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June 18, 2010

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Mr. Craig Hoffman
Project Manager
California Energy Commission
1516 Ninth Street, MS 15
Sacramento, CA 95814-5512

Subject: Mariposa Energy Project (09-AFC-03)
Staff Queries Set 1, Addenda to CEC Staff Data Request 52, Responses to Keith Freitas E-mail, CCC ALUC Letter, Hal Yeager Letter, and Contra Costa County Board of Supervisors Letter

Dear Mr. Hoffman:

Attached please find thirteen hard copies and one electronic copy on CD-ROM of the Mariposa Energy Project's Staff Queries Set 1. This Staff Query Set was prepared in response to CEC Staff Data Request 52 (supplemental response); an e-mail from Keith Freitas, Director of Airports for Contra Costa County; a letter from the Contra Costa County Airport Land Use Commission; a letter from Hal Yeager, Vice Chairman of the Contra Costa County Airport Land Use Commission; and a letter from the Contra Costa County Board of Supervisors for the Application of Certification for the Mariposa Energy Project (MEP) (09-AFC-03).

This document has also been sent to Keith Freitas, Director of Airports for Contra Costa County, each Commissioner of the Contra Costa County Airport Land Use Commission, each member of the Contra Costa County Board of Supervisors, and each member of the Contra Costa County Aviation Advisory Committee.

If you have any questions about this matter, please contact me at (916) 286-0348.

Sincerely,
CH2M HILL

Doug Urry
AFC Project Manager

Attachment
cc: B. Buchynsky, Mariposa Energy, LLC.

APPLICATION FOR CERTIFICATION

STAFF QUERIES, SET 1

(ADDENDA TO CEC STAFF DATA REQUEST 52, RESPONSES TO KEITH FREITAS E-MAIL, CCC ALUC LETTER, HAL YEAGER LETTER, AND CONTRA COSTA COUNTY BOARD OF SUPERVISORS LETTER)

SUBMITTED TO THE

California Energy Commission

FOR THE

Mariposa Energy Project

(09-AFC-03)

SUBMITTED BY

Mariposa Energy, LLC

TECHNICAL ASSISTANCE BY

CH2MHILL

JUNE 2010

EY012009005SAC

Mariposa Energy Project

Executive Summary, Staff Queries, Set 1

Mariposa Energy, LLC is developing the Mariposa Energy Project (MEP or the Project) in northeastern Alameda County. MEP is a 200 MW gas-fired project, selling energy and capacity to Pacific Gas and Electric Company under a long term contract. The Project is located approximately 2.7 miles southeast of the Byron Airport, which is located in neighboring Contra Costa County. The Project's location was chosen based on a number of factors. These factors included proximity to natural gas pipelines, an electrical substation, and water; the naturally hilly terrain, which will shield MEP from view and minimize noise; the proximity to the Altamont Pass Wind Resource Area, as the Project will be used to help integrate intermittent renewable resources into the California Grid; its location within the San Francisco Bay Area Load Pocket to provide dependable capacity, which was seen as beneficial to the Project's offtaker, PG&E; and its location vis-à-vis the Byron Airport. There were a number of other potential sites in the region that Mariposa Energy rejected because these other sites were much closer to the Byron Airport and its various runway patterns. In contrast, the chosen MEP site, which is nestled between high voltage power lines to the east and west, and neither directly under nor adjacent to established Byron Airport traffic patterns, will not impact Byron Airport operations.

Because of the Project's proximity to the Byron Airport, Mariposa Energy has received inquiries about potential impacts on the current and future operations of the Byron Airport from the operation of MEP. The attached data response provides detailed responses to specific inquiries from CEC Staff; Keith Freitas, Director of Airports for Contra Costa County; the Contra Costa County Airport Land Use Commission; Hal Yeager, Vice Chairman of the Contra Costa County Airport Land Use Commission; and the Contra Costa County Board of Supervisors.

The results of the analyses performed in support of these data responses show that the Project will not have any significant impacts on the current or future operations of the Byron Airport. The data responses specifically address the following concerns:

- **Airport Flight Patterns:** Byron Airport flight patterns are too distant from MEP to be of significant concern to aircraft approaching or departing from Byron Airport, and even if an aircraft were to venture into the air space over MEP, it is highly unlikely that the pilot would ever experience more than light turbulence.

- **Thermal Plume Velocity:** The average vertical plume velocity assessment performed by Mariposa Energy's consultant, Katestone Environmental, indicated that plumes would never exceed light turbulence levels at pattern altitudes.

- **Thermal Plume Characteristics:** MEP's thermal plume will be very close to ambient levels and therefore have sufficient oxygen for airplane engines to operate should a pilot fly through the plume. The temperature of the plume will reach ambient temperatures at 750 feet above ground level (AGL), and will be below 120°F at 320 feet AGL, which is well below the pattern altitude of 954 feet AGL or 1079 feet above mean sea level (AMSL).

- **FAA Safety Risk Analysis:** FAA Safety Study Report – DOT-FAA-AFS-420-06-1 "Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes" dated January 2006 concludes "hazard(s) associated with plume overflight represent an extremely low risk to aviation and the flying public." FAA deemed the risk associated with overflight of plumes to be "acceptable without restriction, limitation or further mitigation." In order to make an already safe condition even safer, FAA recommended continuance of training and awareness programs such as publication of power plant locations in the applicable Airport/Facility Directory and issuance of a Notice to Airmen (NOTAM). MEP has indicated a willingness to work with the Byron Airport authorities to implement training and awareness programs.

- **Pilot Exhaust Exposure Analysis:** If a pilot were to pass through MEP's plume, no adverse health impacts would be expected to occur because the predicted pilot exposure would be significantly less than the recognized federal and state worker/public safety standards.

- **No Potential to Attract Birds:** It is anticipated that the MEP exhaust stacks and thermal plumes would not cause a change in the behavior of migrating and local birds in the area. It is not common for birds to congregate above power plant stacks and such stacks do not contribute to increased avian mortality. It is also not expected that migrating birds would alter their flight patterns to an extent that would increase avian presence in Byron Airport approach and take-off routes.

- **Analysis of Impacts to Various Types of Aircraft:** Senta Engineering of Davis, California, evaluated the potential impacts on various types of aircraft, should such aircraft venture into the air space above MEP. The analysis determined that the load limits imparted by the plume were significantly below the load limits of the various aircraft; the turbulence experienced by aircraft would be light to initial stages of moderate; and any roll upset could be addressed with only 5.0 to 6.7 degrees of aileron deflection. If aircraft fly through the plume at flight pattern elevation or higher, there should be no significant impact on the airframe.

- **Analysis of Impacts to Transient Pilots:** As all pilots, whether conducting local or transient operations, are required by Federal Air Regulations to become familiar with all available information concerning the flight and the airport, there is no distinction between local and transient pilots. However, to assist transient pilots in fulfilling their responsibility to become familiar with the Byron Airport, the FAA publishes notifications of items of interest in the airspace. Mariposa Energy is willing to assist the Byron Airport operation with information or other requirements that may be needed to implement such pilot notifications.

- **Compliance with Byron Airport Master Plan**: MEP will be in conformance with all standards set forth in both the Byron Airport Master Plan and Contra Costa County Airport Land Use Compatibility Plan. All proposed MEP facilities are below 100 feet AGL, as required in Compatibility Zone "D" criteria and no structures approach any of the indicated Air Protection Surfaces. MEP will not impact future precision instrument landing system upgrades to lower the decision height and visibility requirements, as it is located approximately 1.0 mile from the precision instrument approach path. Future expansion of Runway 05-23 by 900 feet and /or Runway 12-30 by 1,500 feet would not be significantly impacted by the Project.

- **FAA Determinations of No Hazard:** The FAA issued Determinations of No Hazard to MEP during the period from July 29, 2009, through October 06, 2009 for the Project's four (4) exhaust stacks and eight (8) power poles. In the Determinations for the four exhaust stacks, FAA Flight Standards Division addressed the issue of thermal plumes and recommended that Mariposa Energy work with the Byron Airport to develop pilot education material and provide information on plume efflux rates at various altitudes at least as high as 1,000 feet above the source. FAA also suggested that Byron Airport provide the MEP location and avoidance information in the listing for Byron Airport contained in the Airport/Facility Directory. These recommendations are consistent with the recommendations of the 2006 FAA Safety Risk Analysis.

Mariposa Energy Project

(09-AFC-03)

Staff Queries, Set 1

(Addenda to CEC Staff Data Request 52, Responses to Keith Freitas E-mail, CCC ALUC Letter, Hal Yeager Letter, and Contra Costa County Board of Supervisors Letter)

Submitted to

California Energy Commission

Submitted by

Mariposa Energy, LLC

with assistance from

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June 2010

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Attachments

Introduction

Attached are Mariposa Energy's addenda to the California Energy Commission (CEC) Staff Data Request Number 52 and responses to CEC Staff Queries (SQ) Set 1 (numbers SQ1 through SQ22) regarding the Mariposa Energy Project (MEP) (09-AFC-03) Application for Certification (AFC). CEC Staff has requested that Mariposa Energy respond to several inquires to the CEC from outside parties, including:

- E-mail from Keith Freitas to the CEC dated September 28, 2009 (SQ1–SQ3)
- Letter from the Contra Costa County Airport Land Use Commission to the CEC received November 30, 2009 (SQ4–SQ11)
- Letter from Hal Yeager to the CEC dated December 14, 2009 (SQ12–SQ17)
- Letter from the Contra Costa County Board of Supervisors to the CEC dated April 13, 2010 (SQ18–SQ22)

The responses are presented in the same order as the questions within the original correspondence to CEC and are keyed to the Staff Query or Data Response number. New or revised graphics or tables are numbered in reference to the Staff Query or Data Response number. For example, the first table used in response to Staff Query 36 would be numbered Table SQ36-1. The first figure used in response to Staff Query 42 would be Figure SQ42-1, and so on. Similarly, the first table used in response to Data Response 36 would be numbered Table DR36-1. The first figure used in response to Data Response 42 would be Figure DR42-1, and so on.

Additional tables, figures, or documents submitted in response to a data request (supporting data, stand-alone documents such as plans, folding graphics, etc.) are found at the end of each discipline-specific section and are not sequentially page-numbered consistently with the remainder of the document, though they may have their own internal page numbering system.

Traffic and Transportation (52)

Background

On pg 5.12-13, it is noted that the Byron Airport is located 2.7 miles northwest of the Mariposa (MEP) site and during a 12-month period ending on January 29, 2004, the Airport had an average of 164 aircraft operations per day. It is also noted that the MEP site is located within the airport's influence area. There is additional discussion on pg. 5.12-19 about the MEP site location with respect to instrument and visual flight paths as displayed on Figure 5.12-5. Staff is interested in potential aviation safety impacts from MEP exhaust plumes during operations on aircraft using the Byron Airport.

Data Request

DR52. Please provide a copy of any aviation safety analysis that was performed to determine if there would be any adverse impacts from MEP plumes on aircraft flying overhead. If no analysis is available, please prepare one and submit it for staff's review.

Response:

Summary of Previous Submittals

On November 30, 2009, Mariposa Energy submitted a response to Data Request 52. The original submittal included Mariposa Energy's initial assessment of the potential impacts from the MEP exhaust plumes to overhead aircraft operations. Key elements and conclusions of the November 30 submittal are summarized below:

- **Airport Flight Patterns**—Byron Airport flight patterns are too distant from MEP to be of significant concern to aircraft approaching or departing from Byron Airport, and even if an aircraft were to venture into the air space over MEP, it is highly unlikely that the pilot would ever experience more than light to moderate turbulence.
- **MEP Thermal Plume Assessment**—The average vertical plume velocity assessment performed by Katestone Environmental indicated that plumes would never exceed light turbulence levels at the Flight Pattern Altitude.
- **FAA Safety Risk Analysis**—FAA Safety Study Report – DOT-FAA-AFS-420-06-1 "Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes" dated January 2006 concludes "hazard(s) associated with plume overflight represent an extremely low risk to aviation and the flying public." FAA deemed the risk associated with overflight of plumes to be "acceptable without restriction, limitation or further mitigation." In order to make an already safe condition even safer, FAA recommended continuance of training and awareness programs such as publication of power plant locations in the applicable Airport/Facility Directory and that a Notice to Airmen (NOTAM) be issued.

- **FAA Determinations of No Hazard to Air Navigation**—Additionally, in response to Data Request 51, Mariposa Energy previously provided the Determinations of No Hazard to Air Navigation that were issued by FAA for each of the four exhaust stacks and eight transmission poles associated with MEP. In the Determinations for the four exhaust stacks, FAA Flight Standards Division addressed the issue of thermal plumes and recommended that Mariposa Energy work with the Byron Airport to develop pilot education material and provide information on plume efflux rates at various altitudes at least as high as 1,000 feet above the source. FAA also suggested that Byron Airport provide the MEP location and avoidance information in the listing for Byron Airport contained in the Airport/Facility Directory. These recommendations are consistent with the recommendations of the 2006 FAA Safety Risk Analysis.

The MEP AFC also discussed consistency with FAA Airspace Protection Surface restrictions and airport compatibility zones. As discussed in Section 5.12 of the AFC, MEP is located within Compatibility Zone D, which limits any new construction to less than 100 feet above ground level (AGL) and requires Contra Cost County Airport Land Use Commission review of proposed structures over 100 feet AGL. All proposed MEP facilities are at or below 100 feet AGL and no structures approach any of the indicated Air Protection Surfaces.

Supplemental Information for Data Request 52

Subsequent to the initial submittal on November 30, 2009, Mariposa Energy has commissioned several additional studies to further assess potential impacts to aircraft flying in the vicinity.

Katestone Environmental Assessment of Vertical Plume Velocities

At the request of Mariposa Energy, Katestone Environmental provided an updated Assessment of Vertical Plume Velocities for MEP (Attachment DR52-6). This assessment, dated April 30, 2010, expands upon, but does not differ in conclusion from, the prior assessment dated October 12, 2009.

This updated assessment provides a calm wind analysis (zero wind) in addition to the Australian Civil Aviation Authority (CASA) methodology using The Air Pollution Model (TAPM) to simulate hourly meteorological conditions over a year. As previous reported in the original response to Date Response #52, the CASA methodology resulted in a prediction that the average vertical plume velocity would exceed the CASA threshold velocity of 9.6 miles per hour (mph) (4.3 meters per second [m/s]) at the Flight Pattern Altitude of 954 feet AGL (1,079 feet above mean sea level [AMSL])[1] for 26 hours of the year, and would never exceed the upper limit of light turbulence (13.6 mph) at that elevation. The new calm wind analysis (zero wind) predicts that the maximum height at which the average plume velocity is reduced to below 9.6 mph is 1,841 feet AGL, versus 1,309 feet AGL with the TAPM assumptions, and 307 feet AGL above which an average vertical velocity of 13.6 mph is not exceeded.

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[1] According to AIRNAV the official elevation of the Byron Airport is 79 feet. Elevation across the airport varies, and in its analysis, Katestone Environmental used an airport elevation of 76 feet, which resulted in a Flight Pattern Altitude of 1,076 feet AMSL or 950 feet AGL. The difference between the Flight Pattern Altitude that Katestone Environmental used in its analysis and the Flight Pattern Altitude based on an airport elevation of 79 feet (954 feet AGL or 1,079 AMSL) is insignificant, and does not affect the conclusions presented herein.

Additionally, Katestone Environmental provided detailed plume and meteorology characteristics for a 1-hour period (out of 8,760 hours in a year) when the maximum plume height was predicted. These data, and additional background information and results in the updated report, were used to develop responses to several of the Staff Queries addressed in subsequent sections of this document.

Computation Fluid Dynamics Turbine Exhaust Velocity Characterization

The Katestone Environmental analysis following the CASA methodology does not provide detailed three-dimensional plume characteristics to assess plume velocities at discrete points; rather this methodology determines average vertical velocities at a given height. Computational fluid dynamics (CFD) mathematical modeling methodologies can be used to simulate detailed plume characteristics spatially. At the request of Mariposa Energy, CH2M HILL prepared a Turbine Exhaust Velocity Characterization analysis using CFD (Attachment DR52-7). This analysis characterized MEP exhaust plume parameters (vertical velocity, temperature, and oxygen [O_2] content) under 5 mph and 10 mph wind conditions, for ambient temperatures of 59 and 112 degrees Fahrenheit (°F). At these conditions, peak vertical plume velocities (at any discrete point in the plume) of 9.6 mph and 13.6 mph did not exceed 760 feet AGL and 142 feet AGL, respectively. The plume temperatures were found to cool to within 20°F of the ambient temperature within 361 feet AGL. Oxygen level at the stack discharge was given as 14.5 percent (70 percent of ambient levels), and was found to increase to 20 percent (95 percent of ambient levels) within 160 feet AGL. These data were used to develop responses to several of the Staff Queries addressed in subsequent sections of this document.

Additionally, CH2M HILL prepared a CFD analysis of the vertical velocity profile across the MEP plumes using the Katestone Environmental TAPM meteorological parameters associated with the maximum 1-hour plume height, for comparison of the CFD and TAPM methodologies. This analysis was conducted across the plume at 950 feet AGL (Flight Pattern Altitude), and 1,309 feet AGL (greatest height predicted by TAPM at which average vertical velocity of the plume equals or exceeds 9.6 mph). This analysis demonstrated that the two methodologies produce very similar results for average plume velocities at these elevations, and also provided cross-section plume velocity profile data for perpendicular paths through the plume at these elevations. These cross-section plume velocity profile data were used in the analysis of plume impacts on various airframes, as discussed below.

Aircraft Engine Oxygen Requirement Assessment

An analysis of aircraft engine oxygen requirements was prepared by Senta Engineering, LLC, in association with the Department of Mechanical and Aeronautical Engineering at UC Davis and is attached as Attachment DR52-8. The report indicates that, based on an exhaust stack concentration of 14.5 percent oxygen, both reciprocating and turbine aircraft engines can operate in the exhaust plume with minimal effects due to oxygen reduction. Air to fuel ratios were used to evaluate lower oxygen levels, since a lower oxygen condition is equivalent to an excess fuel or rich mixture operation. The higher-than-ambient stack temperatures equate to a higher density altitude, which will result in a momentary reduction in power, equivalent to operating at that density altitude. The lower air density with increased temperature was equated to density variations with altitude or equivalent density altitude.

Plume characterization information about oxygen content and temperature as a function of plume height were taken from the Katestone study attached as Attachment DR52-6.

Aircraft Loads and Handling Assessment

An analysis of the possible plume effects on aircraft airframes and on aircraft handling was conducted by Senta Engineering, LLC in association with the Department of Mechanical and Aeronautical Engineering at UC Davis and is attached as Attachment DR52-9. The analysis is based upon the plume characteristics established by the Katestone Environmental analysis and the CH2M HILL exhaust velocity characterization report, attached as Attachments DR52-6 and DR52-7, respectively. The analysis assumes that an aircraft flies through the gas turbine plume produced by all four units of the MEP operating at maximum capacity at an elevation of 950 AGL or approximately at the Flight Pattern Altitude for the Byron Airport.

Once instantaneous plume velocities were established by the CH2M HILL analysis, they were utilized to determine a critical gust case based on a one-minus cosine vertical gust profile. This profile was then employed to determine the incremental vertical load factor on the aircraft due to the gust. The aircraft evaluated included a Cessna 172, a Cessna Citation II, a Vans RV-6 and a powered parachute. Depending on the aircraft, the load imparted by the plume ranged from +1.24g to +1.67g, while the load limits ranged from +6.0g to -1.75g indicating that the loads imparted by the MEP plume are well within the prescribed operating load limits of the aircraft.

The critical gust case was also utilized to evaluate the potential of an asymmetric vertical velocity gradient across the wingspan of an aircraft, which could result when one wing enters the plume, while the other does not, and is therefore unaffected. The previously determined critical gust case was utilized to calculate the maximum rolling moment coefficient and then the required neutralizing aileron deflection for a Cessna 172, a Beech 99 and a Learjet 24. The neutralizing aileron deflections ranged from 5.0 to 6.7 degrees, while the maximum aileron deflections are from 14 to 20 degrees, depending upon the aircraft. The aileron input required to counter the roll upset imparted by the MEP plume is well within the aileron operating range of all evaluated aircraft.

