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PALMDALE ENERGY PROJECT
TRAFFIC AND TRANSPORTATION

Supplemental Testimony of James Adams

As noted in the **Traffic and Transportation** section of the Final Staff Assessment, Palmdale Energy Project (PEP or Project), did not include the air-cooled condenser (ACC) in its thermal plume analysis (2016a). In a recent filing, PEP submitted a Plume Vertical Velocity Assessment for the Air Cooled Condenser (Assessment) (PEP 2016). "Based on updated ACC stack perimeter data, provided by Siemens, a revised analysis of the ACC plume characteristics on vertical winds was prepared and compared to the California Energy Commission significance criteria for the average vertical plume velocities." (Ibid. pg. 1)

The Assessment notes staff's assumed critical velocity (average) is 5.3 meters per second (m/s) and the Australian *Manual of Aviation Meteorology* defines severe turbulence as a vertical wind velocity in excess of 10.6 m/s peak velocity (AGBM 2007). The Assessment notes the screening results show the thermal turbulence levels from the ACC remain in the light turbulence category and below the significance level of 5.3 m/s at all heights above 1,500 feet AGL (above ground level). Energy Commission staff's **Traffic and Transportation Appendix TT-2** discusses why staff has adopted the revised threshold of 5.3 m/s average and 10.6 m/s peak velocity.

Traffic and Transportation Appendix TT-3 provides an independent analysis of the Assessment and the project's plumes using the 5.3 m/s plume average velocity and the 10.6 m/s plume peak velocity. Staff modeled plume velocities for the PEP's Heat Recovery Steam Generator stack and the ACC. Staff found that thermal plume vertical velocity for the HRSG stack exceeded 5.3 m/s up to an altitude of approximately 569 feet AGL. The worst case ACC plume average velocity is calculated to drop below 5.3 m/s at a height of approximately 1,400 feet AGL (CEC 2016b).

For the original Palmdale Hybrid Power Project, the Energy Commission August 2011 Decision found that aircraft using Air Force Plant 42 (Plant 42) would not be affected by the project's thermal plumes because arriving or departing aircraft would not fly over the HRSGs and cooling tower and aircraft in the traffic pattern would be flying at least at 1,500 feet AGL (CEC 2011). This conclusion was included in staff's Traffic and Transportation analysis in the FSA for the PEP. In other words, the PEP site is 3,000 feet north of Runway 7/25 (closest runway) which is the major Runway (RY) at Plant 42, and is not under the traffic pattern. In addition, a departure to the west from RY 4/22 could fly over the project but staff believes that pilots could fly further west before turning north towards Edwards Air Force Base. The traffic pattern for both runways is 1,500 feet AGL. **Traffic and Transportation Figure 1** shows the traffic patterns at Plant 42 (2016c). Staff is unaware of any changes to the traffic patterns subsequent to the December 2010 **Traffic and Transportation** analysis in the FSA for the original project. Staff has provided Plant 42 personnel a copy of **Figure 1** and has not received any response to date.

While the results of the project owner's analysis and staff's analysis of the PEP show an increase in the ACC thermal plume height compared to the original project, the PEP's plumes would still be below 1,500 feet AGL and would not affect the airspace in the traffic pattern for RY 7/25 or RY 4/22. Based on current information, the conclusion in the Decision and staff's conclusion in the FSA for the PEP of no significant impact on U.S. Air Force Plant 42 operations from thermal plumes would be unchanged (CEC 2016a).

REFERENCES

AGBM 2007 – Australian Government Bureau of Meteorology, *Manual of Aviation Meteorology*, Second Edition, 2007.

CEC 2011 – Palmdale Hybrid Power Project, Energy Commission Decision, August 2011

CEC 2016a – Palmdale Energy Project, Final Staff Assessment, Traffic and Transportation, September 2016.

CEC 2016b – Plume Velocity Analysis for the PEP, Energy Commission Staff, December 2016.

CEC 2016c – Traffic and Transportation Figure 1, a modified version of Traffic and Transportation Figure 3, Palmdale Hybrid Power Project, Final Staff Assessment, Traffic and Transportation, December 2010.

PEP 2016 – Palmdale Energy, LLC’s Plume Vertical Velocity Assessment for the Air Cooled Condensers, November 2016.

