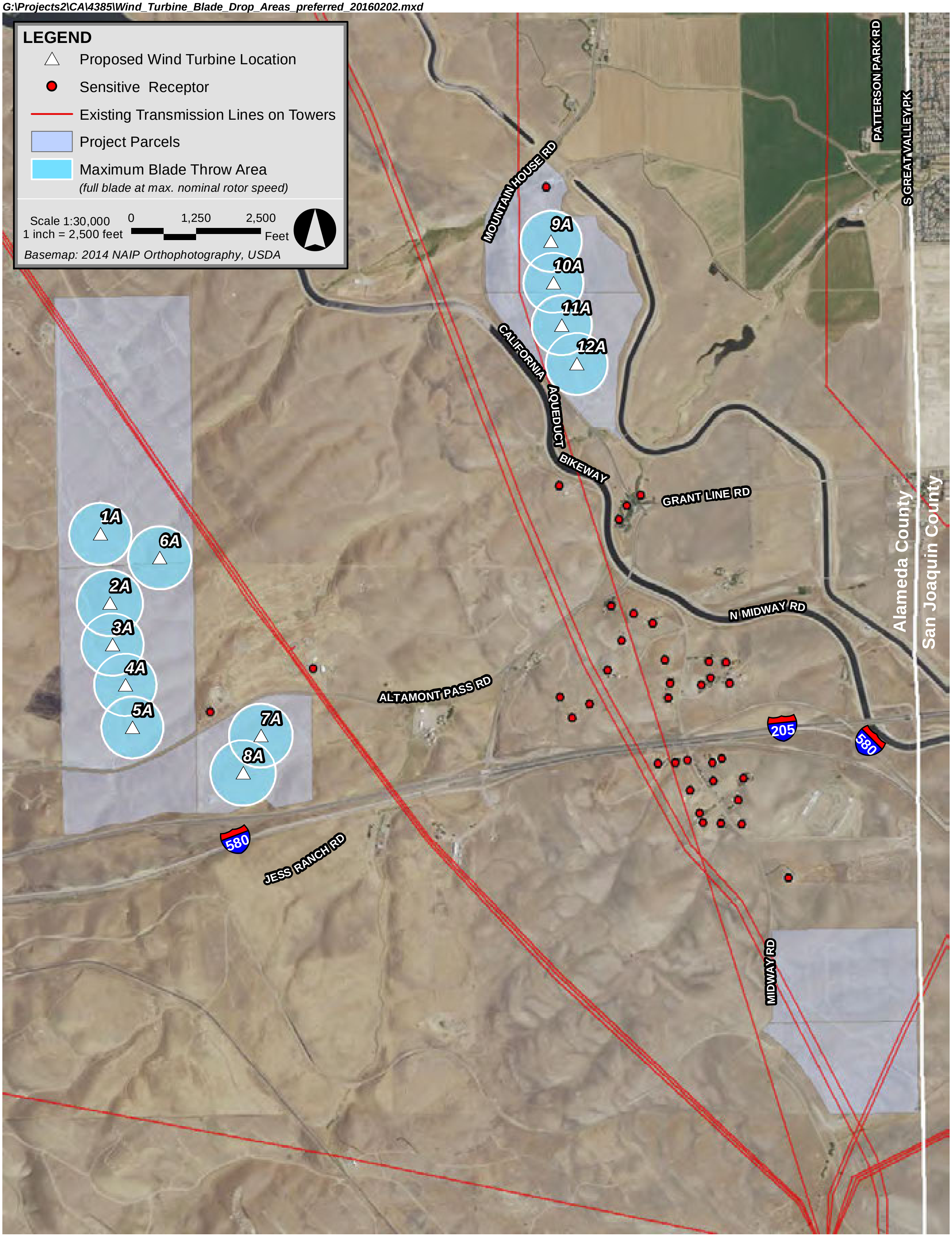
Sincerely,

EPSILON ASSOCIATES, INC.