Pilot Exhaust Exposure Analysis

Based on concerns raised at prior meetings, Mariposa Energy conducted an analysis of the potential health impacts that could be experienced if pilots flew aircraft directly through the MEP exhaust plumes. The potential health impacts were evaluated based on a comparison of both the exhaust concentration at the stack tip and the diluted exhaust concentrations to safe exposure limits established by the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), the American Conference of Industrial Hygienists (ACGIH), the Agency for Toxic Substances and Disease Registry (ATSDR), and the Office of Environmental Health Hazard Assessment (OEHHA). The potential exhaust characteristics at various heights were predicted based on the TAPM and CFD modeling conducted by Katestone Environmental and CH2M HILL, respectively (included as Attachments DR52-6 and DR52-7).

For the purposes of this analysis, a minimum pilot elevation of 675 feet AGL (800 feet AMSL), which is approximately 280 feet below the stated Byron Airport approach pattern altitude, was used to determine potential exposure concentrations. The existing high-voltage transmission towers to the east and west of MEP extend slightly higher than 300 feet AMSL. Aircraft in proximity to MEP would be required to maintain a minimum of 500-foot clearance from these towers, in accordance with FAA clearance requirements in rural areas. The Byron Airport Traffic Pattern Altitude is higher than this elevation, at approximately 954 feet AGL. Aircraft would generally be expected to be flying at or above the Traffic Pattern Altitude elevation; however, 675 feet AGL was used for this analysis to be conservative.

The exhaust plumes of all four turbines operating at 100 percent load were modeled using CFD. Conditions evaluated included both 5 mph and 10 mph wind speeds, as well as two ambient temperature conditions of 59°F and 112°F. Exhaust plume vertical velocities, temperatures, and oxygen concentrations were calculated three-dimensionally for each case. The oxygen level at the stack discharge will be approximately 14.5 percent (70 percent of the ambient O_2 concentration of 20.95 percent), and was found to be 20 percent (95 percent of ambient O_2 concentration) within 135 feet AGL. At 675 feet AGL, the O_2 level is predicted to be greater than 20.85 percent.[2] Similarly, the O_2 content predicted by the TAPM model at 675 feet AGL is also predicted to be greater than 20.85 percent[3]. Dilution of the stack exhaust from 14.5 percent O_2 to 20.85 percent O_2 with ambient air results in a calculated dilution factor of 60 (i.e., emission concentrations would be one sixtieth [1/60] of stack exit concentrations). Therefore, a dilution factor of 60 was used to estimate the exhaust concentrations at 675 feet AGL. Because the dilution would continue to increase at heights above 675 feet AGL, the concentrations calculated using a dilution factor of 60 are expected to conservatively represent the potential pilot exposure for all flight operations at or above 675 feet AGL.

The potential duration of exposure was also estimated based on a plume width and aircraft speeds for general aviation aircraft, gliders, ultra-lights, and power parachutes. Based on a review of both modeling analyses, a plume width of 500 feet was determined to be a reasonable assumption at 675 feet AGL. Because oxygen concentrations are predicted to exceed 20.85 percent (equivalent to a dilution factor of 60) prior to reaching this elevation, it is highly conservative to assume that pilots fly through the full 500 feet of plume at this concentration level. It should be noted that for closed-cockpit aircraft, pilots would be exposed to even lower concentrations because it takes some time for ambient air to enter the cockpit unless windows are open. Based on this plume diameter, the duration of exposure for each of the aircraft categories are presented in Table DR52-1. As presented, the maximum duration of exposure for an aircraft flying through a 500-foot plume diameter at 675 feet AGL would range from 5 to 34 seconds.

Therefore, the duration of pilot exposure is expected to be significantly less than the 15-minute and 8-hour occupational exposure averaging periods and the 60 minute OEHHA averaging period evaluated in the following sections. For instance, a general aviation pilot would have to travel within a plume for more than 18 miles before being exposed for 15 minutes.

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[2] See Figure 1.9, CH2M HILL. 2010. Mariposa Energy Project Turbine Exhaust Velocity Characterization. May 14 (Attachment DR52-7).

[3] See Figure B6 Plume oxygen content versus height above ground for the hour when the maximum threshold plume height of 1,309 feet AGL occurs", Katestone Environmental, 2010. Assessment of Vertical Plume Velocities for the Mariposa Energy Project, April 30 (Attachment DR52-6).

TABLE DR52-1
Duration of Travel Through A 500-Foot Plume

Aircraft Type	Approximate Low End Speed (mph)	Duration of Travel Through 500-foot Plume (seconds)
General Aviation	75	5
Glider	40	9
Ultralight	20	17
Powered Parachute	10	34

Comparison of Predicted Concentrations to the Occupational Exposure Limits

A comparison of the MEP stack exhaust concentrations to the OSHA, NIOSH, ACGIH, and the ATSDR occupational exposure limits are presented in Table DR52-2. Exposure limits are expressed as permissible, reference or threshold as indicted below:

- The permissible exposure limit (PEL) is expressed as a time weighted average (TWA) and is the concentration of a substance to which most workers can be exposed without adverse effect averaged over a normal 8-hour workday or a 40-hour work week, on a continual basis. The PEL is the value published and enforced by OSHA as a legal standard.
- The reference exposure limit (REL) is an exposure limit published by NIOSH which represents the recommended exposure limit for an 8- or 10-hour TWA.
- The threshold limit value (TLV), which is published annually by the ACGIH, is a time-weighted average concentration under which most people can work consistently for 8 hours a day, day after day, with no harmful effects.
- The Short Term Exposure Limits (STEL) have been developed for 15-minute exposure durations.

The short-term and 8-hour occupational exposure limits presented in Table DR52-2 for all pollutants represent the most stringent of the four agencies. For example, the 25 ppm ACGIH threshold limit value was chosen for carbon monoxide (CO) because the value was lower than the OSHA PEL for CO of 50 ppm (8-hour TWA) and the NIOSH REL for CO of 35 ppm (8-hour TWA).

The stack exhaust concentrations presented in Table DR52-2 have been corrected to 15.0 percent O_2, representing stack exit conditions, and 20.85 percent O_2 (i.e., a dilution factor of 60), representing maximum predicted plume concentrations at 675 feet AGL. Based on the information summarized in Table DR52-2, the instantaneous pilot exposure would be less than the short-term and 8-hour exposure limits for most pollutants at the stack exhaust outlet. For the estimated plume concentrations at 675 feet AGL, the instantaneous concentrations for all pollutants would be even less and all would be well below the 15-minute and 8-hour occupational exposure limits. Furthermore, pilot exposures are expected to be less than one minute, as shown in Table DR52-1. Therefore, the potential pilot exposure is expected to be significantly less than the acceptable worker exposure limits based on the OSHA, NIOSH, ACGIH, and ATSDR standards. A pilot or passengers would not be exposed to any pollutant concentration that would have any significant impact on their health and safety based on criteria established by all the aforementioned agencies.

TABLE DR52-2
Comparison of Predicted MEP Exhaust Concentrations to Occupation Exposure Limits

Pollutant	MEP Stack Exhaust Concentrations at 15.0% O_2	Estimated Plume Concentration at 675 feet AMSL	Short-term Occupational Exposure Limit (i.e., 15 min)	8-hour Occupational Exposure Limit
NOx NO_2 [a]	2.5 ppm NOx 0.25 ppm NO_2	0.042 ppm	ATSDR/OSHA PEL: 5 ppm NO_2 [b]	OSHA PEL: 25 ppm NOx
CO [c]	2 ppm	0.034 ppm	NA	ACGIH TLV: 25 ppm CO
SO_2 [d]	0.37 ppm (0.66 grains/100 dscf of natural gas)	0.062 ppm	ATSDR: 5 ppm[e]	OSHA PEL/NIOSH REL: 2 ppm SO_2
Particulates	1.88 mg/m^3	NA	NA	OSHA PEL: 15 mg/m^3 (total dust) 5 mg/m^3 (respirable dust)
Benzene[f]	0.0015 ppm	0.000035 ppm	NIOSH REL: 1 ppm	NIOSH REL: 0.1 ppm (CA TWA)
Formaldehyde[g]	0.04 ppm	0.0063 ppm	NIOSH REL: 0.1 ppm	NIOSH REL: 0.016 ppm (CA TWA)
Ammonia[h]	5 ppm	0.084 ppm	NIOSH REL/ACGIH: 35 ppm	NIOSH REL/ACGIH: 25 ppm

[a] NO_2 concentration assumes a 10 percent thermal conversion of NOx to NO_2 in the exhaust stack
[b] Agency for Toxic Substances and Disease Registry (ATSDR). 2002. Managing Hazardous Materials Incidents. Volume III – Medical Management Guidelines for Acute Chemical Exposures: Nitrogen Oxides. Atlanta, GA: U.S. Dept. of Health and Human Services, Public Health Service
[c] The OSHA PEL for CO is 50 ppm (8-hour TWA) and the NIOSH REL for CO is 35 ppm (8-hour TWA).
[d] The OSHA PEL for SO_2 is for an 8-hour, 5-day workweek while the NIOSH REL is for a 10-hour period.
[e] ATSDR. 1998. Toxicological profile for Sulfur Dioxide. Atlanta, GA: U.S. Dept. of Health and Human Services, Public Health Service
[f] The OSHA PEL for benzene is 1 ppm (TWA) and 5 ppm for short term exposure.
[g] The OSHA PEL for formaldehyde is 0.75 ppm (TWA) and 2 ppm for short term exposure.
[h] The OSHA PEL for ammonia is 50 ppm (TWA).

Comparison of Predicted Concentrations to the OEHHA Exposure Limits

A comparison of the MEP stack exhaust concentrations to the OEHHA short-term (acute) reference exposure levels are presented in Table DR52-3. The OEHHA REL is defined as the concentration level at or below which no adverse health effects are anticipated and is based on the most sensitive adverse health effect reported in the medical and toxicological literature. The OEHHA RELs are also designed to protect the most sensitive individuals in the population by the inclusion of margins of safety.

Based on the information summarized in Table DR52-3, the instantaneous pilot exposure would be less than the 1-hour OEHHA REL exposure limits for most pollutants at the stack exhaust outlet. For the estimated plume concentrations at 675 feet AGL, the instantaneous concentrations for all pollutants would be even less and all would be well below the

OEHHA RELs. Furthermore, any pilot exposures to these plume concentrations would be less than one minute in duration, leading to the conclusion that even if the pilot continuously circled through the exhaust plume he or she would not experience continuous exposure because the plume is not large enough to make a complete turn in without leaving the plume, and non-exhaust plume air would be entering the cockpit when the aircraft was out of the plume, purging the cockpit. Therefore, the potential pilot exposure is expected to be significantly less than the acceptable 1-hour OEHHA RELs for all pilots and passengers.

TABLE DR52-3
Comparison of Predicted MEP Stack Exhaust Concentrations to OEHHA Acute Reference Exposure Levels

Pollutant	MEP Stack Exhaust Concentrations at 15.0% O_2	Estimated Plume Concentration at 675 feet AMSL	OEHHA REL* (1-hour Exposure)	% of REL at 675 Feet AMSL
Ammonia	5 ppm	0.084 ppm	4.6 ppm	1.8%
Acetaldehyde	0.038 ppm	0.00064 ppm	0.26 ppm	0.25%
Acrolein	0.00081 ppm	0.000014 ppm	0.0011 ppm	1.2%
Benzene	0.0029 ppm	0.000035 ppm	0.41 ppm	0.01%
Formaldehyde	0.374 ppm	0.0063 ppm	0.045 ppm	14.0%
Propylene oxide	0.010 ppm	0.00017 ppm	1.3 ppm	0.013%
Toluene	0.0094 ppm	0.00016 ppm	9.8 ppm	0.0016%
Xylene	0.0030 ppm	0.000051 ppm	5.1 ppm	0.0010%

*Source: California Air Resource Board (ARB). 2009. Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values, February 9.

Conclusion

The results of this analysis show that were a pilot to pass through the MEP plume at the lowest expected elevation, no adverse health impacts would occur because the predicted pilot exposure would be significantly less than the recognized worker/public safety standards published by OSHA, NIOSH, ACGIH, ATSDR, and OEHHA. It is also expected that the concentrations in Tables DR52-2 and DR52-3 represent a conservative assumption of the potential pilot exposures for the following reasons:

- The expected duration of aircraft exposure is less than 1 minute. Therefore, the aircraft exposure adjusted to the 1-hour and 8-hour time-weighted average concentrations would be significantly less than the exposure limits.
- This analysis assumed the exhaust concentrations are equivalent to the permissible air emission concentrations when in reality the plant will be designed to achieve emission levels below the permit limits to provide a compliance safety margin.
- The exhaust plume concentrations would be further diluted as a result of the mixing induced by the aircraft flying through the plume.

Therefore, this analysis demonstrates that MEP exhaust plume exposure will not create a significant health risk to either aircraft pilots or aircraft passengers.

Attachment DR52-6
Plume Velocity Assessment
Katestone Environmental, April 2010

Assessment of Vertical Plume Velocities for the Mariposa Energy Project

Prepared for

Ellison, Schneider & Harris, LLP

KE0907697

April 2010

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Glossary

Term	Definition
μg/m^3	micrograms per cubic metre
μm	microns
°C	degrees Celsius
°F	Degrees Fahrenheit
km	kilometre
km/h	kilometre per hour
m	metre
m/s	metres per second
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
mi	miles
mph	miles per hour
ft	feet

Conversions

1 m/s	=	2.2 mph
4.3 m/s	=	9.6 mph
6.3 m/s	=	13.6 mph
1 mph	=	0.45 m/s
1 ft	=	0.3 m
1 m	=	3.28 ft

Executive Summary

Katestone Environmental has been commissioned by Ellison, Schneider & Harris, LLP to prepare a plume vertical velocity assessment of a proposed gas-fired power station located near Tracy in California. The proposed power station, called the Mariposa Energy Project (MEP) is to consist of four simple-cycle gas-turbines and a configuration of thirty-two cooling fans for an air cooled refrigeration condenser.

An assessment of vertical plume velocities has been conducted in accordance with Australian Civil Aviation Safety Authority (CASA) requirements for the Mariposa Energy Project power station. The outcomes of the assessment can be used to define the size of the plume around the Mariposa Energy Project power station. The closest airport to the facility is the Byron Airfield located approximately 2.7 miles to the northwest which has a Flight Pattern Altitude above the proposed MEP site at a height of 950 feet above ground level (AGL), 1075 feet above mean sea level (AMSL).

The assessment has shown the following important characteristics:

- *The average plume vertical velocities generated by the Mariposa Energy Project are unlikely to exceed the CASA threshold of 9.6 mph above a height of 1300 feet above ground level.*
- *The average plume vertical velocities generated by the Mariposa Energy Project are unlikely to exceed the threshold of light turbulence (13.6 mph) above a height of 700 feet above ground level.*
- *At the Flight Pattern Altitude of 950 feet above ground level the average plume vertical velocity is predicted to be above the threshold velocity of 9.6 mph for 26 hours of the year, and never above the vertical velocity of 13.6 mph, the upper limit of light turbulence.*
- *The average plume vertical velocities are likely to be below 9.6 mph under all meteorological conditions at a horizontal distance of approximately 300 feet from the Mariposa Energy Project power station stacks.*
- *The average plume vertical velocities are likely to be below 13.6 mph under all meteorological conditions at a horizontal distance of approximately 100 feet from the Mariposa Energy Project power station stacks.*
- *At no time will the cooling fans for the air cooled refrigeration condenser result in a plume exit velocity exceeding 9.6 mph.*
- *Assuming a worst case calm, zero mph, wind scenario the maximum height at which the average plume velocity is reduced to below the threshold velocity of 9.6 mph is 1841 feet and a velocity of 13.6 mph at 307 feet above ground level.*

1. Introduction

Katestone Environmental has been commissioned by Ellison, Schneider & Harris, LLP to prepare a plume vertical velocity assessment of a proposed gas-fired power station located near Tracy in California. The proposed power station, called the Mariposa Energy Project (MEP) is to consist of four simple-cycle gas-turbines and a configuration of thirty-two cooling fans.

The assessment presented in this report is based on the guidelines for aviation safety set out by the Australian Civil Aviation Safety Authority (CASA) and presented in "*Guidelines for conducting plume rise assessments (CASA, 2004)*". As an addition to the requirements set out by CASA, of an analysis of the plume velocities during the worst case meteorological conditions, an analysis has also been undertaken assuming a calm wind scenario.

The aim of this assessment is to determine the height at which the average vertical plume velocity emitted from the power station achieves the threshold value of 9.6 mph and the upper limit of light turbulence of 13.6 mph. This report details the methodology used for the vertical plume velocity assessment and summarises the plume heights of interest based upon local flight path elevation and plume downwind distance from the MEP power station.

2. Local terrain and surrounding land use

The MEP is to be located in a rural area on the western edge of San Joaquin Valley, California. The MEP is located approximately 7.4 miles west-northwest of the town of Tracy. The terrain within the region consists of undulating hills to the west, with agricultural activities located across the valley floor. The Pacific Ocean is located 50 miles to the west of the site. There are many terrain influences that would affect local scale meteorology between the ocean and the site.

Figure 1 shows an image of the area surrounding the MEP. The closest airport to the facility is the Byron Airfield located approximately 2.7 miles to the northwest.

3. Vertical plume velocity guidelines

Since the development of an open-cycle gas turbine power station at the end of a runway in Australia in the mid 1990s, the CASA has taken a keen interest in the siting of industries with discharges to the atmosphere. Potential risks that could affect the safety of aircraft include tall visible or invisible obstructions. Visible obstructions include structures such as tall stacks or communication towers. Invisible obstructions include vertical industrial exhausts that are of high velocity and buoyancy. CASA has issued an Advisory Circular, (CASA 2004) that specifies the requirements and methodologies to be used to assess whether a new industrial plume is likely to have adverse implications for aviation safety. In the absence of any guidance for such activities in California, the CASA guidelines have been used in this assessment. This methodology was accepted by the California Energy Commission for the Russell City Energy Center assessment of vertical plume velocities (CEC, 2007).

The general CASA requirement is to determine the height at which the plume (or plumes) could exceed an average vertical velocity threshold of 4.3 m/s (9.6 mph) and to determine the dimensions of the plume in these circumstances. If the average vertical velocity threshold of 9.6 mph is significantly exceeded at the expected flight path elevation, then additional evaluations may be under taken. The frequency of in-plume vertical velocities at the lowest height an aircraft may possibly travel over the site, and at other heights are also required. For large plumes that are remote from airports, CASA requires an assessment that determines the size of potential plumes. The maximum height and horizontal extent of the plume or plumes which may exceed the vertical velocity threshold is determined for the 0.1 percentile over one or more years.

The Flight Pattern Altitude (FPA) from the Byron Airfield above the proposed site is 1076 feet above mean sea level. With a base elevation of the site at 126 feet, the plume elevation of interest above ground level is 950 feet. Subsequently results of this study will be presented as above ground level and compared to the FPA of 950 feet above ground level.

For this report, the average plume vertical velocity has been used. While there are some sections of the plume that may have a vertical velocity higher than the average, it has been Katestone Environmental's experience that these peak plume vertical velocity predictions do not assess aviation safety risk appropriately. The TAPM model used for this assessment predicts a plume average velocity, satisfying the CASA requirement however does not predict a maximum instantaneous velocity within the plume. A peak plume vertical velocity can be estimated as double the average velocity. Past discussions between Katestone Environmental and CASA have concluded that analysis of the average plume vertical velocity is appropriate for these assessments.

In addition to the use of the CASA vertical velocity threshold of 9.6 mph, a velocity of 13.6 mph has also been assessed, which represents the upper limit of light turbulence (see Lester, 2007) generated by the MEP power station.