APPENDIX TT-2
PLUME THRESHOLD DETERMINATION

Testimony of James Adams

INTRODUCTION

A plume velocity analysis involves calculating the altitude at which a plume would have an average velocity exceeding a threshold of significance; planes flying through the plume at this point or below could experience turbulence threatening aircraft control. Staff has historically used an average thermal plume vertical velocity of 4.3 meters per second (m/s) as the threshold for potential impacts to aviation.

Staff has concluded that based on recent publications, an average vertical velocity of 4.3 m/s is no longer an appropriate threshold. The purpose of this appendix is to provide documentation of staff's determination that a 5.3 m/s average vertical velocity should now be considered the appropriate threshold.

BACKGROUND

The FAA identifies thermal plumes as a potential source of impacts to aviation, but currently does not have an adopted threshold of significance for vertical plume velocities. Staff has relied on a 4.3 m/s threshold which originated from the Australian Government Civil Aviation Safety Authority (CASA) Advisory Circular, AC 139-05 (0), "Guidelines for Conducting Plume Rise Assessments", dated June 2004. The Advisory Circular stated that "[a]viation authorities have established that an exhaust plume with a vertical gust in excess of 4.3 m/s may cause damage to an aircraft airframe, or upset an aircraft when flying at low levels" (FAA 2006). However, recent publications state that 4.3 m/s represents light turbulence, which would only result in "rhythmic bumpiness and momentary changes in altitude and attitude" if an aircraft flew through the plume (AGBM 2007, Table 10.1). This would not be a significant impact to aircraft. Furthermore, the origin of CASA's 4.3 m/s threshold is unknown, and CASA has been unable to verify the source of the threshold (TRB 2014, page 55).

REVISED PLUME THRESHOLD

For the reasons described below, staff has concluded that the appropriate threshold to use to determine potential impacts from thermal plumes to aircraft is a peak vertical velocity of 10.6 m/s.

The FAA-sponsored "Guidebook for Energy Facilities Compatibility with Airports and Airspace" includes information supporting the use of 10.6 m/s as a screening threshold (TRB 2014). The 10.6 m/s screening threshold is also referenced in CASA's November 2012 Advisory Circular as a screening threshold for severe turbulence to aircraft (CASA 2012). The 2012 circular is an update to the AC 139-05 (0) CASA Advisory Circular which staff has historically referenced as the origin of the 4.3 m/s threshold.

Plume Threshold Determination Table 1 is a modified version of Table10.1 in the Australian Government Bureau of Meteorology's "Manual of Aviation Meteorology", Second Edition, dated 2007. A 10.6 m/s vertical gust corresponds to the initial threshold of severe turbulence, which would result in "large abrupt changes in altitude and attitude, and momentary loss of control" (AGBM 2007).

Plume Threshold Determination Table 1

Intensity	Airspeed fluctuations (knots)	Vertical gusts (feet per second)	Vertical gusts (meters per second)	Aircraft reaction
Light	5 - 14.9	5 - 20	1.5 - 6.1	Rythmic bumpiness. Momentary changes in altitude and attitude.
Moderate	15 - 24.9	20 - 35	6.1 - 10.6	Rapid bumps or jolts. Appreciable changes in altitude and attitude.
Severe	=> 25	35 - 50	10.6 - 15.2	Large abrupt changes in altitude and attitude. Momentary loss of control.
Extreme		> 50	> 15.2	Practically impossible to control aircraft. May cause structural damage.

Source: *Manual of Aviation Meteorology*, Table 10.1, Second Edition, 2007, Australian Government Bureau of Meteorology,

When considering the potential effects of thermal plumes in terms of G-load, 1G is considered as the start of severe turbulence and corresponds with the severe turbulence threshold of 10.67 m/s (AGBM 2007). The FAA-sponsored "Guidebook for Energy Facilities Compatibility with Airports and Airspace" (TRB 2014) supports the 1G threshold (and thus, the corresponding threshold of 10.67 m/s) as the start of severe turbulence. The Guidebook also states on page 52 that NOAA defines severe turbulence as starting at 1G. Finally page 56 of the Guidebook references a MITRE study's conclusion that an appropriate safety threshold is the potential for a plume to create more than a 1G vertical acceleration on an aircraft.