Cory Emil

Cory Emil, P.E., INCE
Senior Engineer

G:\Projects2\CA\4385\Wind_Turbine_Blade_Drop_Areas_preferred_20160202.mxd



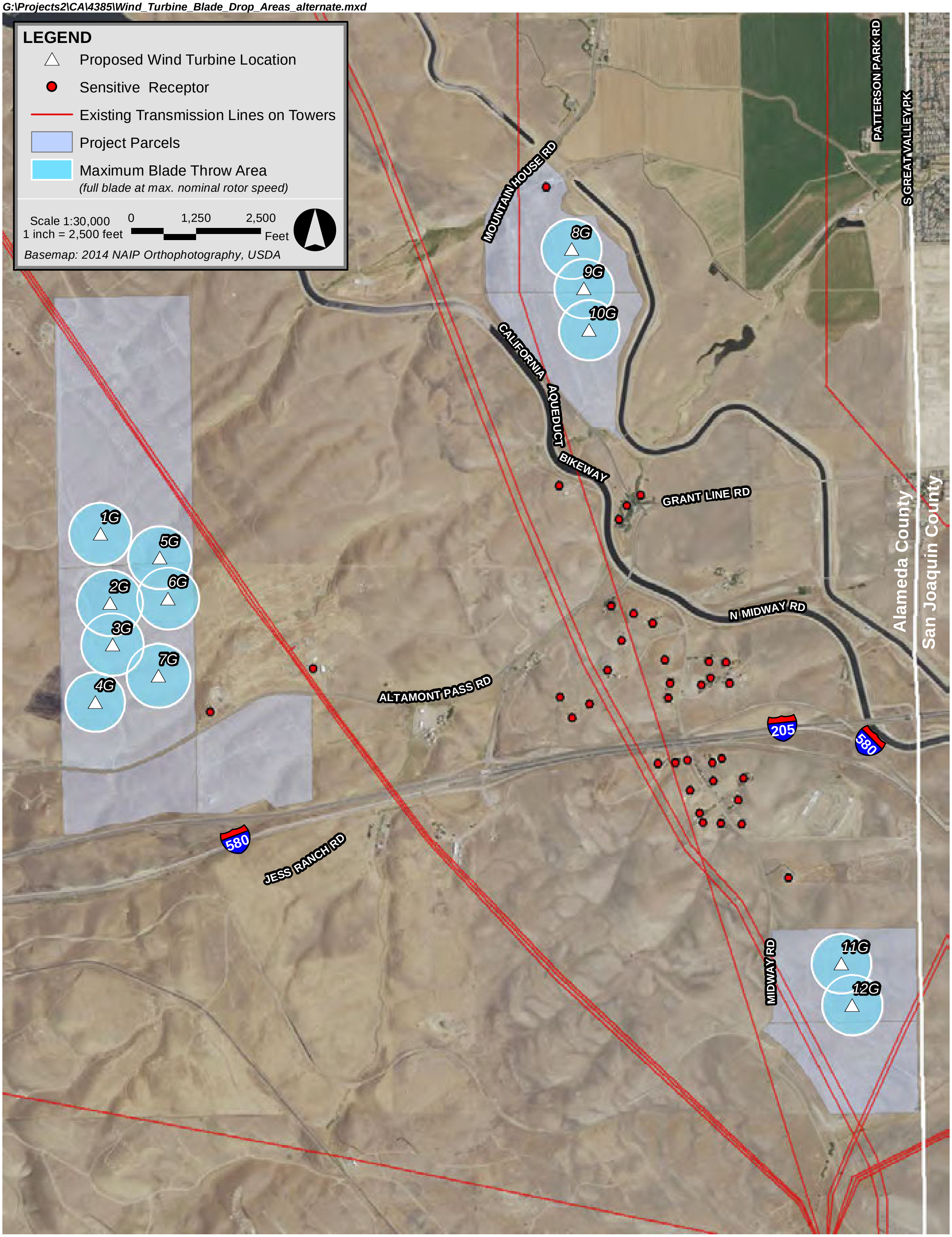
Sand Hill Wind **Alameda County, California**

Epsilon
ASSOCIATES INC.

Figure 1

Maximum Wind Turbine Blade Throw Areas
Layout 1 (Preferred)

G:\Projects2\CA\4385\Wind_Turbine_Blade_Drop_Areas_alternate.mxd



Sand Hill Wind **Alameda County, California**

Epsilon ASSOCIATES INC.

Figure 2

Maximum Wind Turbine Blade Throw Areas

Layout 2 (Alternate)