4. Stack Characteristics

For this assessment it is assumed that the power station operates continuously throughout the year. A normal operating scenario for the gas turbines and cooling fans have been modelled as detailed below. For each of the plumes, an assessment has been made of a single plume from one operating gas turbine and of merged plumes from all operating turbines. The stack characteristics for various operating conditions used in this assessment are presented in Table 1.

Table 1 Stack characteristics used in modelling

Parameters	Units	Gas Turbines	Cooling Fans
Number of units	-	4	32
Stack height	metres	24.23	9.41
	feet	79.5	30.88
Stack diameter	metres	3.66	5.5
	feet	12	18
Stack temperature	°C	449	n/a
	°F	840	Ambient + 18.3°F
Exit velocity	metres/sec	27.5	3.11
	feet/sec	90.2	10.2
	miles/hour	61.5	6.9
Flow rate per unit (actual)	m^3/ sec	289	73
	ft^3/min	612,224	155,875
Stack separation	metres	47	n/a
	feet	154	n/a

5. Methodology

5.1 CASA methodology

In Australia, CASA requires that the proponent of a facility with an exhaust plume that has an average vertical velocity exceeding the threshold value 4.3 m/s (9.6 mph) at the Obstacle Limitation Surface or at 110 metres (361 feet) above ground level anywhere else to assess the level of risk posed by the plume to aircraft operations. Attachment A of CASA's Advisory Circular provides a recommended methodology that adopts TAPM (The Air Pollution Model) to conduct plume rise assessments for single exhaust plumes. The CASA Advisory Circular does not specify a method for dealing with multiple plumes and possible buoyancy enhancements but allows for the use of alternative techniques.

In this study TAPM (Version 4.0.2) was used to calculate the plume height and horizontal movement downwind after discharge from the stack for a full year of meteorological conditions. TAPM simulates the meteorological conditions and plume dispersion for every hour for the entire year, 8760 hours. Modelling a year takes into account a wide range of meteorological conditions the power station plume is likely to experience once in operation.

For a scenario involving the merging of stack plumes, plume growth will involve several stages:

(a) In the first stage very close to the stack exit, the high plume momentum will result in a short section in which the conditions at the centre of each plume are unaffected by ambient conditions. The potential core in which maximum core velocity and temperature remain constant extends approximately a distance of 6.25 D (D is the stack diameter) above the outlet in calm conditions or 75 feet in the case of the Mariposa facility. At the end of this stage, the plume-average velocity has decreased to half of the exit velocity, with a corresponding increase in effective plume diameter.

(b) In the second stage, the plume dynamics and trajectories respond to ambient conditions, with much cooler air being entrained into the outer regions of the plume. The momentum and buoyancy of the plume significantly influence its rise as this air mixes into the plume and provides dilution of the exhaust. This dilution is very sensitive to ambient wind speed.

(c) In the third stage of plume development, plume rise is due entirely to the buoyancy of the plume and continues until there is an equalization of turbulence conditions within and outside the plume.

Possible buoyancy enhancement associated with multiple plumes has been accounted for as follows:

- A single gas turbine plume is firstly modelled using TAPM.
- The methodology described by Manins et al (1992) has been used to calculate the enhancement of vertical velocities that would occur if the plumes from multiple stacks merge and form a higher buoyancy combined plume. The average final plume rise height of a single plume, the number of stacks and the average separation distance between stacks is used to derive the buoyancy enhancement factor.
- This enhancement factor is input into TAPM as a second iteration to represent the impacts on vertical velocities from the four merged turbine plumes.

A detailed description of how TAPM has been configured, along with a verification of meteorology is included in Appendix A. The methodology presented and used in this assessment is the recommended approach in the TAPM documentation.

5.2 Calm wind scenario

5.2.1 Single plume

The equations governing the growth of an isolated plume under calm wind conditions in a neutral environment are given in Appendix C. The analytical solution of the governing equations under these conditions is given by:

$$a = 0.16(z - z_v) \quad (1)$$

and

$$(Va)^3 = (Va)_o^3 + 0.12F_o\left[(z - z_v)^2 - (6.25D - z_v)^2\right] \quad (2)$$

Where the subscript 'o' refers to values of the parameters at the outlet and the variables are (See Appendix C for details):

a	plume radius (m)
V	average vertical velocity (m/s)
z	height above stack top (m)
z_v	virtual source height (m)
D	stack diameter (m)
F_o	buoyancy flux evaluated at the outlet (m^4s^{-3})

Characteristics of the plume radius, average vertical velocity and plume potential temperature for an isolated plume are plotted in the figures of Appendix C.

This analytical solution is used in the analysis of the merging of multiple identical plumes.

5.2.2 Two or more identical plumes

Determining the height at which the plumes first touch and when they are considered to be fully merged is the crucial first step to determining the vertical profile of plume radius and thus the vertical velocity of the plume that results from two or more identical plumes merging.

Although it may not be difficult to argue that two identical plumes begin to merge when the radius of the plumes is equal to half the stack separation distance, the height at which the multiple plumes (N) may assume to be fully merged is not so apparent. It has been suggested (Best et al, 2003) that under calm conditions, multiple plumes may be assumed to have fully merged at a height that corresponds to a single plume radius of:

$$\frac{1}{2}S(N-1) \text{ for } N \geq 3. \quad (3)$$

This expression suggests that three identical plumes will have merged fully at a height that is equivalent to the stack separation distance. An additional radial distance S/2 is assumed to be required for each additional plume greater than three. Assuming that all plumes will be fully merged at a height corresponding to a single plume radius of S regardless of the number of plumes assessed will, result in a conservative estimate for the plume height. A more accurate estimate of the plume height would require a more accurate representation of the height at which buoyancy enhancement of the plume is applied.

During the three stages of plume growth that are described in Section 5.1 the assumed characteristics of plume growth are as indicated in Figure 2.

See Appendix D for details of the methodology involving the merging of multiple, identical plumes.

6. Meteorology

The MEP is located approximately 37 miles from the nearest meteorological monitoring station. For this assessment, meteorological data for the dispersion modelling was generated using the TAPM meteorological model for the year 2003. A comparison of meteorological data that was generated using TAPM (without data assimilation) with data from the Modesto meteorology station, suggested that the TAPM meteorology adequately represented actual conditions. The Modesto meteorological station data was used to verify the appropriateness of the TAPM meteorological dataset. The use of this model is described further together with verification in Appendix A.

The seasonal, diurnal and all hours wind roses for the MEP site are presented in Figure 3 to Figure 5. The wind roses show that the site is dominated by winds from the south west.

The most important meteorological conditions that could results in significant plume rise and potentially high vertical velocities at significant elevation are calm or light winds from ground level throughout the lower atmosphere.

An analysis of the vertical wind profiles that were simulated using TAPM indicates that for only three hours out of a possible 8760 the winds at the MEP site are less than 1 mph up to a height of 984 feet. The low number of hours indicates that the scenario of calm winds (i.e. zero mph) throughout the lower atmosphere is extremely conservative and unlikely to happen in reality.

The seasonal, diurnal and all hours wind roses for the closest meteorological station, Modesto, are presented in Figure 6 to Figure 8. The wind roses show that the site is dominated by winds from the north west.

Figure 9 presents the frequency distribution of wind speed observed at the Modesto meteorological station. Nearly 15% of the winds observed at the site were calm winds. This high number is likely attributed to a high stall speed of the anemometer. Wind speeds between 0 and 3 mph occur infrequently at the site.

7. Results

7.1 Calm wind scenario

An assessment assuming calm winds for the entire length and height of the plume is presented here to represent the absolute worst-case. The height at which the average vertical velocity is reduced below the threshold velocities of 9.6 and 13.6 mph for the single and multiple plumes is presented in Table 2. The stack and plume characteristics used in the analysis are those presented in Table 1.

Table 2 Summary of height above ground level the average vertical velocity of the plume (or plumes) is reduced to 9.6 mph and 13.6 mph for a calm wind scenario

	Height (feet) at which average vertical plume velocity falls below	
	9.6 mph	13.6 mph
Single plume	730	307
Merged plumes	1841	n/a [1]

Note [1] Merged plumes do not exceed an average vertical velocity of 13.6 mph. The velocity of the sing plumes decrease below this value before merging.

The estimated vertical plume velocity at the height of 950 feet above ground level is presented in Table 3. Figure 13 presents a vertical profile of predicted average vertical velocities for one to four plumes. It can be seen from this figure that once the plumes are fully merged the decrease in vertical velocity is linear and is a consequence of the assumption that the buoyancy flux is conserved.

At the lowest height that planes are likely to pass over the MEP site the average vertical velocity for all scenarios under worst-case calm wind conditions is estimated to be 10.8 mph, approximately 12.5% higher than the 9.6 mph threshold value, but still in the range of light turbulence which extends to 13.6 mph.

Table 3 Average vertical velocity (mph) at 950 feet above ground level for calm wind scenario

	Average vertical velocity (mph)
Single plume	8.7
Merged plumes	10.8

In reality, wind speed and direction can vary dramatically with height and the above results are very conservative indications of adverse conditions. The important factor for a given location is the appropriateness of available information for estimating true wind and temperature profiles throughout a typical year. Theoretical predictions, as shown in Table 2 are likely to overestimate the expected vertical velocities, for the following reasons:

- The wind profile is assumed constant with height with no occurrence of wind-shear. In reality, there is a considerable variation with height, especially in light winds.
- Wind direction is assumed to be parallel with the line of stacks resulting in the maximum enhancement and merging of the plumes.
- Worst-case scenarios are for very light-wind, near-neutral atmospheric conditions with maximum loading.

Section 7.2 details a more realistic approach to estimating the average in-plume vertical velocity profiles using vertical profiles of meteorological data generated by a prognostic wind-field model for an entire year and estimates the frequency of occurrence of the height at which the plume achieves the threshold vertical velocity.

7.2 CASA method

A one-year TAPM simulation using site representative meteorological conditions for 2003 has been conducted to quantify:

(a) The plume height of interest at which the average vertical velocity of the plume falls below the plume threshold velocities of 9.6 mph and 13.6 mph.

(b) The frequency at which plume heights of various magnitudes are likely to occur.

(c) The maximum extent of the plume for various heights above the ground where the vertical velocity of the plume is above the threshold velocity.

The year 2003 was selected from a five year period (2000 – 2004) of available data from the Modesto monitoring station. This year had the highest data capture rate, and a large number of light winds.

Modelling of the cooling fans has identified that insufficient buoyancy is generated from merging of adjacent fans to result in an enhanced vertical plume velocity that will exceed 9.6 mph. At no time will the cooling fans result in an exit velocity exceeding 9.6 mph. There is no interaction between the cooling fan discharges of the air cooled condenser plumes and the gas turbine plumes that will result in additional enhancement of plume buoyancy.

Results for the MEP gas turbines operating under normal conditions are presented in Table 4 to Table 8.

The height above ground level at which the average vertical plume velocity for four merged gas turbines is above the threshold plume velocity of 9.6 mph for less than 0.1% of the time is 1132 feet above ground level. For a threshold plume velocity of 13.6 mph, the plume reaches 564 feet above ground level for less than 0.1% of the time.

Figure 10 and Figure 11 show the frequency of plume heights for each hour of the day for the single and merged gas turbine plumes for threshold velocities of 9.6 mph and 13.6 mph respectively. The average vertical plume velocity is predicted to be above 9.6 mph at the FPA of 950 feet above ground level, for 26 hours of the year, and never above 13.6 mph.

The plume extent is calculated as the sum of the distance the plume travels downwind plus the plume radius. The results in Table 7 indicate that the average vertical velocity of the plume is likely to be below 9.6 mph under all meteorological conditions at a horizontal distance of 313 feet from the power station stacks. The results in Table 8 indicate that the average vertical velocity of the plume is likely to be below 13.6 mph under all meteorological conditions at a horizontal distance of 115 feet from the power station stacks.

A summary of the frequency the plume average vertical velocity achieves 9.6 mph for heights above ground level is presented in Figure 12 for multiple plumes for one, two, three and all four turbines operating simultaneously as generated by TAPM. This is also summarised in Table 6. The results show that for approximately 85% of the time the average vertical velocity of the plume falls below 9.6 mph by 250 ft above ground level.

Table 9 presents the maximum height and downwind distances for the hours in which the plume exceeds the threshold velocity of 9.6 mph at the FPA height of 950 feet above ground level. Further detailed information of the plume and the meteorological conditions on the highest hour is presented in Appendix B.

The conservative nature of the buoyancy enhancement methodology employed for the interaction of the four gas turbines (i.e. conservation of buoyancy of all plumes at stack top); will ensure that this assessment defines the upper limit of any plume generated by the MEP under realistic meteorological conditions.

Table 4 Plume height above ground level for the Mariposa Energy Project gas turbines and the proportion of the simulation year that the threshold velocity of 9.6 mph is exceeded at that plume height

Percent of time (%)	Plume height (Feet above ground level)	
	Single Turbine	Four Merged Turbines
90	121	121
80	121	125
70	121	125
60	121	125
50	125	141
40	125	144
30	125	177
20	128	213
10	148	312
9	184	328
8	187	354
7	200	374
6	203	397
5	220	427
4	226	469
3	243	535
2	272	653
1	308	794
0.5	387	896
0.3	456	955
0.2	486	1033
0.1	522	1132
0.05	614	1220
Maximum	689	1309

Table 5 Plume height above ground level for the Mariposa Energy Project gas turbines and the proportion of the simulation year that the threshold velocity of 13.6 mph is exceeded at that plume height

Percent of time (%)	Plume height (Feet above ground level)	
	Single Turbine	Four Merged Turbines
90	115	135
80	135	135
70	135	135
60	135	135
50	135	135
40	135	135
30	135	138
20	138	161
10	141	210
9	141	213
8	161	233
7	161	240
6	164	259
5	164	259
4	164	272
3	167	292
2	187	338
1	203	400
0.5	217	476
0.3	236	509
0.2	249	531
0.1	262	564
0.05	292	640
Maximum	374	696

Table 6 Frequency of occurrence a threshold velocity of 9.6 mph is achieved versus height in feet for four merged gas turbine plumes

Height above ground level (feet)	Number of hours per annum	Percentage (%)	Cumulative number of hours per annum	Cumulative Percentage (%)
0 – 50	0	0.0	8760	100
>50 – 100	0	0.0	8760	100
>100 – 150	5373	61.3	8760	100
>150 – 200	1405	16.0	3387	39
>200 – 250	657	7.5	1982	23
>250 – 300	372	4.2	1325	15
>300 – 350	239	2.7	953	11
>350 – 400	196	2.2	714	8.1
>400 – 450	132	1.5	518	5.9
>450 – 500	78	0.9	386	4.4
>500 – 550	60	0.7	308	3.5
>550 – 600	43	0.5	248	2.8
>600 – 650	30	0.3	205	2.3
>650 – 700	43	0.5	175	2.0
>700 – 750	26	0.3	132	1.5
>750 – 800	20	0.2	106	1.2
>800 – 850	24	0.3	86	1.0
>850 – 900	22	0.3	62	0.73
>900 – 950	13	0.1	40	0.43
>950 – 1000	7	0.1	27	0.33
>1000 - 1050	3	0.03	20	0.23
>1050 – 1100	5	0.06	17	0.20
>1100 – 1150	4	0.05	12	0.14
>1150 – 1200	4	0.05	8	0.09
>1200 – 1250	2	0.02	4	0.04
>1250 – 1300	1	0.01	2	0.02
>1300	1	0.01	1	0.01

Table 7 **Predicted plume extent (plume radius + distance downwind in feet) for a single gas turbine and four merged gas turbines where the average vertical velocity exceeds the 9.6 mph threshold for various heights above ground level**

Height above ground level (ft)	Single Gas Turbine				Four Merged Gas Turbines			
	Min	Mean	0.1 percentile	Max	Min	Mean	0.1 percentile	Max
x <=100	NA	NA	NA	NA	NA	NA	NA	NA
100 < x <= 200	49	65	79	82	61	87	131	135
200 < x <= 300	72	83	101	101	100	138	177	177
300 < x <= 400	85	98	115	115	139	169	201	201
400 < x <= 500	79	105	125	125	141	189	221	221
500 < x <= 600	100	111	124	124	151	207	252	252
600 < x <= 700	96	114	138	138	154	206	253	253
700 < x <= 800	120	124	132	132	163	210	281	281
800 < x <= 900	NA	NA	NA	NA	166	231	313	313
900 < x <= 1000	NA	NA	NA	NA	166	231	313	313
1000 < x <= 1100	NA	NA	NA	NA	154	218	272	272
1100 < x <= 1200	NA	NA	NA	NA	191	234	312	312
1200 < x <= 1300	NA	NA	NA	NA	248	263	286	286
1300 < x <= 1400	NA	NA	NA	NA	232	232	232	232

Table 8 Predicted plume extent (plume radius + distance downwind in feet) for a single gas turbine and four merged gas turbines where the average vertical velocity exceeds the 13.6 mph threshold for various heights above ground level

Height above ground level (ft)	Single Gas Turbine				Four Merged Gas Turbines			
	Min	Mean	0.1 percentile	Max	Min	Mean	0.1 percentile	Max
x <=100	NA	NA	NA	NA	NA	NA	NA	NA
100 < x <= 200	33	41	46	47	37	54	73	75
200 < x <= 300	39	42	46	46	59	74	91	91
300 < x <= 400	43	44	46	46	67	87	100	100
400 < x <= 500	NA	NA	NA	NA	79	95	115	115
500 < x <= 600	NA	NA	NA	NA	85	96	112	112
600 < x <= 700	NA	NA	NA	NA	87	97	103	103

Table 9 Date and time where the threshold plume velocity of 9.6 mph exceeds a height of 950 feet above ground level

Year	Month	Day	Hour	Height above ground (Feet)	Maximum downwind distance (Feet)
2003	2	6	5	955	221
2003	1	1	23	981	313
2003	1	17	18	984	247
2003	11	23	6	984	184
2003	1	17	6	991	197
2003	9	21	7	991	168
2003	2	9	8	1007	194
2003	4	14	8	1027	260
2003	1	17	19	1033	272
2003	3	30	7	1060	200
2003	9	21	6	1063	154
2003	7	26	11	1079	200
2003	1	18	7	1089	196
2003	1	20	12	1089	265
2003	2	9	9	1102	194
2003	12	16	14	1109	312
2003	3	29	11	1129	296
2003	10	18	12	1132	224
2003	4	8	11	1161	235
2003	12	21	12	1178	218
2003	11	18	9	1194	191
2003	8	20	11	1198	199
2003	12	21	13	1220	255
2003	10	31	21	1230	248
2003	3	30	12	1253	287
2003	4	8	10	1309	232

8. Conclusions

An assessment of vertical plume velocities has been conducted in accordance with Australian Civil Aviation Safety Authority requirements for the Mariposa Energy Project power station. The outcomes of the assessment can be used to define the size of the plume around the Mariposa Energy Project power station.

The assessment has shown the following important characteristics:

- The average plume vertical velocities generated by the Mariposa Energy Project are unlikely to exceed the CASA threshold of 9.6 mph above a height of 1300 feet above ground level.

- The average plume vertical velocities generated by the Mariposa Energy Project are unlikely to exceed the threshold of light turbulence (13.6 mph) above a height of 700 feet above ground level.

- At the Flight Pattern Altitude of 950 feet above ground level the average plume vertical velocity is predicted to be above the threshold velocity of 9.6 mph for 26 hours of the year, and never above the vertical velocity of 13.6 mph, the upper limit of light turbulence.

- The average plume vertical velocities are likely to be below 9.6 mph under all meteorological conditions at a horizontal distance of approximately 300 feet from the Mariposa Energy Project power station stacks.

- The average plume vertical velocities are likely to be below 13.6 mph under all meteorological conditions at a horizontal distance of approximately 100 feet from the Mariposa Energy Project power station stacks.

- At no time will the cooling fans for the air cooled refrigeration condenser result in a plume exit velocity exceeding 9.6 mph.

- Assuming a worst case calm of zero mph, wind scenario the maximum height at which the average plume velocity is reduced to below the threshold velocity of 9.6 mph is 1841 feet and a velocity of 13.6 mph at 307 feet above ground level.