In light of the literature cited above, staff determines the threshold of a peak vertical velocity of 10.6 m/s to be appropriate.

PEAK VERTICAL VELOCITY

It should be noted that while staff previously used a threshold representing a plume's *average* vertical velocity (4.3 m/s), staff's new threshold of 10.6 m/s represents a plume's *peak* vertical velocity. The problem with using an average vertical velocity as a threshold is that it is an average across the entire plume and does not represent the worst-case velocity that could be encountered within the plume. The peak vertical velocity for a plume, which generally occurs toward the middle of the plume, can be up to twice the average vertical velocity at a particular altitude. Using staff's past analysis method as an example, at the altitude where the average vertical velocity was 4.3 m/s across the entire plume, the peak velocity at that altitude could be twice that, at approximately 8.6 m/s toward the middle of the plume. Examining staff's new threshold as another example, at the altitude where the plume's peak vertical velocity would be

10.6 m/s, the average vertical velocity would be 5.3 m/s, slightly higher than the previously used threshold of 4.3 m/s average vertical velocity.

CONCLUSION

Based on review of the recent publications discussed above, staff will use 10.6 m/s peak vertical plume velocity as the new threshold. The altitude at which a plume would have a peak vertical velocity of 10.6 m/s would be the same altitude at which a plume would have an average vertical velocity of half that, 5.3 m/s.

REFERENCES

AGBM 2007 – Australian Government Bureau of Meteorology. Manual of Aviation Meteorology, Second Edition, dated 2007. Published by Airservices Australia.

CASA 2012 – Australian Government Civil Aviation Safety Authority, Advisory Circular AC 139-5(1), Plume Rise Assessments, November 2012, https://www.casa.gov.au/files/139c05pdf, accessed May 2016.

FAA 2006 – Federal Aviation Administration, Flight Procedures Standards Branch. Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes, dated January 2006. http://www.ctcombustion.com/oxc/sources/20-safetyriskanalysis.pdf, accessed September 2016.

TRB 2014 – Transportation Research Board of the National Academies, Airport Cooperative Research Program. ACRP Report 108, Guidebook for Energy Facilities Compatibility with Airports and Airspace, dated 2014. Sponsored by the Federal Aviation Administration. http://www.trb.org/Publications/Blurbs/170609.aspx, accessed September 2016.

APPENDIX TT-3: PLUME VELOCITY ANALYSIS

Nancy Fletcher

INTRODUCTION

This appendix updates the proposed Palmdale Energy Project (PEP) air cooled condenser (ACC) plume velocity analysis based on revised data provided by the applicant on November 28, 2016 (PHPP 2016qq). For completeness, this appendix also includes the analysis of the PEP combustion gas turbines (CTGs) and heat recovery steam generators (HSRGs).

Staff completed calculations to determine the worst-case vertical plume velocities at different heights above ground based on the project owner's proposed facility design, with staff corrections to some of the operational data. The purpose of this appendix is to provide documentation of the method used to estimate worst-case vertical plume velocities to assist evaluation of the project's impacts on aviation safety in the vicinity of the PEP.

The results originally reported in **Appendix TT-1** of the PEP Final Staff Assessment were based on a significance threshold average velocity of 4.3 meters per second (m/s). The results reported in this analysis are based on updated significance thresholds of a plume peak vertical velocity of 10.6 m/s and an average plume velocity of 5.3 m/s. See **Appendix TT-2** for a discussion of the basis for updating this significance threshold.

SUMMARY OF THE DECISION

On August 10, 2011, the Energy Commission approved the Palmdale Hybrid Power Plant (PHPP), a 570 megawatts (MW) (nominal output) hybrid of a natural gas-fired combined-cycle generating equipment integrated with solar thermal generating equipment. The Final Commission Decision (CEC 2011b) for the PHPP evaluated the potential for thermal plumes to be generated from the two HRSG stacks and a ten-cell cooling tower. The Final Commission Decision concluded the turbine and cooling tower (using vendor design data available at the time) could generate thermal plumes with average velocities exceeding the significance threshold (applicable at that time) up to a height of 990 feet above ground level for the HRSG and 875 feet above ground level for the cooling tower.

PROJECT DESCRIPTION

The proposed PEP would be a natural-gas-fired, combined-cycle, air-cooled electrical generating facility located in the city of Palmdale in the Antelope Valley. The PEP power block would consist of two 214 MW Siemens SGT6-5000F combustion turbines with inlet evaporative cooling and dry low NOx combustors, one 276 MW (nominal base load) Siemens steam turbine, and two HRSGs with duct burners. The PEP would employ dry cooling through an ACC. The PEP would also include a 110 million British thermal unit per hour natural gas fired auxiliary boiler, two emergency engines and other ancillary equipment.

PLUME VELOCITY CALCULATION METHOD

SPILLANE APPROACH

Staff uses a calculation approach from a technical paper (Best 2003) to estimate the worst-case plume vertical velocities for vertical turbulence from plumes such as the PEP stacks and cooling system. The calculation approach, known as the “Spillane approach”, is based on calm wind conditions to assess average plume vertical velocity as a function of height. Calm wind conditions are considered the worst-case wind conditions for worst case plume rise and velocities. The Spillane approach uses the following equations to determine vertical velocity for single stacks during dead calm wind (i.e., wind speed = 0) conditions:

(1) $(V*a)^3 = (V*a)_o^3 + 0.12*F_o*[(z-z_v)^2-(6.25D-z_v)^2]$

(2) $(V*a)_o = V_{exit}*D/2*(T_a/T_s)^{0.5}$

(3) $F_o = g*V_{exit}*D^2*(1-T_a/T_s)/4$

(4) $Z_v = 6.25D*[1-(T_a/T_s)^{0.5}]$

Where: V = vertical velocity (m/s), plume-average velocity
a = plume top-hat radius (m), increases at a linear rate of $a = 0.16*(z- z_v)$
F_o= initial stack buoyancy flux m^4/s^3
z = height above stack exit (m)
z_v= virtual source height (m)
V_{exit}= initial stack velocity (m/s)
D = stack diameter (m)
T_a= ambient temperature [kelvin (K)]
T_s= stack temperature (K)
g = acceleration of gravity (9.8 m/s^2)

Individual plumes can be broken into three stages. The first stage describes plume conditions close to the stack exit where the plume momentum remains relatively unaffected by ambient and plume buoyancy conditions. This momentum rise stage describes the plume as it travels to a height of 6.25D. In the second stage, the plume responds to differences between ambient and plume buoyancy conditions. Cooler and less turbulent ambient air interacts with the plume and impacts the plume’s vertical velocity. The dilution of the stack exhaust is sensitive to ambient wind speed. Therefore the calm wind conditions are considered to be conservative and yield worst case conditions. In the third stage, the plume rise is largely impacted by the buoyancy of the plume and continues until turbulence within and outside the plume equalizes. This generally takes place at large heights and distances from the stack where the plume vertical velocity is close to zero.

Equation (1) is solved for V at any given height above stack exit that is above the momentum rise stage for single stacks (where $z > 6.25D$) and at the end of the plume merged stage for multiple plumes. This solution provides the plume-average velocity for the area of the plume at a given height above stack exit; the peak plume velocity would be two times higher than the plume-average velocity predicted by this equation. The stack buoyancy flux (Equation 3) is a prominent part of Equation (1). The calm condition calculation basis represents the worst-case conditions, and the vertical velocities will decrease substantially as wind speeds increase.

For multiple stack plumes, where the stacks are equivalent as is the case for PEP, the multiple stack plume velocity during calm winds is calculated by staff in a simplified fashion, presented in the Best paper as follows:

(5) $$V_m = V_{sp} * N^{0.25}$$

Where: V_m = multiple stack combined plume vertical velocity (m/s)
V_{sp} = single plume vertical velocity (m/s), calculated using Equation (1)
N = number of stacks

This simplified multiple stack plume velocity calculation method predicts somewhat lower velocity values than the full Spillane approach methodology for multiple plumes as given in data results presented in the Best paper (Best 2003). However, for a long linear set of plumes, it is very unlikely that all plumes could merge fully to allow this velocity given the stack separation and the height/atmospheric conditions needed for them to fully merge. Therefore the use of this approach would likely over-predict combined plume velocities in this case.