9. References

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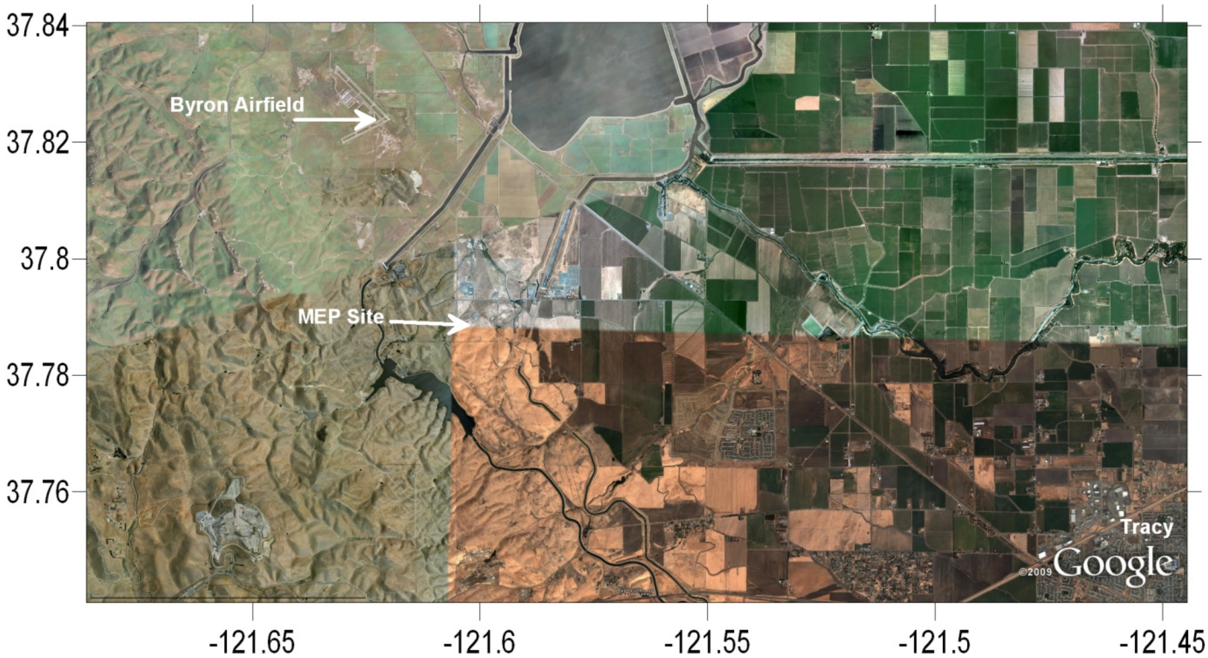


Figure 1 Location of the Mariposa Energy Project

Location: Tracy, California	**Data source:** Google Earth	**Units:** Latitude/Longitude
Type: Aerial map	**Prepared by:** A. Schloss	**Date:** April 2010

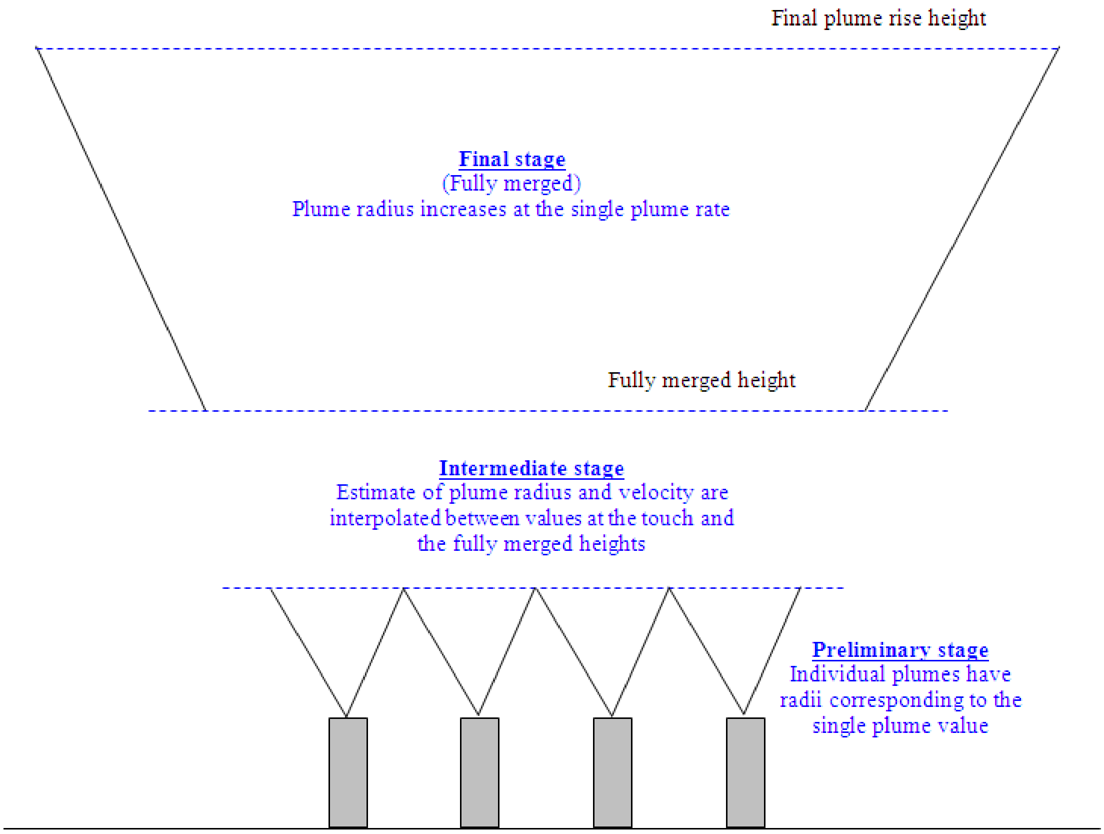


Figure 2 Description of the three phases of plume merging from multiple stacks

Location: MEP site	**Source:** Katestone	**Units:** Feet
Type: Diagram	**Prepared by:** A. Schloss	**Date:** April 2010

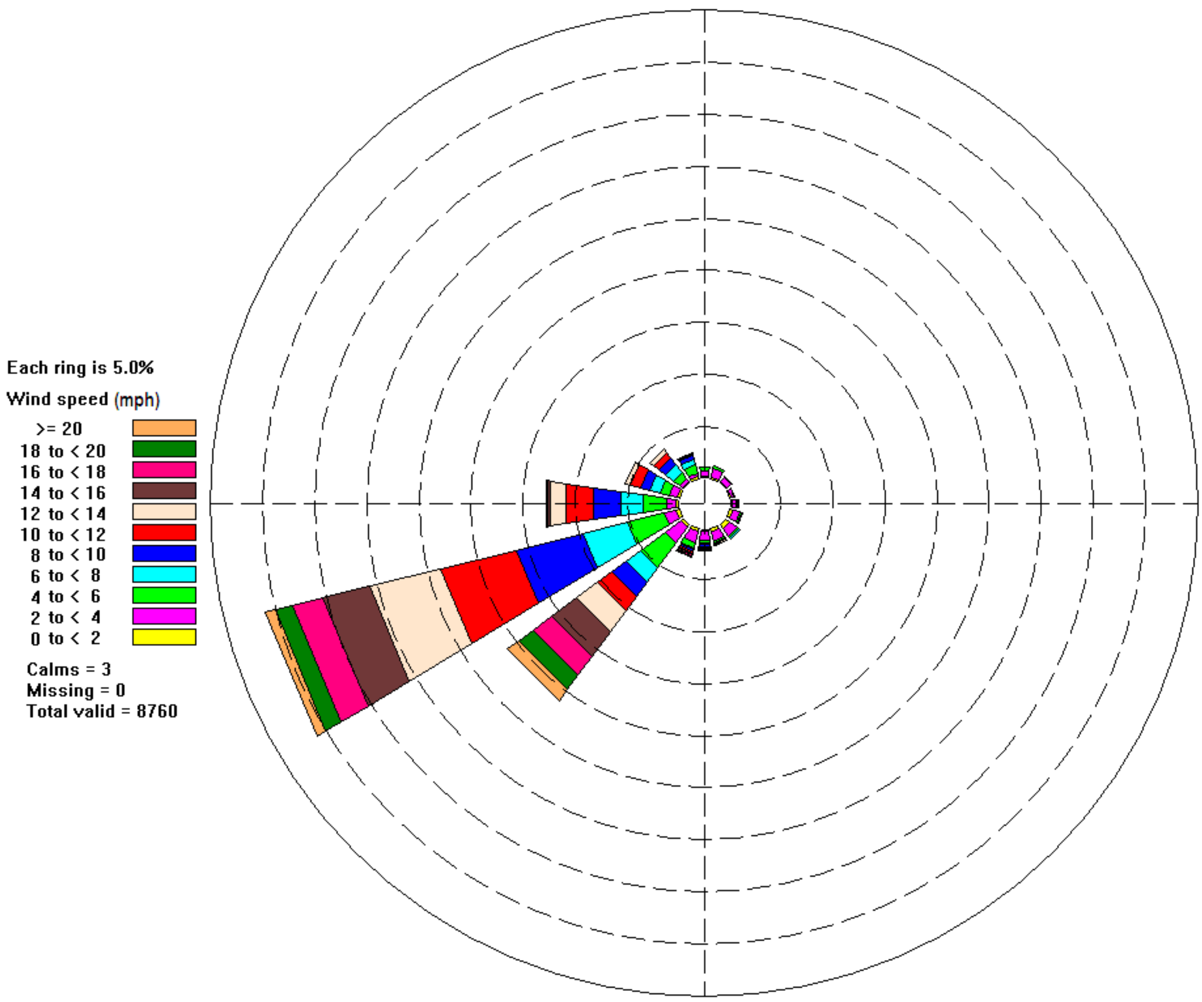


Figure 3 Annual wind rose as predicted by TAPM for the MEP site

Location: MEP Site	**Period:** Jan 2003 – Dec 2003	**Data source:** TAPM	**Units:** mph and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

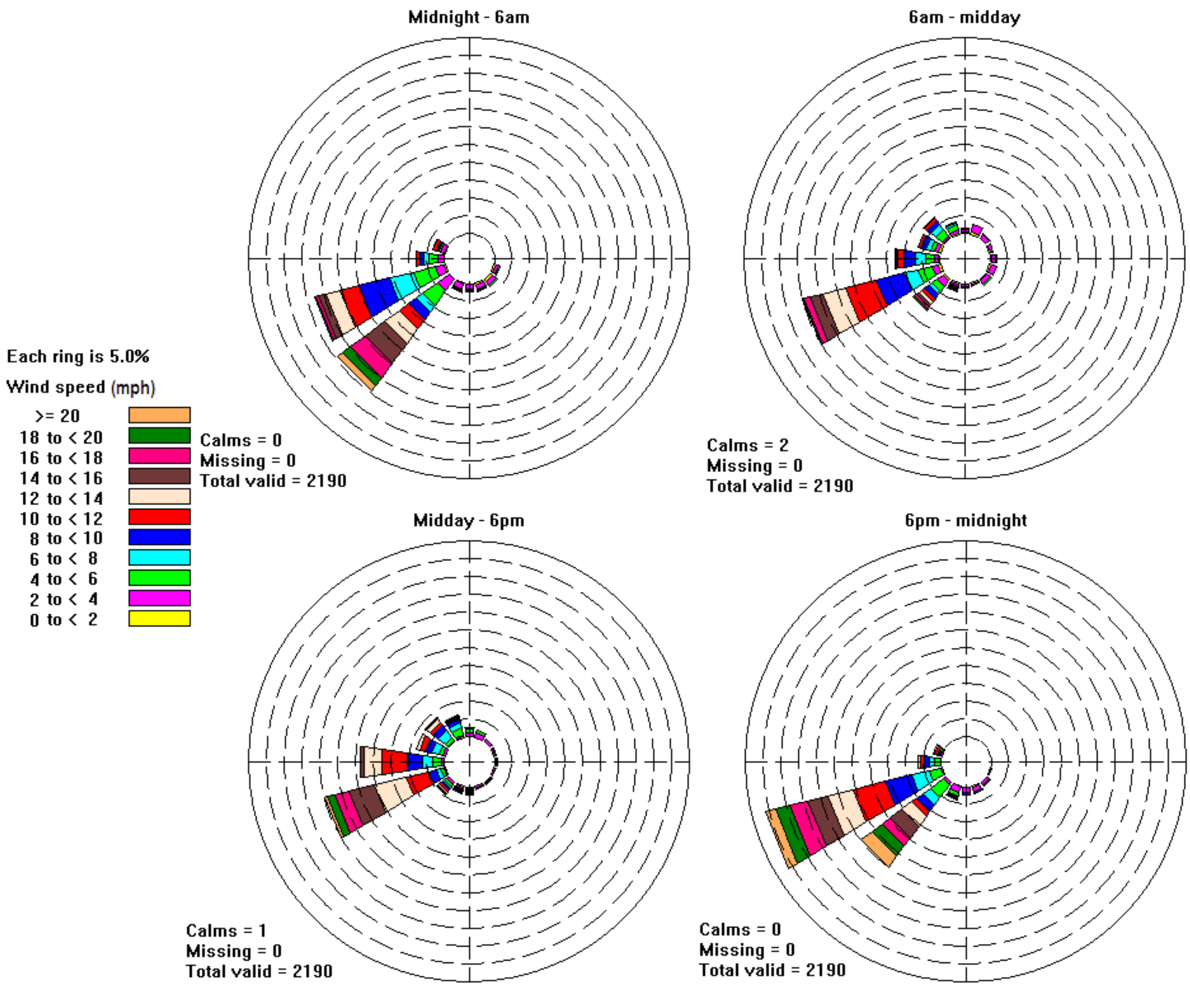


Figure 4 Daily wind roses as predicted by TAPM for the MEP site

Location: MEP Site	**Period:** Jan 2003 – Dec 2003	**Data source:** TAPM	**Units:** mph and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

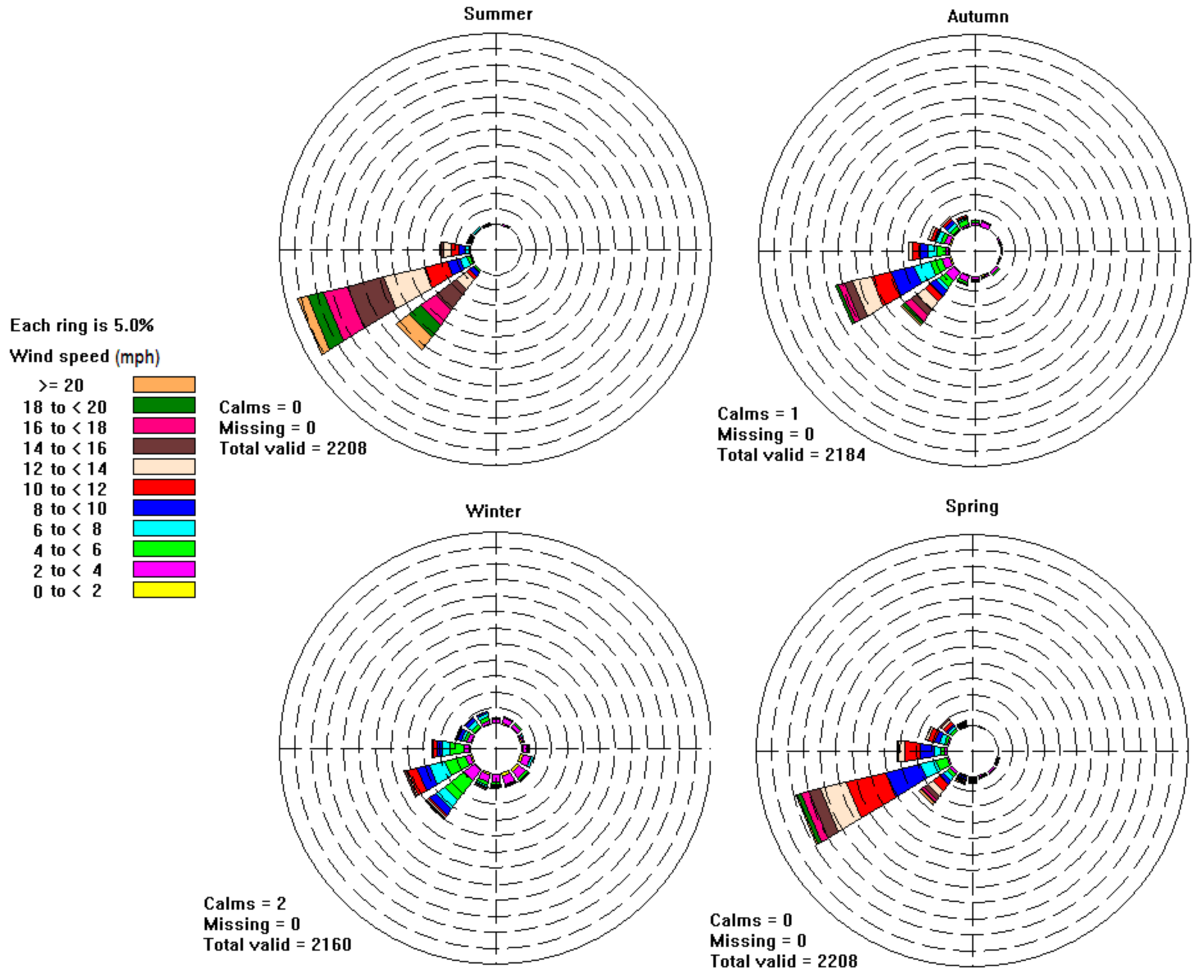


Figure 5 **Seasonal wind rose as predicted by TAPM for the MEP site**

Location: MEP Site	**Period:** Jan 2003 – Dec 2003	**Data source:** TAPM	**Units:** mph and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

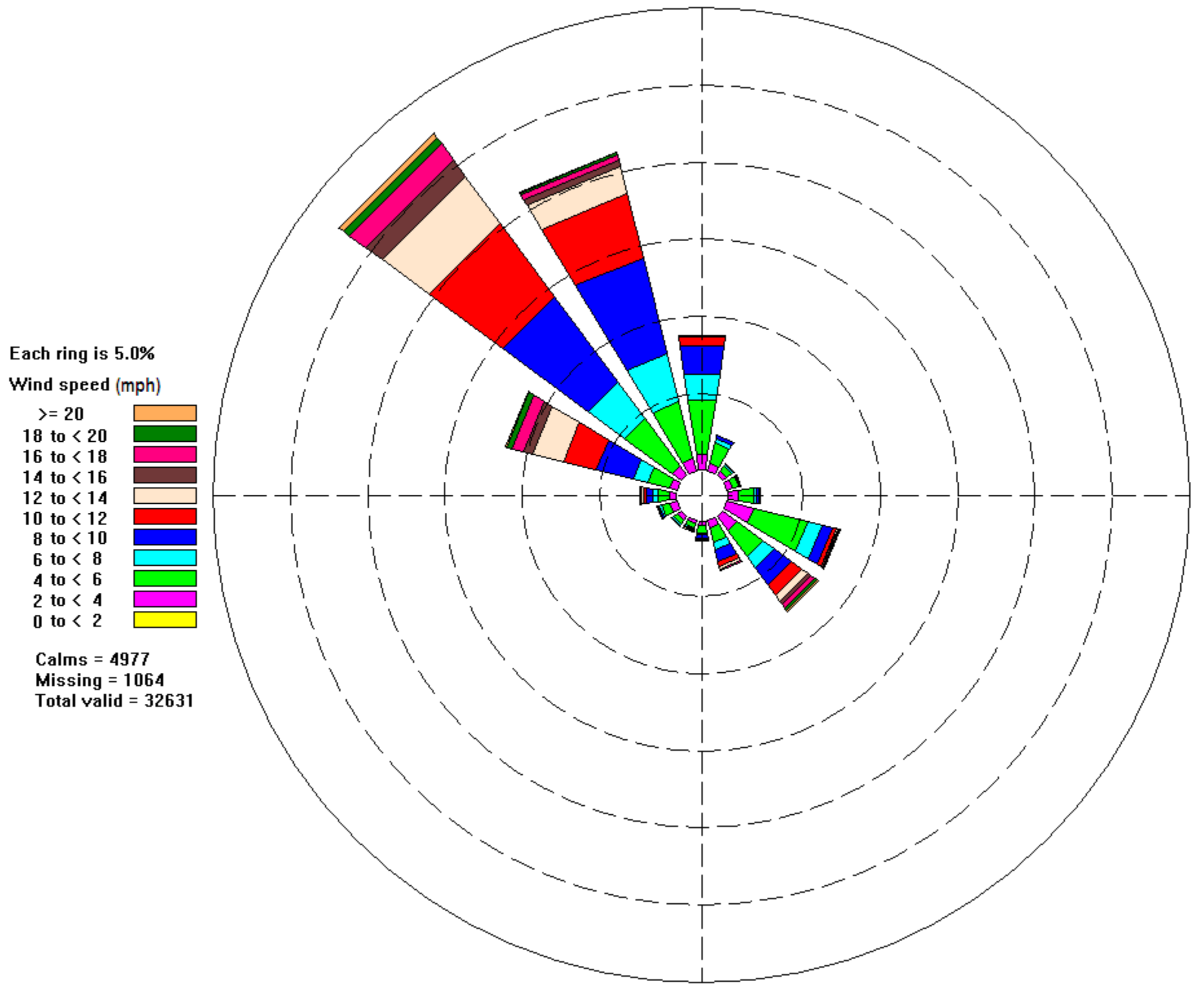


Figure 6 **Annual wind rose as observed for the Modesto monitoring station**

Location: Modesto	**Period:** Jan 2000 – Dec 2004	**Data source:** TAPM	**Units:** mph and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

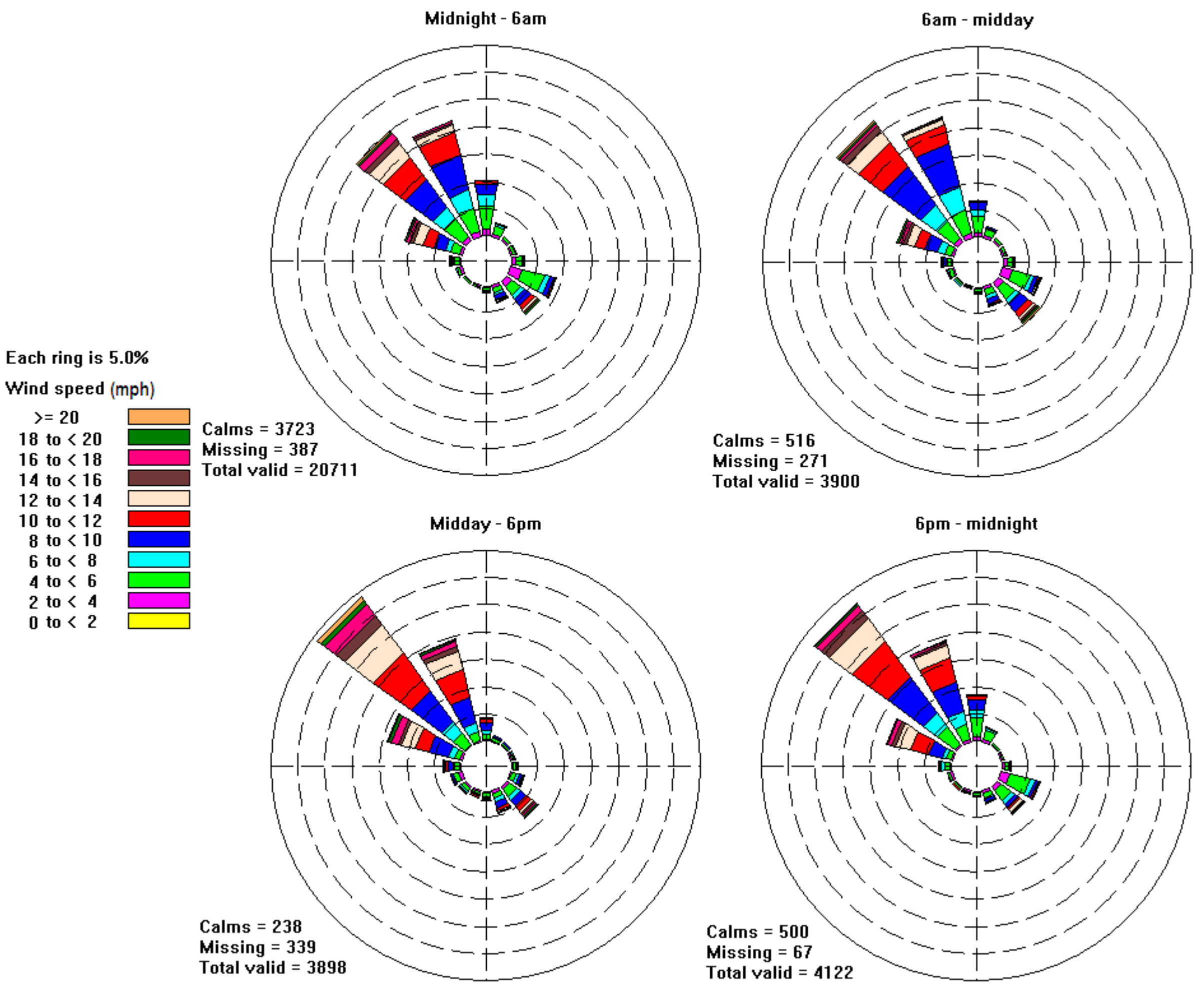


Figure 7 **Daily wind roses as observed for the Modesto monitoring station**

Location: Modesto	**Period:** Jan 2000 – Dec 2004	**Data source:** TAPM	**Units:** mph and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

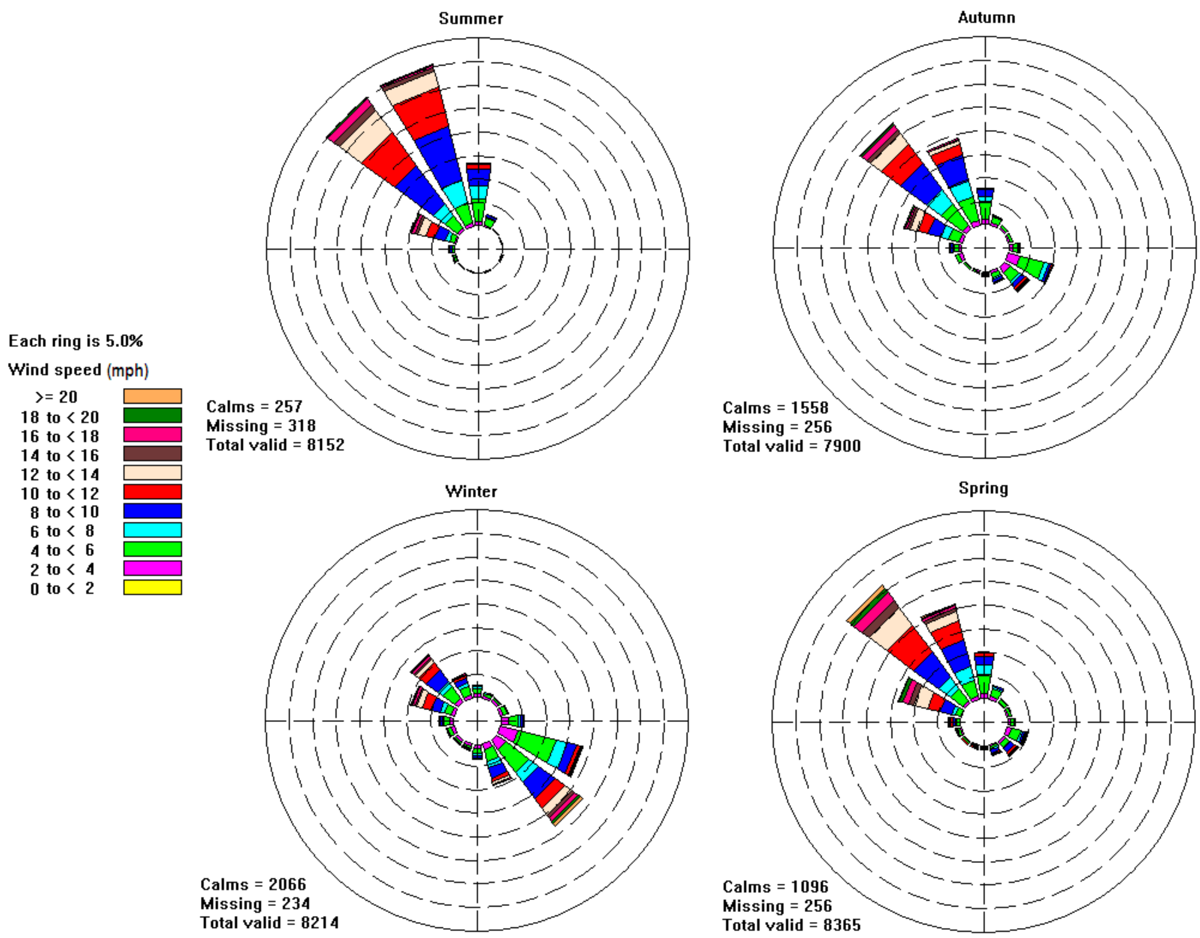


Figure 8	**Seasonal wind rose as observed for the Modesto monitoring station**		
Location: Modesto	**Period:** Jan 2000 – Dec 2004	**Data source:** TAPM	**Units:** mph and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

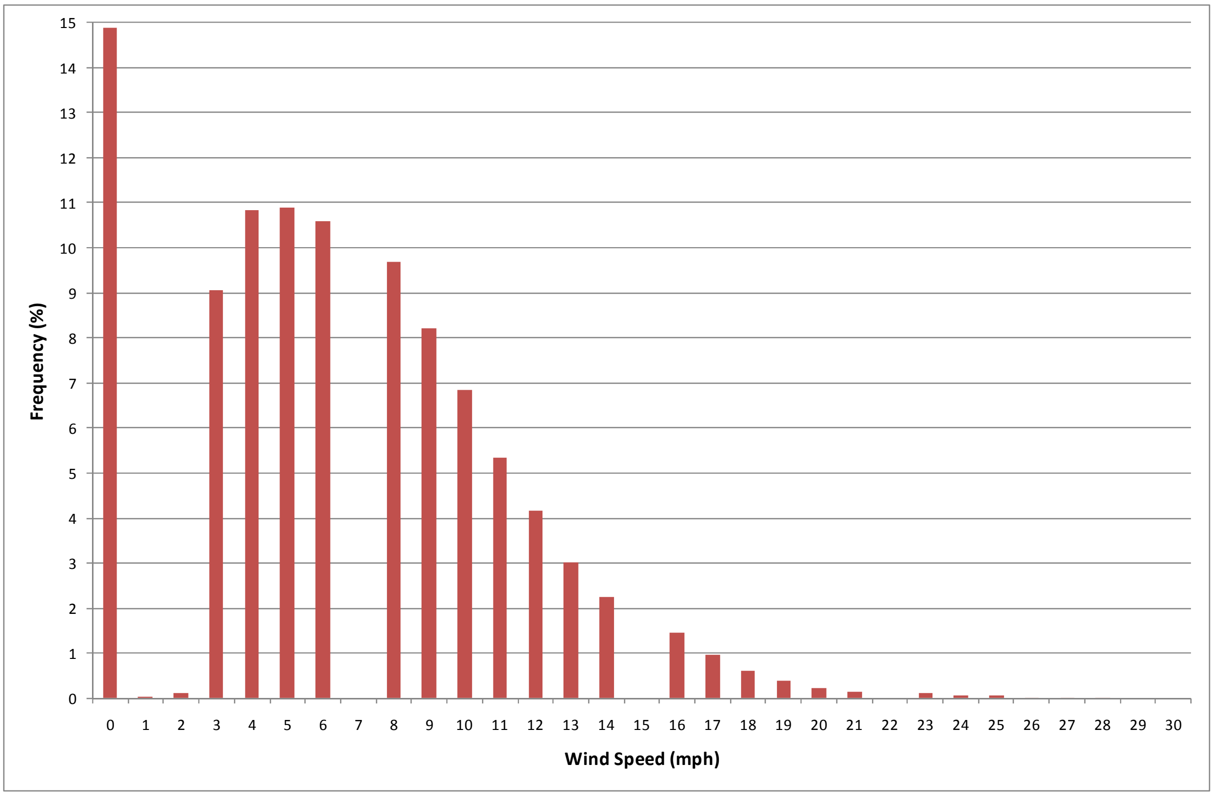


Figure 9	**Frequency Histogram of Modesto Observed Wind Speeds**	
Location: Modesto	**Data source:** 2000 – 2004 Monitoring data	**Units:** mph
Type: Histogram	**Prepared by:** A. Schloss	**Date:** April 2010

a)

b)

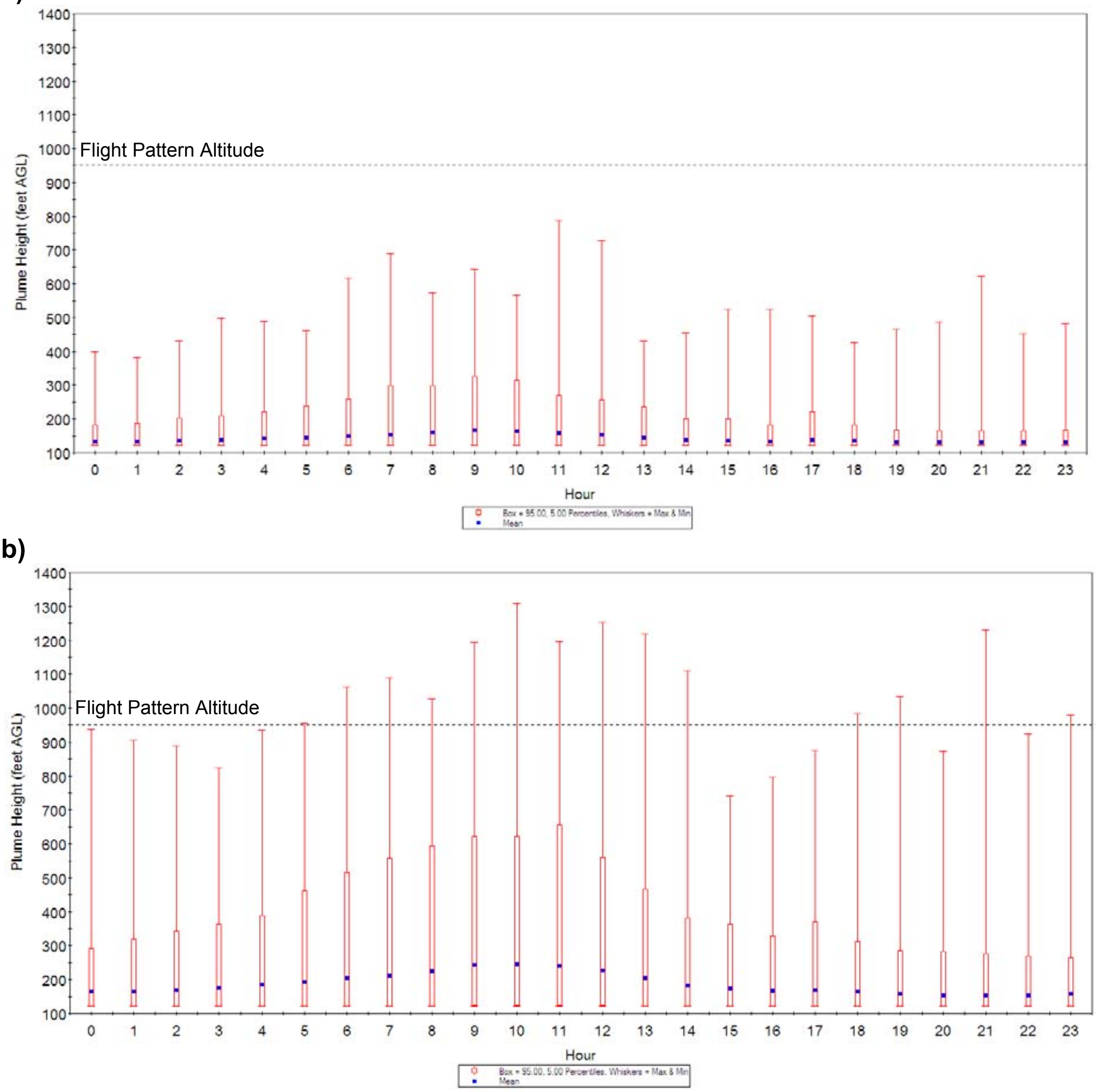
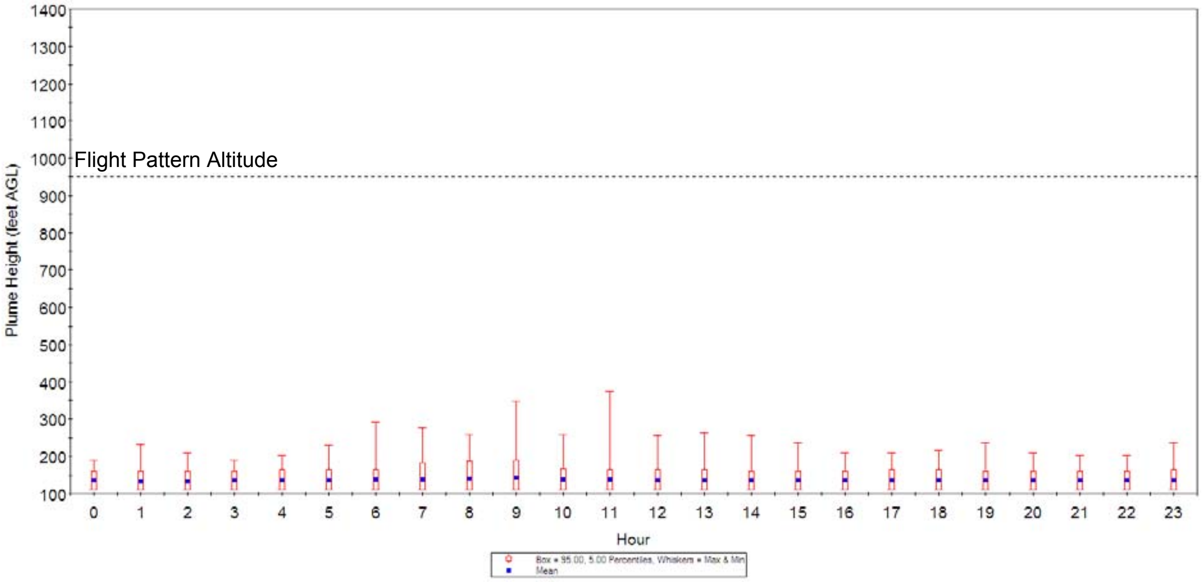


Figure 10 **Plume height versus hour of day for the Mariposa Energy Project gas turbines for a threshold velocity of 9.6 mph for a) single and b) merged plumes**

Source: Gas Turbines	**Threshold Velocity:** 9.6 mph	**Data source:** TAPM	**Units:** Feet above ground-level
Type: Box and Whiskers		**Prepared by:** A. Schloss	**Date:** April 2010

a)



b)