MITRE EXHAUST PLUME ANALYZER

On September 24, 2015, the Federal Aviation Administration (FAA) released a guidance memorandum (FAA 2015) recommending that thermal plumes be evaluated for air traffic safety. FAA determined that the overall risk associated with thermal plumes in causing a disruption of flight is low. However, it determined that such plumes in the vicinity of airports may pose a unique hazard to aircraft in critical phases of flight (such as take-off and landing). In this memorandum a new computer model, different than the analysis technique used by staff and identified above as the Spillane Approach, is used to evaluate vertical plumes for hazards to light aircraft. It was prepared under FAA funding and available for use in evaluating exhaust plume impacts.

This new model, the MITRE Corporation's Exhaust Plume Analyzer (MITRE 2012), was identified by the FAA as a potentially effective tool to assess the impact that exhaust plumes may impose on flight operations in the vicinity of airports (FAA 2015). The Exhaust Plume Analyzer was developed to evaluate aviation risks from large thermal stacks, such as turbine exhaust stacks. The model provides output in the form of graphical risk probability isopleths ranging from 10^{-2} to 10^{-7} risk probabilities for both severe turbulence and upset conditions for four different aircraft sizes. However, at this time the Exhaust Plume Analyzer model cannot be used to provide reasonable risk predictions on variable exhaust temperature thermal plume sources, such as cooling towers and air cooled condensers.

The FAA has not provided guidance on how to evaluate the risk probability isopleth output of the Exhaust Plume Analyzer model. The MITRE Corporation is suggesting that a probability of severe turbulence at an occurrence level of greater than 1×10^{-7} (they call this a Target Safety Level) should be considered potentially significant. This is equivalent to one occurrence of severe aircraft turbulence in 10 million flights. For the past 50 years, the MITRE Corporation has provided air traffic safety guidance to FAA, and their recommended Target Safety Level is based on this experience (MITRE 2016).

Additionally, the MITRE model has a probability of occurrence plot limitation. While it provides output to predict plumes up to a maximum height of 3,500 feet above ground, the meteorological data that is used by the model is currently limited to a maximum height of 3,000 feet. Outputs corresponding to the higher altitudes simply reuse the 3,000 foot meteorological data. The model was developed with the assumption that a plume would not rise higher than 3,000-3,500 feet above ground level, and therefore the modeling output was terminated at that height. There is uncertainty if there will be any effort to expand the data set and model to work properly at altitudes above 3,000 feet above ground level at this point. The results obtained by staff using the Spillane approach suggest that this limitation would not apply to the PEP.

At this time staff does not believe the MITRE model should be used for final work products until the model capabilities are enhanced to include other thermal plume sources such as cooling towers and air-cooled condensers.

STAFF ANALYSIS

This appendix uses the Spillane approach method to be consistent with staff assessments done for other projects and because the Spillane approach is described in the FAA materials as providing similar risk assessments for light aircraft. As stated above, staff will consider using the new MITRE method to the extent that it is applicable after conducting further review of how to evaluate the output of the Exhaust Plume Analyzer.

EQUIPMENT DESIGN AND OPERATING PARAMETERS

SIEMENS SGT6-5000F COMBUSTION GAS TURBINE DESIGN AND OPERATING PARAMETERS

The design and operating parameter data for the two 214 MW Siemens SGT6-5000F combustion gas turbine stacks are provided in **Plume Velocity Table 1**. Operating scenarios from four temperatures across the range of operation were selected for evaluation from the manufacturer performance estimate data sheet provided by the project owner in the Petition to Amend (PTA) **Appendix 4.1A**. Operating parameters chosen to compute worst-case vertical plume velocities include ambient temperatures of 23, 64, 98 and 108 degree Fahrenheit (ºF) at maximum turbine loads without duct burning[1]. The exhaust operating parameters provided in **Plume Velocity Table 1** correspond to full load operation for the corresponding ambient conditions.

[1] Turbine data provided by the vendor indicate a lower stack potential temperature and volumetric flow for cases including duct burning therefore yielding lower potential plume velocities at specified heights.