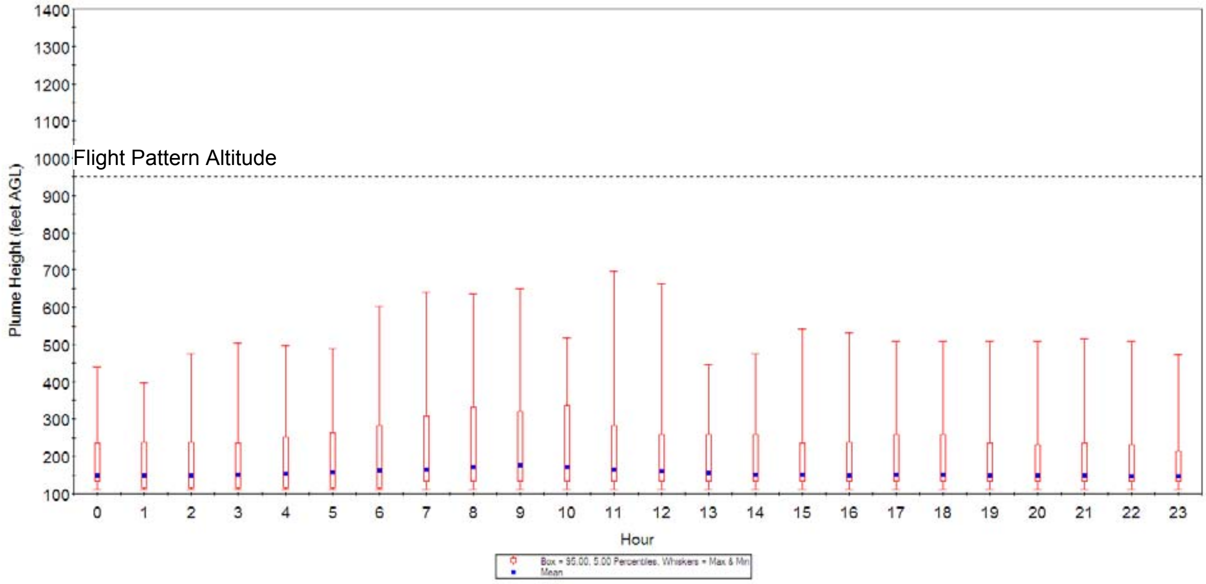


Figure 11 Plume height versus hour of day for the Mariposa Energy Project gas turbines for a threshold velocity of 13.6 mph presented for a) single and b) merged plumes

Source: Gas Turbines	**Threshold Velocity:** 13.6 mph	**Data source:** TAPM	**Units:** Feet above ground-level
Type: Box and Whiskers		**Prepared by:** A. Schloss	**Date:** April 2010

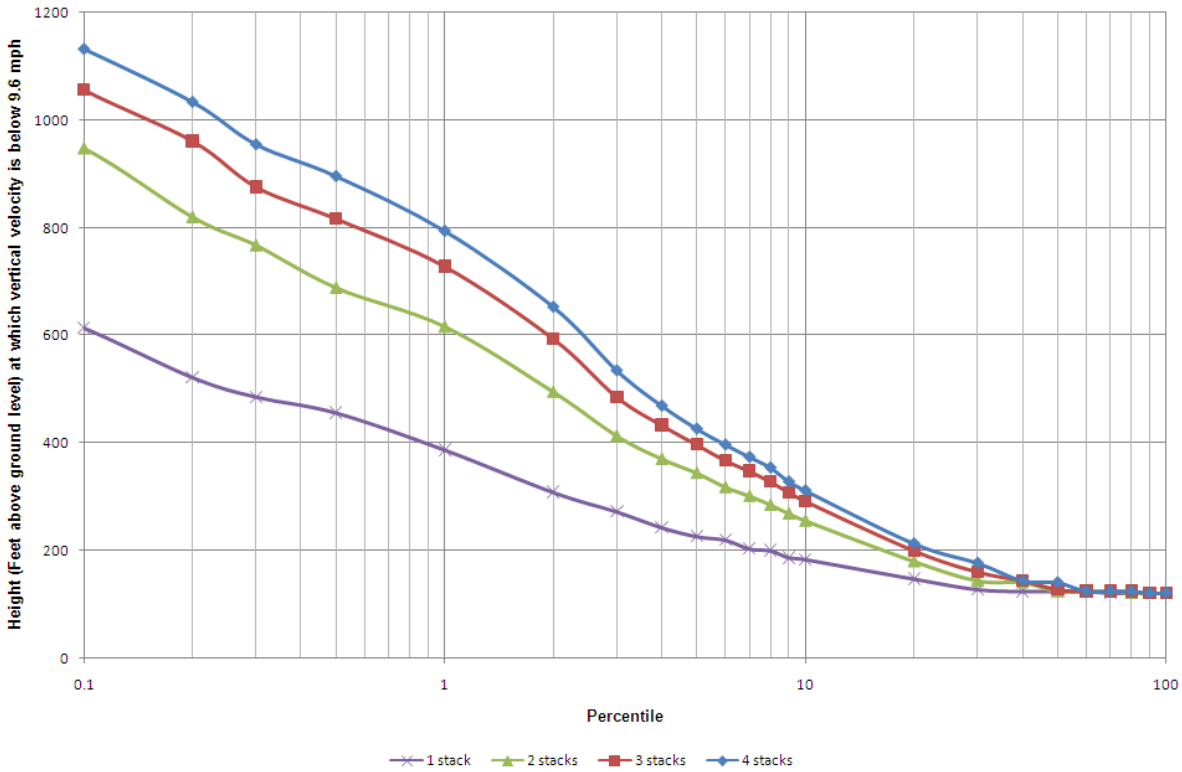


Figure 12	**Frequency distribution of plume height (feet) for multiple plumes with a threshold velocity of 9.6 mph**

Location: Mariposa	**Data source:** TAPM	**Units:** Feet
Type: Histogram	**Prepared by:** A. Schloss	**Date:** April 2010

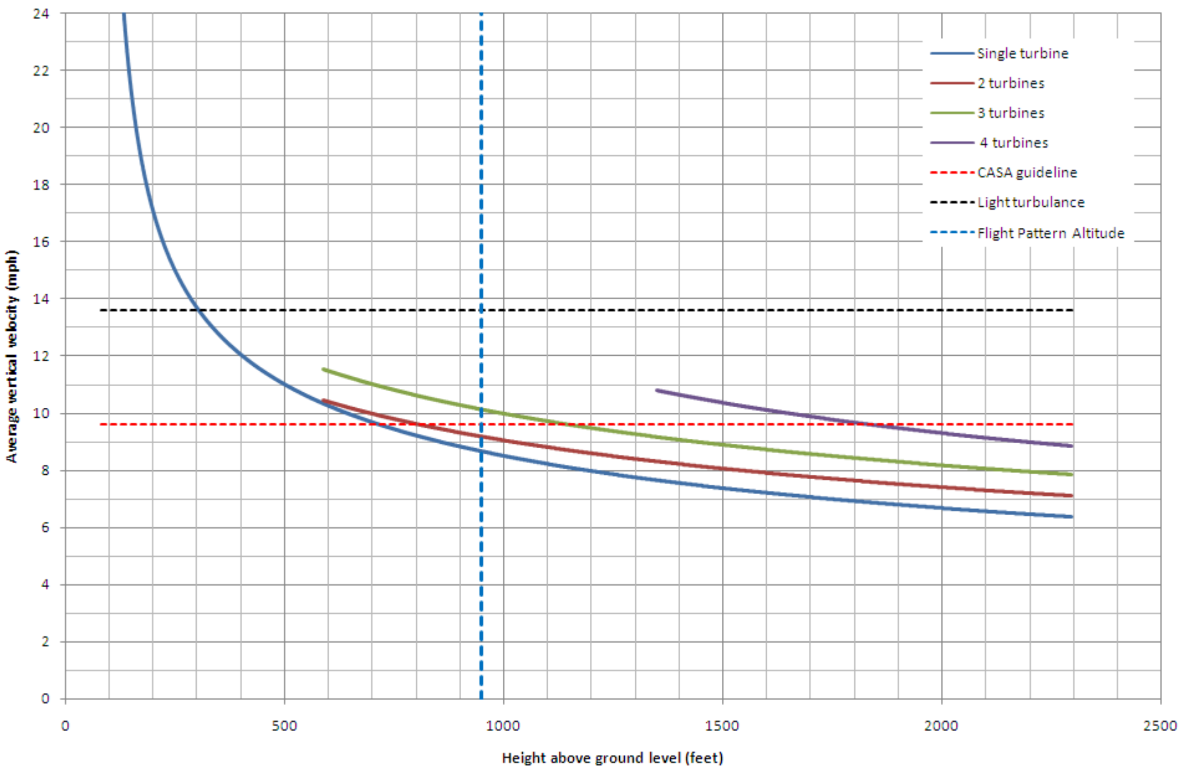


Figure 13 **Average vertical velocity as a function of height above ground level for the calm wind scenario**		
Location: Mariposa	**Data source:** Spillane Method	**Units:** Feet mph
Type: Chart	**Prepared by:** Christine Killip and A. Schloss	**Date:** April 2010

Appendix A
TAPM

Contents

Figures

A1 Methodology

The prognostic meteorological model, TAPM (The Air Pollution Model) Version 4.0.2, was developed by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and has been validated by the CSIRO, Katestone Environmental and others for many locations in Australia, in southeast Asia and in North America (see http://www.csiro.au/products/TAPM.html for more details on the model and validation results from the CSIRO). Katestone Environmental has used the TAPM model throughout Australia as well as in parts of New Caledonia, Bangladesh, Vietnam and California. This model generally has performed well for simulating winds in a region. TAPM has proven to be a useful model for simulating meteorology in locations where detailed monitoring data is unavailable.

TAPM is a prognostic meteorological model which predicts the flows important to regional and local scale meteorology, such as sea breezes and terrain-induced flows from the larger-scale meteorology provided by the synoptic analyses. TAPM solves the fundamental fluid dynamics equations to predict meteorology at a mesoscale (20 kilometres to 200 kilometres) and at a local scale (down to a few hundred meters). TAPM includes parameterizations of cloud/rain micro-physical processes, urban/vegetation canopy and soil, and radiative fluxes.

TAPM requires synoptic meteorological information for the study region as input into the model. This information is generated by a global model similar to the large scale models used to forecast the weather. This assessment used the National Center for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) reanalysis data (Kalnay et al., 1996) on horizontal wind components, temperature and moisture, to obtain the required synoptic fields for the model. These data have a horizontal resolution of 2.5º and a temporal resolution of six hours, while the vertical levels are in a pressure coordinate system with the lowest five levels being 1000, 925, 850, 700 and 600 hPa. TAPM uses this synoptic information, along with specific details of the location such as surrounding terrain, land use, soil moisture content and soil type to simulate the likely meteorology of a region as well as at a specific location.

TAPM was setup as follows:

- 35 x 35 grid point domain with an mother grid of 30 kilometres and nested daughter grids of 10 kilometres, 3 kilometres and 1 kilometre
- 25 vertical levels
- Grid centered latitude 37° 47', longitude -121°-36'
- The TAPM defaults for sea surface temperature
- Default options selected for advanced meteorological inputs
- Default vegetation information
- The synoptic data used in the simulation is for the year 2003
- Sources were modelled in Lagrangian mode

The year 2003 was selected from a five year period (2000 – 2004) of available data from the Modesto monitoring station. This year had the highest data capture rate, and a large number of light winds.

The TAPM land-use at a 1 kilometre resolution was mainly defined as low sparse shrub land and mid-dense seasonal pasture. Small regions of urban characterised land use also existed. The soils were predominantly defined as sandy clay loam within the domain.

A2 Verification of winds

To determine the suitability of the meteorological data generated by TAPM, an evaluation of the predicted and measured winds was conducted for the meteorological station located at Modesto. This site was sourced as the nearest meteorological monitoring station location to the Mariposa Energy Project and used as an evaluation of TAPM model in simulating regional meteorological conditions.

The Modesto monitoring station is located approximately 37 miles east-southeast of the MEP site in an industrial area of the city. This suggests that it may not be representative of meteorological conditions at the Mariposa Energy Project. Wind roses are presented in Figure 6 to Figure 8 for the MEP site. Moderate to strong winds are typical from the north westerly direction.

Wind roses are presented in Figure A1 to Figure A3 that compare the measured and predicted wind speeds and wind directions at Modesto, with the observed monitoring data not assimilated into the model. Figure A4 presents a histogram of wind speeds at Modesto for observed and modelled data.

Statistical correlation has been performed between the TAPM predicted and the measured wind speed and direction at the Modesto monitoring location. A vector correlation between the predicted and measured winds indicates a (magnitude, phase) of (0.711, -13.44). This is reasonably well correlated, suggesting that TAPM is appropriately simulating regional flows for the modelled period.

The wind roses and histogram also suggest that TAPM simulates the regional winds quite well at the Modesto monitoring site. The TAPM predictions at 25 metres height above ground are correlated more closely with the observed Modesto meteorology than the 10 metre level, which would be more subject to surface interference. It can be observed from the wind roses that the general wind pattern at Modesto is quite different to that at the MEP site, suggesting the appropriateness of developing a site specific meteorological dataset with TAPM for this assessment.

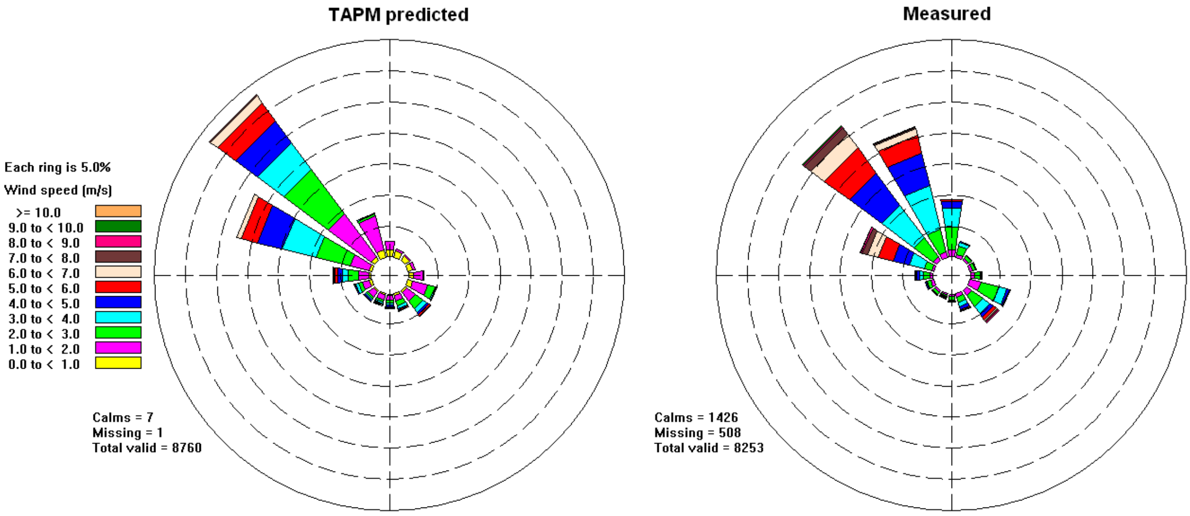
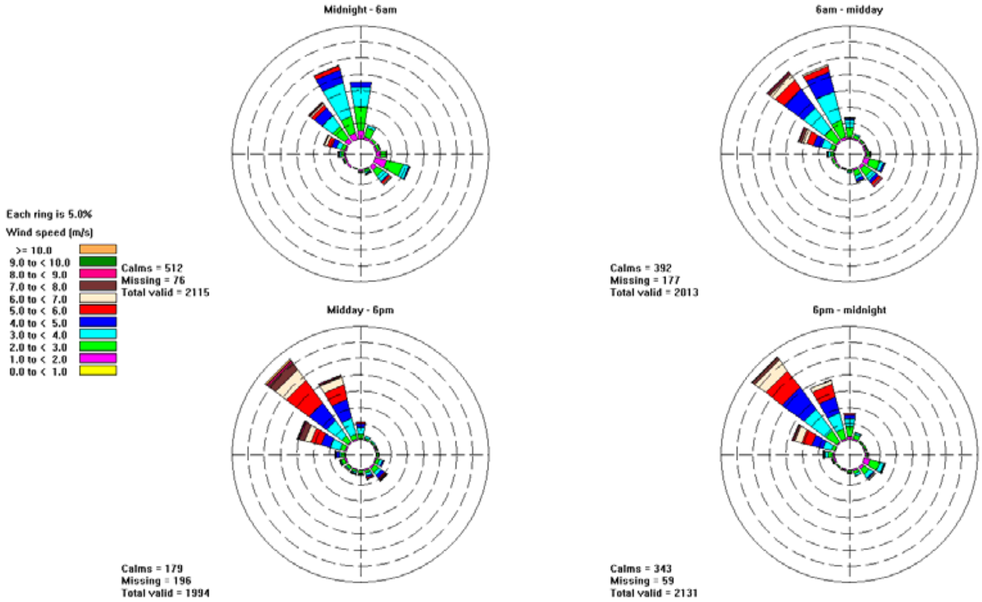


Figure A1 **Wind roses for all hours (i) Measured and (ii) TAPM at the Modesto monitoring location**

Location: Modesto monitoring site	**Period:** Jan 2003 – Dec 2003	**Data source:** TAPM	**Units:** m/s and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

(i) **Measured**



(ii) **TAPM**

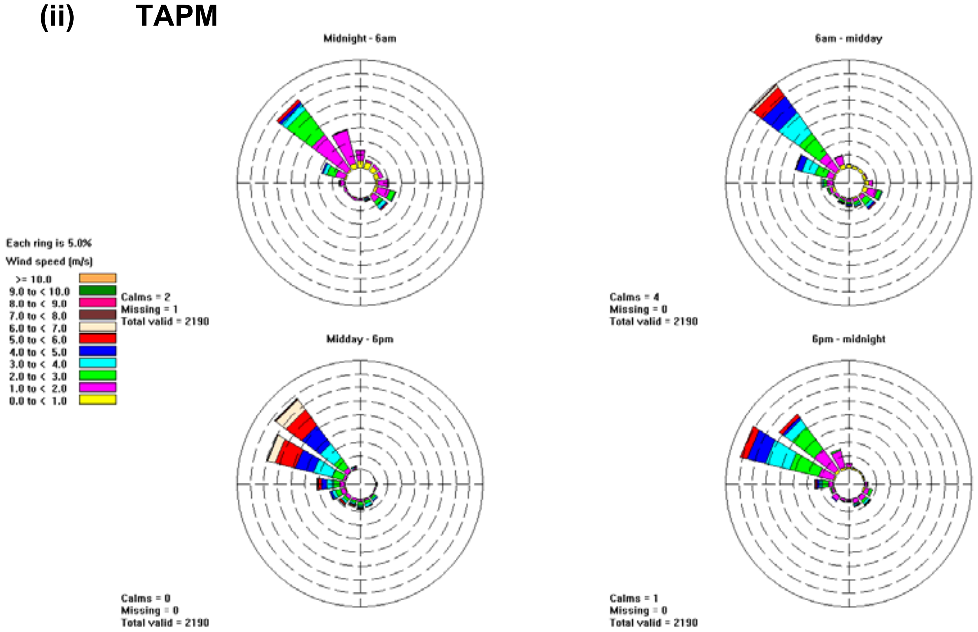
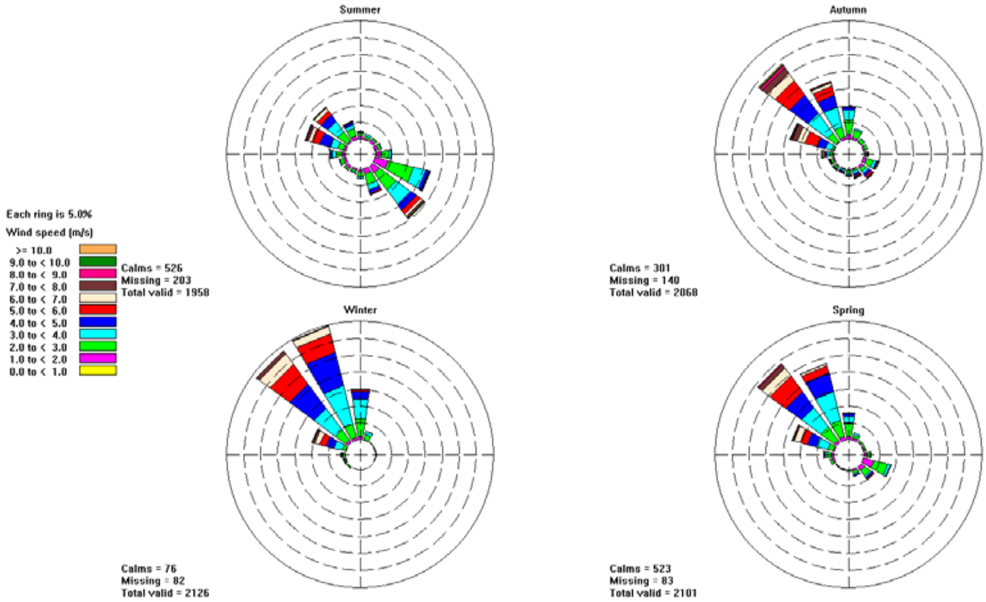