Plume Velocity Table 1
Siemens CTG Exhaust Parameters

Parameter	**Siemens SGT6-5000F**			
Stack Height	160 ft. (48.77 meters)			
Stack Diameter	22 ft. (6.71 meters)			
Number of Stacks (#)	2			
CTG Load (%)	100			
Case Number (#)	1	11	16	21
Ambient Temperature (°F)	23	64	98	108
Evaporative Cooling	No	Yes	Yes	Yes
Exhaust Temperature (°F)	195	215	221	223
Exhaust Flow Rate (ACFM)	1,337,241	1,334,691	1,346,870	1,344,061
Exhaust Velocity (ft/sec)/(m/s)	58.6/17.87	58.5/17.84	59.1/18.00	58.9/17.96
Stack Buoyance Flux (m^4/s^3)	518	394	327	309

Source: PHPP 2015g, Staff analysis

AIR-COOLED CONDENSER DESIGN AND OPERATING PARAMETERS

Plume Velocity Table 2 includes/approximates the design and operating parameter data for the ACC for the combined-cycle power block. The updated ACC stack parameter data submitted by the project owner on November 28, 2016 (PHPP 2016qq) was provided by Siemens and the ACC manufacturer.

Plume Velocity Table 2
ACC Operating and Exhaust Parameters

Parameter	**Air Cooled Condenser**		
Number of Cells (total)	32		
Cell Height (ft)	130 ft. (39.62 meters)		
Cell Diameter (ft)	36.09 ft. (11 meters)		
Case Number (#)	1	2	3
Ambient Temperature (°F)	23	64	98
Number of Cells in Operation	32	32	30
Outlet Air Temperature (°F)	59	90.32	130.1
Exhaust Flow Rate (ACFM)	1,244,980	1,771,830	1,674,167
Exhaust Velocity (ft/sec)/(m/s)	13.16/4.01	18.60/5.67	18.67/5.69

Source: PHPP 2016qq, Staff analysis

PLUME VELOCITY CALCULATION RESULTS

Using the Spillane approach, the plume average vertical velocities at different heights above ground were determined by staff for calm conditions for the proposed CTGs/HRSGs and ACC.

When two plumes merge, the vertical velocity is expected to decrease slower than plumes that have not merged. Therefore the height at which the vertical velocity decreases below the critical plume peak velocity of 10.6 m/s could occur at a higher height for merged plumes than plumes that are not merged. Plumes begin to merge when the sum of the radius of one plume and an adjacent plume equals the distance between the two stacks. Plumes are considered fully merged at the height when the sum of the plume radii is equal to twice the distance between the stacks. Staff evaluated the potential for plume merging using a stack-to-stack distance for the CTGs/HRSGs of approximately 130 feet or 40 meters.

Staff calculated plume average vertical velocities for the four operating cases outlined in **Plume Velocity Table 1** for the CTGs and HRSGs. The worst-case predicted plume velocities occur at 100 percent load without duct firing or evaporative cooling at the 23°F ambient temperature scenario. Staff's calculated worst-case plume average velocity values are provided in **Plume Velocity Table 3**. Height above ground is determined by adding the physical stack height to z, the height above stack exit.

The Siemens SGT6-5000F gas turbine plume average velocity is calculated to drop below 5.3 m/s at a height of approximately 539 feet above ground for the single turbine plume (N=1). The plume diameter at this height would be around 35 meters, which would be less than the distance between the two Siemens SGT6-5000F gas turbine stacks (approximately 40 meters). Results also indicate that the plume diameter would equal two times the stack separation at a height of approximately 1,000 feet above ground. Therefore, partial merging of the adjacent turbine plumes should be considered. In the case of partial plumes merging (N>1), the average velocity is calculated to drop below 5.3 m/s at the height of 569 feet above ground.

Staff calculated plume average vertical velocities for all three operating cases shown in **Plume Velocity Table 2** for the combined-cycle's air-cooled condenser and determined that the worst-case height at which the plume velocities would drop below 5.3 m/s would occur at the 98°F ambient temperature condition. This result was based on the assumption all cells of the ACC were in operation at the 98°F ambient temperature condition and the plumes from all cells in operation would be fully merged. Staff's calculated worst-case plume average velocity values are provided in **Plume Velocity Table 4**. The combined-cycle air-cooled condenser plume average velocity is calculated to drop below 5.3 m/s at a height of approximately 1,400 feet above ground.

Plume Velocity Table 3
Siemens Turbine Plume Size (m) and Average Vertical Plume Velocities (m/s)

Height Above Ground Level (Feet)	Plume Diameter (m) [a]	Number of Merged Stacks	Average Plume Velocity (m/s)
300	11.76	1.00	8.82
400	21.51	1.00	6.47
500	31.27	1.00	5.54
600	41.02	1.20	5.24
700	50.77	1.45	5.08
800	60.53	1.70	4.96
900	70.28	1.94	4.87
1,000	80.04	2.00	4.69
1,100	89.79	2.00	4.51
1,200	99.54	2.00	4.36
1,300	109.30	2.00	4.22
1,400	119.05	2.00	4.10
1,500	128.80	2.00	3.99
1,600	138.56	2.00	3.90
1,700	148.31	2.00	3.81
1,800	158.07	2.00	3.73
1,900	167.82	2.00	3.65
2,000	177.57	2.00	3.59

Notes:
a – The separation between the two stacks would be about 130 ft (40 m) and the plumes will begin to merge when the plume diameter is the same as the separation and is assumed to be fully merged when the plume diameter is twice the stack separation.

It should be noted that additional thermal plume merging between the gas turbine and air-cooled condenser could occur and increase the plume heights where vertical peak velocities of 10.6 m/s are exceeded under worst case conditions. The model used for this analysis is not able to add different kinds of thermal plumes together. However, the approach is still conservative given the conservatism built in the model.

Plume Velocity Table 4
Combined-Cycle Air-Cooled Condenser Vertical Average Plume Velocities (m/s)

Height Above Ground Level (Feet)	Average Plume Velocity(m/s)
400	6.22
500	7.024
600	6.90
700	6.65
800	6.39
900	6.16
1,000	5.95
1,100	5.76
1,200	5.59
1,300	5.44
1,400	5.30
1,500	5.17
1,600	5.06
1,700	4.95
1,800	4.86
1,900	4.76
2,000	4.68

In addition, the ACC thermal plume analysis submitted by the project owner followed a different set of assumptions. For cases involving more than two stacks such as the ACC, plume merging can become more complex. The 32 individual cells of the ACC would be arranged in four rows of eight cells (4 x 8 matrix). The analysis provided by the project owner conservatively used an effective stack diameter calculated based on the number of cells in operation for each case. The calculated effective stack diameter represents a single merged cell that is then used with the Spillane methodology. The results provided by the project owner were replicated by staff. Per the project owner's analysis methodology the plume would not be expected to exceed a vertical average velocity of 5.3 m/s under worst case conditions, however the single plume would retain the peak vertical velocity at higher altitudes.

WIND SPEED STATISTICS

The **Air Quality** section of this document uses meteorological data from Palmdale Air Force Plant 42 Automated Surface Observing System (ASOS) located approximately 2.5 km east-southeast of the PEP site. The wind roses and wind frequency distribution data collected from the ASOS monitoring station are considered to be representative for the project site location. The project owner provides the calm wind speed statistics from the ASOS monitoring station from ground-level meteorological data collected for 2010 through 2014 (PHPP 2015g). Calm winds for the purposes of the reported monitoring station statistics are those hours with average wind speeds below 0.5 m/s. Calm or very low wind speeds can also occur for shorter periods of time within each of the monitored average hourly conditions. However, the shortest time resolution for the available meteorological data is one hour. The annual wind rose data shows calm/low wind speed conditions averaging an hour or longer is 3.82 percent in the site area, or about 335 hours per year.

CONCLUSIONS

The worst case calm wind condition vertical plume average velocities from the proposed Siemens SGT6-5000F combined-cycle turbine stacks are predicted to drop below 5.3 m/s at the height of 539 feet above ground. The worst case air-cooled condenser plume average velocity is calculated to drop below 5.3 m/s at a height of approximately 1,400 feet above ground. Thus, the thermal plume from the ACC would pose a greater risk to light aircraft than the combined-cycle turbines.

Also, there is the potential for additional thermal plume merging between the gas turbine stacks and the ACC. This merging could potentially increase the plume heights where vertical velocities of 5.3 m/s are exceeded under worst case conditions. Calm/low wind speed conditions (wind speeds less than 0.5 m/s) conducive to the formation of worst-case thermal plume velocities would occur on average approximately 3.82 percent of the time.