Figure A2 Diurnal wind roses for (i) Measured and (ii) TAPM at the Modesto monitoring location

Location: Modesto monitoring site	**Period:** Jan 2003 – Dec 2003	**Data source:** TAPM	**Units:** m/s and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

(i) **Measured**



(ii) **TAPM**

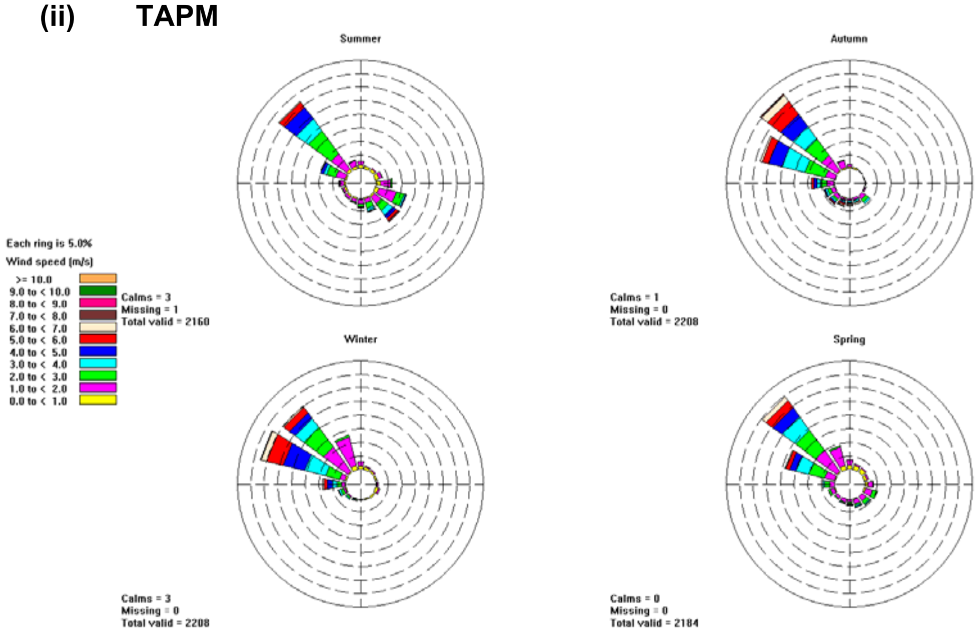


Figure A3 Seasonal wind roses for (i) Measured and (ii) TAPM at the Modesto monitoring location

Location: Modesto monitoring site	**Period:** Jan 2003 – Dec 2003	**Data source:** TAPM	**Units:** m/s and °
Type: Wind rose		**Prepared by:** A. Schloss	**Date:** April 2010

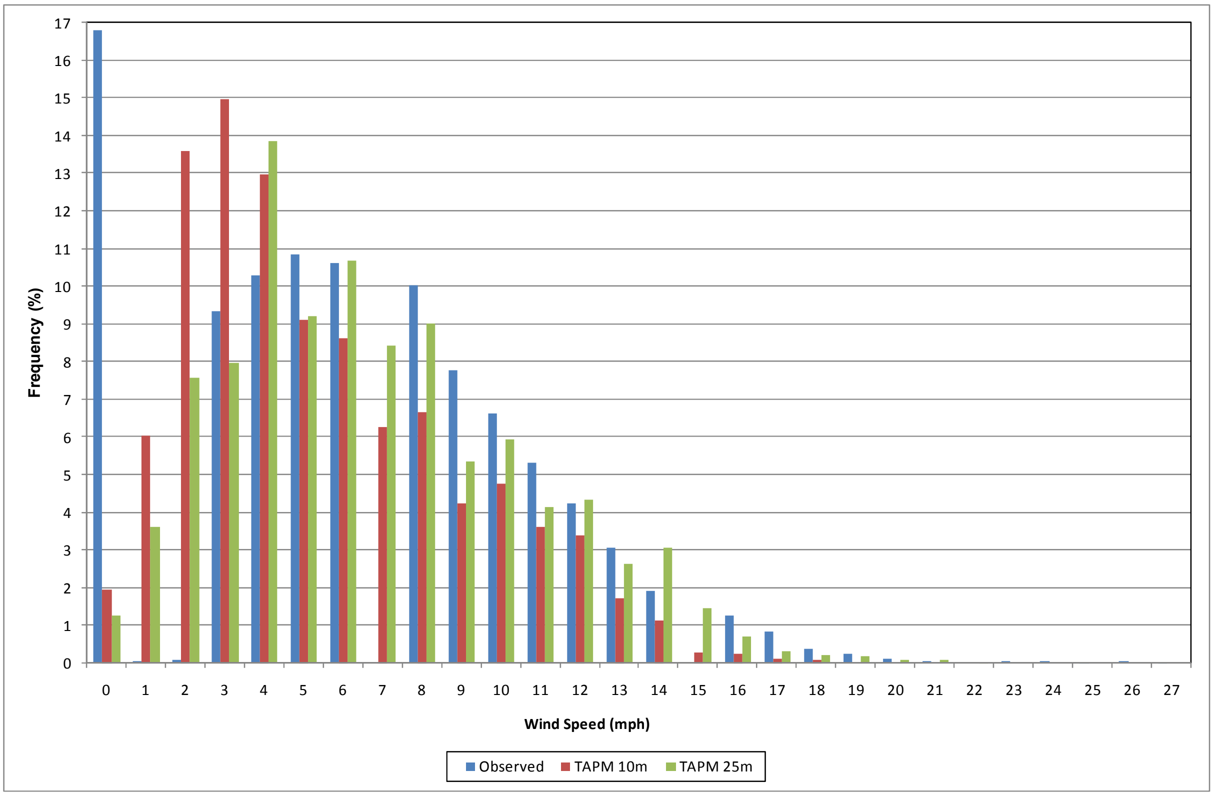


Figure A4	**Frequency Histogram of Modesto TAPM wind speeds versus Modesto Observed Wind Speeds**	
Location: Modesto	**Data source:** TAPM	**Units:** mph
Type: Histogram	**Prepared by:** A. Schloss	**Date:** April 2010

Appendix B

DETAILED PLUME CHARACTERISTICS

Contents

Tables

Figures

B1 Detailed plume information

This section describes in further detail the results presented in the main report in addition to identifying the meteorological conditions for the 26 hours in which the threshold vertical velocity of 9.6 mph for four merged turbines exceeded the FPA of 950 feet above ground level.

The information presented in the box and whisker plots in Figure 10 and Figure 11 of the main report body is detailed in Table B1 to Table B4 . These tables present the statistics for the threshold plume height in feet above ground level as a function of time of day for a single and merged gas turbine plumes with threshold velocities of 9.6 mph and 13.6 mph.

Table B5 to Table B7 present the ambient wind speed, wind direction and ambient temperature for the 26 hours in which the threshold vertical velocity of 9.6 mph for four merged turbines exceeded the FPA of 950 feet above ground level.

Figure B1 to Figure B4 present the vertical profiles of relative humidity (percent), ambient temperature (degrees Fahrenheit), ambient wind velocity (feet per second) and wind direction (degrees) respectively for the hour when TAPM predicts the highest plume height (8-April-2003 10:00 am). The vertical profiles are presented to the height at which the plume achieves the threshold vertical velocity of 9.6 mph.

Figure B5 presents the plume temperature as a function of height above ground, for the hour when the maximum threshold plume height occurs.

Figure B6 presents plume oxygen content as a function of height. Oxygen content is predicted to be 20.97% at the maximum threshold plume height of 1309 feet. This oxygen content is essentially the same as average ambient atmospheric concentration of 21%.

Figure B7 presents the average plume vertical velocity as a function of height for the hour when the maximum plume height of 1309 feet occurs with a threshold vertical velocity of 9.6 mph.

Table B8 presents the temperature range of the plume at the maximum threshold plume height of 1309 feet occurs with a threshold vertical velocity of 9.6 mph.

Table B1 Statistics for the threshold plume height (feet above ground level) as a function of time of day for a single gas turbine plume (9.6 mph velocity threshold)

Hour	Minimum	5th Percentile	Mean	Median	95th Percentile	Maximum
0	121	121	133	125	184	400
1	121	121	134	125	187	381
2	121	121	136	125	203	430
3	121	121	139	125	210	499
4	121	121	141	125	220	489
5	121	121	146	125	239	463
6	121	121	150	125	259	617
7	121	121	155	125	299	689
8	121	121	161	128	299	574
9	121	121	167	128	325	643
10	121	121	164	128	315	567
11	121	121	158	128	269	787
12	121	121	153	125	256	728
13	121	121	146	125	236	430
14	121	121	139	125	200	456
15	121	121	136	125	200	525
16	121	121	134	125	184	525
17	121	121	137	125	220	505
18	121	121	135	125	184	426
19	121	121	131	125	167	466
20	121	121	130	125	164	485
21	121	121	131	121	164	623
22	121	121	131	125	164	453
23	121	121	131	125	167	482

Table B2 Statistics for the threshold plume height (feet above ground level) as a function of time of day for four merged gas turbine plumes (9.6 mph velocity threshold)

Hour	Minimum	5th Percentile	Mean	Median	95th Percentile	Maximum
0	121	121	164	125	292	938
1	121	121	166	128	318	905
2	121	121	170	128	344	889
3	121	121	176	141	364	823
4	121	121	184	141	387	935
5	121	121	194	141	463	955
6	121	121	205	144	515	1063
7	121	121	212	144	558	1089
8	121	121	226	161	594	1027
9	121	125	242	161	623	1194
10	121	125	246	161	623	1309
11	121	125	242	161	656	1197
12	121	125	228	144	561	1253
13	121	121	205	144	466	1220
14	121	121	183	141	381	1109
15	121	121	173	141	364	741
16	121	121	167	128	328	797
17	121	121	169	125	371	876
18	121	121	164	125	312	984
19	121	121	159	125	285	1033
20	121	121	154	125	282	873
21	121	121	153	125	276	1230
22	121	121	153	125	269	925
23	121	121	158	125	266	981

Table B3 Statistics for the threshold plume height (feet above ground level) as a function of time of day for a single gas turbine plume (13.6 mph velocity threshold)

Hour	Minimum	5th Percentile	Mean	Median	95th Percentile	Maximum
0	112	112	135	134	161	190
1	112	112	134	134	161	233
2	112	112	135	134	161	210
3	112	112	135	134	161	190
4	112	112	135	134	164	203
5	112	112	136	134	164	230
6	112	112	138	134	164	292
7	112	112	138	134	184	276
8	112	112	140	134	187	259
9	112	112	142	134	190	348
10	112	112	139	134	167	259
11	112	112	137	134	164	374
12	112	112	137	134	164	256
13	112	112	136	134	164	262
14	112	112	135	134	161	256
15	112	112	135	134	161	236
16	112	112	135	134	161	210
17	112	112	136	134	164	210
18	112	112	136	134	164	216
19	112	112	136	134	161	236
20	112	112	135	134	161	210
21	112	112	135	134	161	203
22	112	112	135	134	161	203
23	112	112	135	134	164	236

Table B4 Statistics for the threshold plume height (feet above ground level) as a function of time of day for four merged gas turbine plumes (13.6 mph velocity threshold)

Hour	Minimum	5th Percentile	Mean	Median	95th Percentile	Maximum
0	112	134	149	134	236	440
1	112	115	148	134	239	397
2	112	115	149	134	239	476
3	112	115	152	134	236	505
4	112	115	154	134	253	499
5	112	115	158	134	262	489
6	112	115	162	134	282	604
7	112	134	166	134	308	640
8	112	134	171	134	331	636
9	112	134	175	138	321	649
10	112	134	172	138	338	518
11	112	134	164	134	282	695
12	112	134	161	134	259	663
13	112	134	157	134	259	446
14	112	134	151	134	259	476
15	112	134	151	134	236	541
16	112	134	150	134	239	531
17	112	134	152	134	259	508
18	112	134	152	134	259	508
19	112	134	149	134	236	508
20	112	134	148	134	233	508
21	112	134	148	134	236	515
22	112	134	148	134	233	508
23	112	134	147	134	213	472

Table B5 Ambient wind speeds (mph) for the 26 hours in which the threshold velocity of 9.6 mph for four merged turbines exceeds a height of 950 feet above ground level

Date Time	Plume Height (feet AGL)	Feet Above Ground Level								
		33	82	164	328	492	656	820	984	1312
8/04/2003 10:00	1309	0.7	0.7	0.7	0.4	0.2	0.0	0.2	0.7	1.6
30/03/2003 12:00	1253	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.6
31/10/2003 21:00	1230	3.1	3.1	1.8	0.2	0.2	0.4	0.7	1.1	1.8
21/12/2003 13:00	1220	1.6	1.6	1.6	1.3	1.1	0.9	0.9	1.1	1.8
20/08/2003 11:00	1198	1.3	1.3	1.3	1.1	0.9	0.7	0.4	0.7	1.1
18/11/2003 9:00	1194	1.3	1.3	1.1	0.7	0.2	0.2	0.7	1.1	1.8
21/12/2003 12:00	1178	1.8	1.8	1.6	1.1	0.7	0.2	0.2	0.7	1.8
8/04/2003 11:00	1161	0.9	0.9	1.1	1.1	1.3	1.6	1.8	2.0	2.7
18/10/2003 12:00	1132	0.0	0.0	0.0	0.2	0.4	0.9	1.1	1.6	2.5
29/03/2003 11:00	1129	1.1	1.1	1.1	0.7	0.4	0.4	0.7	1.1	2.0
16/12/2003 14:00	1109	2.7	2.9	2.7	2.5	1.8	1.3	0.7	0.4	2.5
9/02/2003 9:00	1102	2.7	2.7	2.5	1.3	0.4	0.9	0.7	0.4	1.3
18/01/2003 7:00	1089	2.2	1.8	0.4	0.7	0.9	0.9	0.9	1.1	1.3
20/01/2003 12:00	1089	1.1	1.1	1.1	0.4	0.0	0.4	1.1	2.0	3.6
26/07/2003 11:00	1079	1.1	1.1	1.1	1.1	0.9	0.9	1.1	1.1	1.8
21/09/2003 6:00	1063	1.8	1.3	0.2	0.2	0.2	0.2	0.4	0.7	0.9
30/03/2003 7:00	1060	0.4	0.2	0.4	0.7	0.9	1.1	1.1	1.1	0.9
17/01/2003 19:00	1033	4.9	6.0	4.3	1.8	0.7	0.7	0.9	1.6	2.5
14/04/2003 8:00	1027	0.9	0.9	1.1	1.1	1.3	1.3	1.6	1.6	1.8
9/02/2003 8:00	1007	1.3	1.1	0.7	0.7	0.7	1.1	1.1	1.6	2.0
17/01/2003 6:00	991	2.2	1.3	0.7	1.3	1.6	1.6	1.3	1.3	2.5
21/09/2003 7:00	991	1.1	0.9	0.4	0.2	0.0	0.2	0.7	1.1	1.6
17/01/2003 18:00	984	4.5	4.5	2.7	0.4	0.4	0.4	0.0	0.4	1.3
23/11/2003 6:00	984	3.8	2.2	0.4	0.7	0.4	0.4	1.6	2.7	4.3
1/01/2003 23:00	981	4.5	6.9	5.1	2.7	0.4	0.2	0.2	0.7	2.5
6/02/2003 5:00	955	1.8	1.6	1.1	1.3	1.1	0.7	0.0	0.2	1.1

Table B6 Ambient wind direction (°) for the 26 hours in which the threshold velocity of 9.6 mph for four merged turbines exceeds a height of 950 feet above ground level

Date Time	Plume Height (feet AGL)	Feet Above Ground Level								
		33	82	164	328	492	656	820	984	1312
8/04/2003 10:00	1309	30	29	30	27	20	256	221	216	212
30/03/2003 12:00	1253	342	342	340	332	321	307	294	280	262
31/10/2003 21:00	1230	232	234	235	242	355	346	334	330	333
21/12/2003 13:00	1220	356	355	352	344	330	309	286	265	238
20/08/2003 11:00	1198	53	54	55	60	67	82	107	138	172
18/11/2003 9:00	1194	62	67	69	69	87	156	160	149	120
21/12/2003 12:00	1178	30	29	28	26	21	4	261	224	202
8/04/2003 11:00	1161	236	235	234	229	225	221	218	215	210
18/10/2003 12:00	1132	54	57	135	207	208	209	208	208	207
29/03/2003 11:00	1129	20	20	18	8	344	306	273	258	244
16/12/2003 14:00	1109	37	37	36	35	32	27	12	290	227
9/02/2003 9:00	1102	54	55	58	71	138	190	185	187	47
18/01/2003 7:00	1089	221	218	172	108	105	121	125	135	122
20/01/2003 12:00	1089	37	37	36	29	327	243	233	229	225
26/07/2003 11:00	1079	338	337	334	324	309	290	272	257	237
21/09/2003 6:00	1063	234	239	329	33	62	145	175	188	182
30/03/2003 7:00	1060	79	137	155	162	155	168	172	180	164
17/01/2003 19:00	1033	221	219	216	205	158	150	166	171	165
14/04/2003 8:00	1027	225	225	225	226	228	228	230	230	232
9/02/2003 8:00	1007	88	102	129	219	267	277	298	298	353
17/01/2003 6:00	991	224	210	114	101	105	105	94	80	47
21/09/2003 7:00	991	246	252	303	327	315	189	187	188	182
17/01/2003 18:00	984	223	223	225	256	11	16	57	164	151
23/11/2003 6:00	984	217	209	146	65	72	180	200	204	206
1/01/2003 23:00	981	224	226	229	231	224	98	126	191	203
6/02/2003 5:00	955	245	266	331	347	352	349	345	184	168

Table B7 Ambient temperature (°F) for the 26 hours in which the threshold velocity of 9.6 mph for four merged turbines exceeds a height of 950 feet above ground level

Date Time	Plume Height (feet AGL)	Feet Above Ground Level								
		33	82	164	328	492	656	820	984	1312
8/04/2003 10:00	1309	69	69	68	67	66	65	64	64	62
30/03/2003 12:00	1253	81	81	80	79	78	77	76	75	73
31/10/2003 21:00	1230	53	54	54	54	53	52	51	51	49
21/12/2003 13:00	1220	60	60	60	59	58	57	56	55	54
20/08/2003 11:00	1198	90	89	89	88	87	86	85	84	82
18/11/2003 9:00	1194	58	58	57	57	58	58	59	59	60
21/12/2003 12:00	1178	59	59	58	57	56	56	55	54	53
8/04/2003 11:00	1161	72	71	71	70	69	68	67	66	64
18/10/2003 12:00	1132	83	82	82	80	80	78	78	77	75
29/03/2003 11:00	1129	76	75	75	74	73	72	71	70	68
16/12/2003 14:00	1109	60	59	59	58	57	56	55	55	53
9/02/2003 9:00	1102	53	52	51	50	50	51	51	51	51
18/01/2003 7:00	1089	56	59	61	62	63	64	64	64	65
20/01/2003 12:00	1089	65	65	64	63	62	61	60	60	58
26/07/2003 11:00	1079	90	90	89	88	87	86	85	84	83
21/09/2003 6:00	1063	75	77	78	80	81	81	82	82	83
30/03/2003 7:00	1060	65	64	64	65	65	66	66	66	66
17/01/2003 19:00	1033	64	67	70	70	69	69	69	68	68
14/04/2003 8:00	1027	53	53	52	51	50	49	49	48	46
9/02/2003 8:00	1007	49	48	48	49	50	50	50	50	51
17/01/2003 6:00	991	56	59	60	61	62	63	64	64	65
21/09/2003 7:00	991	76	78	78	80	81	81	82	82	83
17/01/2003 18:00	984	66	68	69	69	69	68	68	68	68
23/11/2003 6:00	984	44	47	47	48	48	48	49	49	50
1/01/2003 23:00	981	52	55	59	60	60	59	58	58	58
6/02/2003 5:00	955	43	46	47	48	49	50	50	50	51