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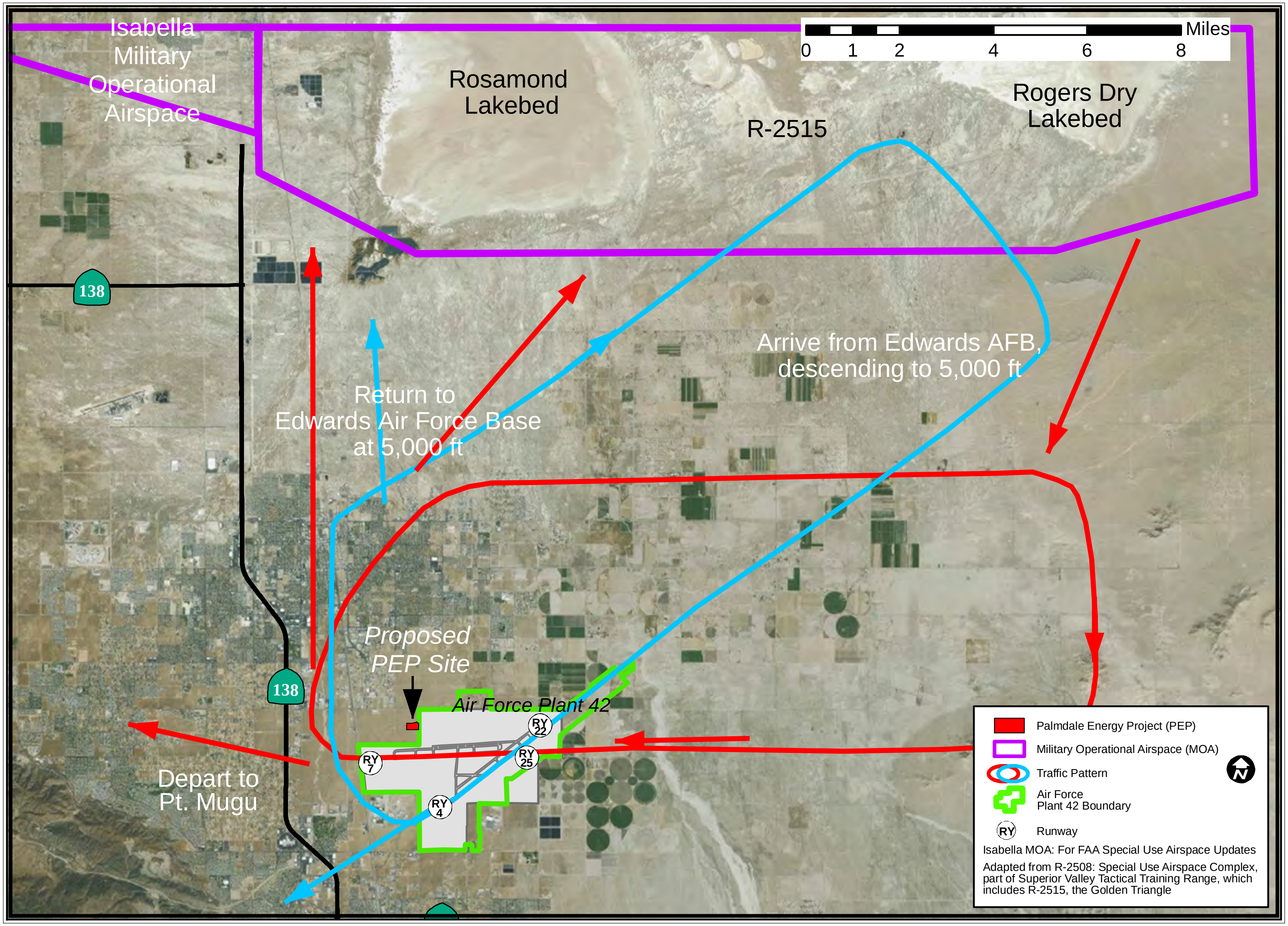
TRAFFIC AND TRANSPORTATION - FIGURE 1
Palmdale Energy Project - Plant 42 Air Traffic Patterns



CALIFORNIA ENERGY COMMISSION - SITING, TRANSMISSION AND ENVIRONMENTAL PROTECTION DIVISION
SOURCE: CEC Staff