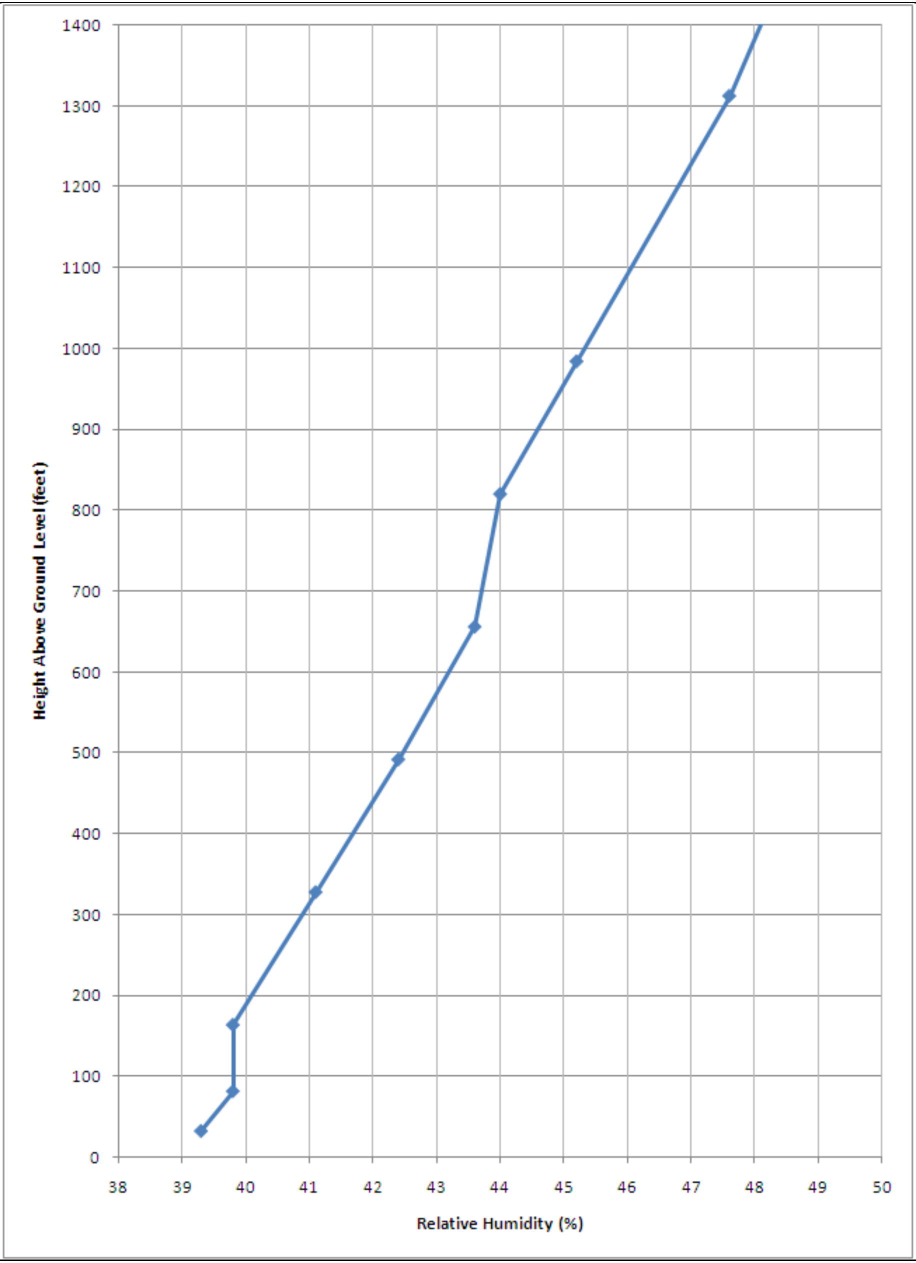


Figure B1 **Ambient relative humidity versus height above ground for the hour when the maximum threshold plume height above ground level occurs**		
Location: Mariposa	**Data source:** TAPM	**Units:** % and feet
Type: X-Y Plot	**Prepared by:** A. Schloss	**Date:** April 2010

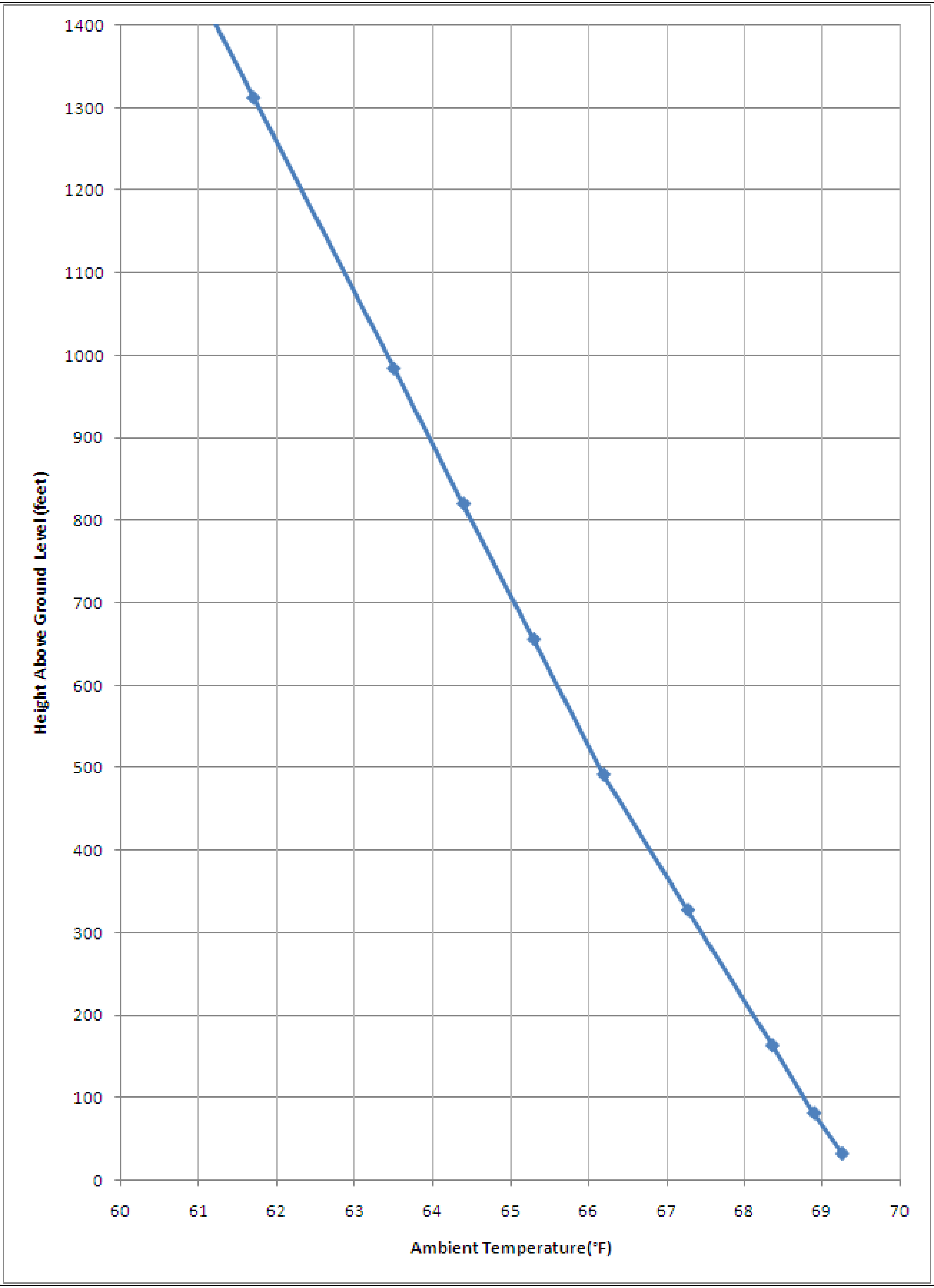


Figure B2 Ambient temperature versus height above ground for the hour when the maximum threshold plume height above ground level occurs

Location: Mariposa	**Data source:** TAPM	**Units:** Degrees Fahrenheit and feet
Type: X-Y Plot	**Prepared by:** A. Schloss	**Date:** April 2010

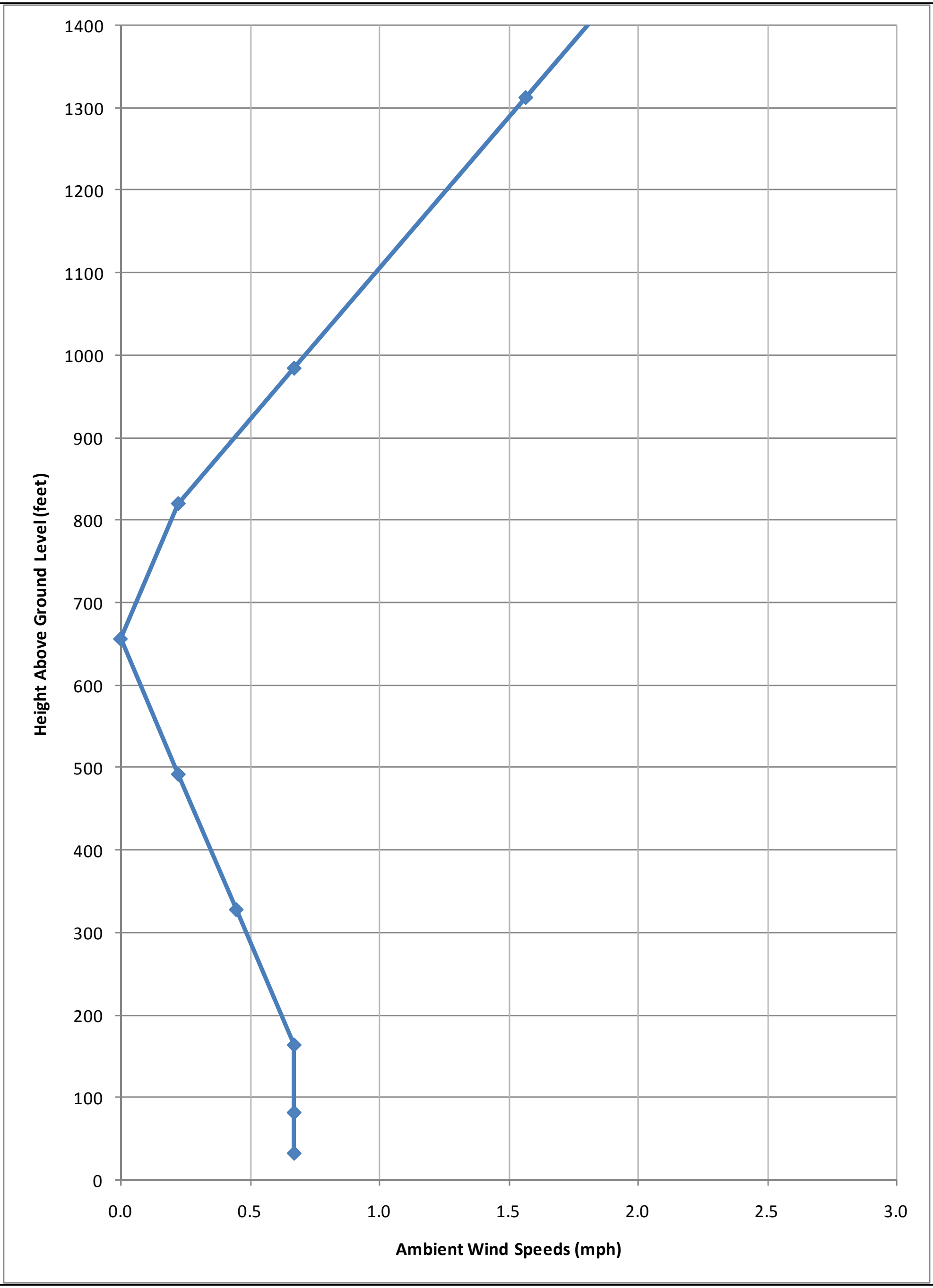


Figure B3 Ambient wind speed versus height above ground for the hour when the maximum threshold plume height above ground level occurs

Location: Mariposa	**Data source:** TAPM	**Units:** mph and feet
Type: X-Y Plot	**Prepared by:** A. Schloss	**Date:** April 2010

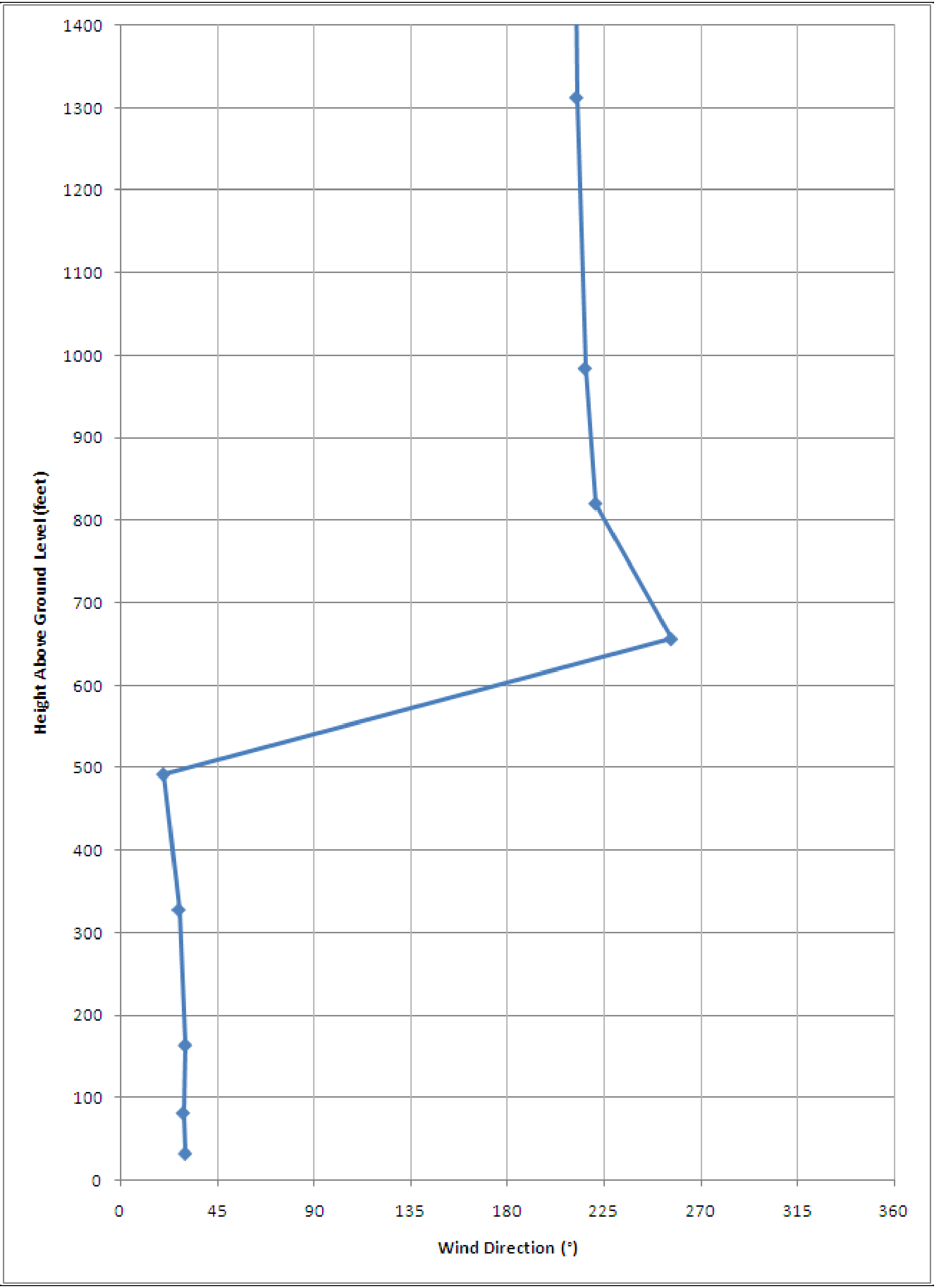


Figure B4 Wind direction versus height above ground for the hour when the maximum threshold plume height above ground level occurs

Location: Mariposa	**Data source:** TAPM	**Units:** Degrees and feet
Type: X-Y Plot	**Prepared by:** A. Schloss	**Date:** April 2010

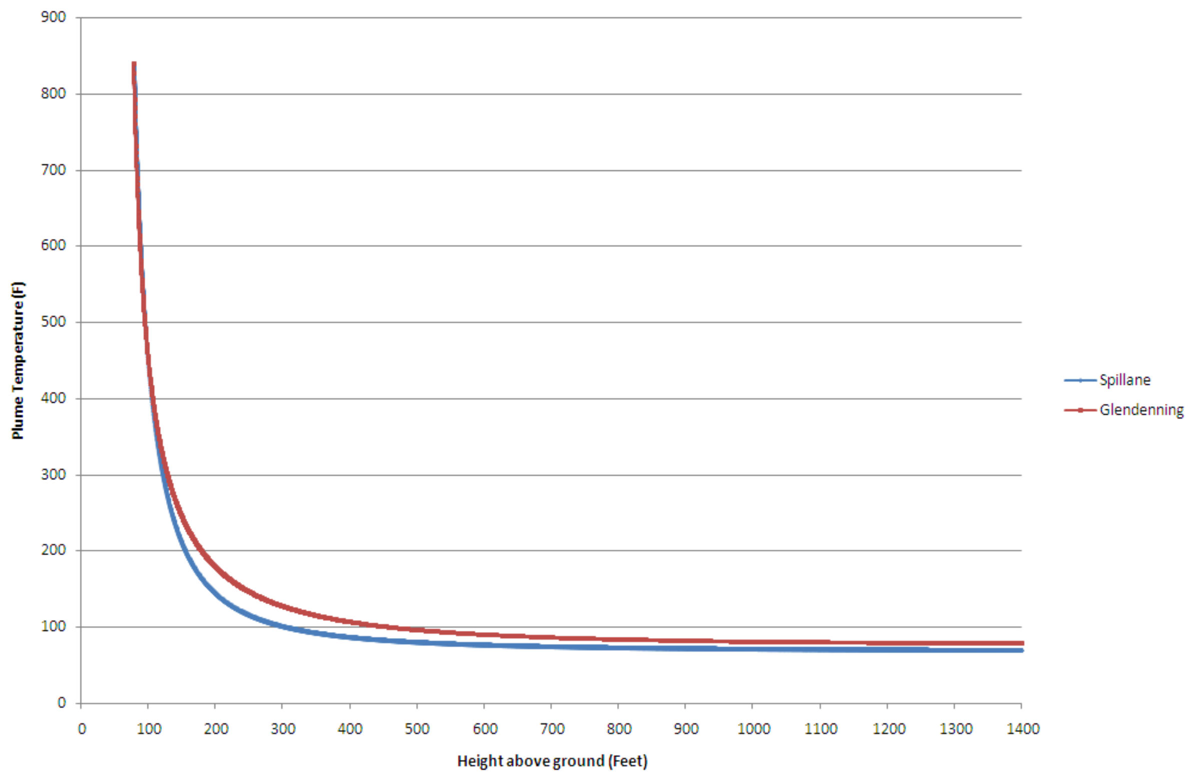


Figure B5 Plume temperature versus height above ground for the hour when the maximum threshold plume height of 1309 feet above ground level occurs

Location: Mariposa	**Data source:** Glendenning & Spillane	**Units:** Fahrenheit and feet
Type: X-Y Plot	**Prepared by:** F. Quintarelli and A. Schloss	**Date:** April 2010

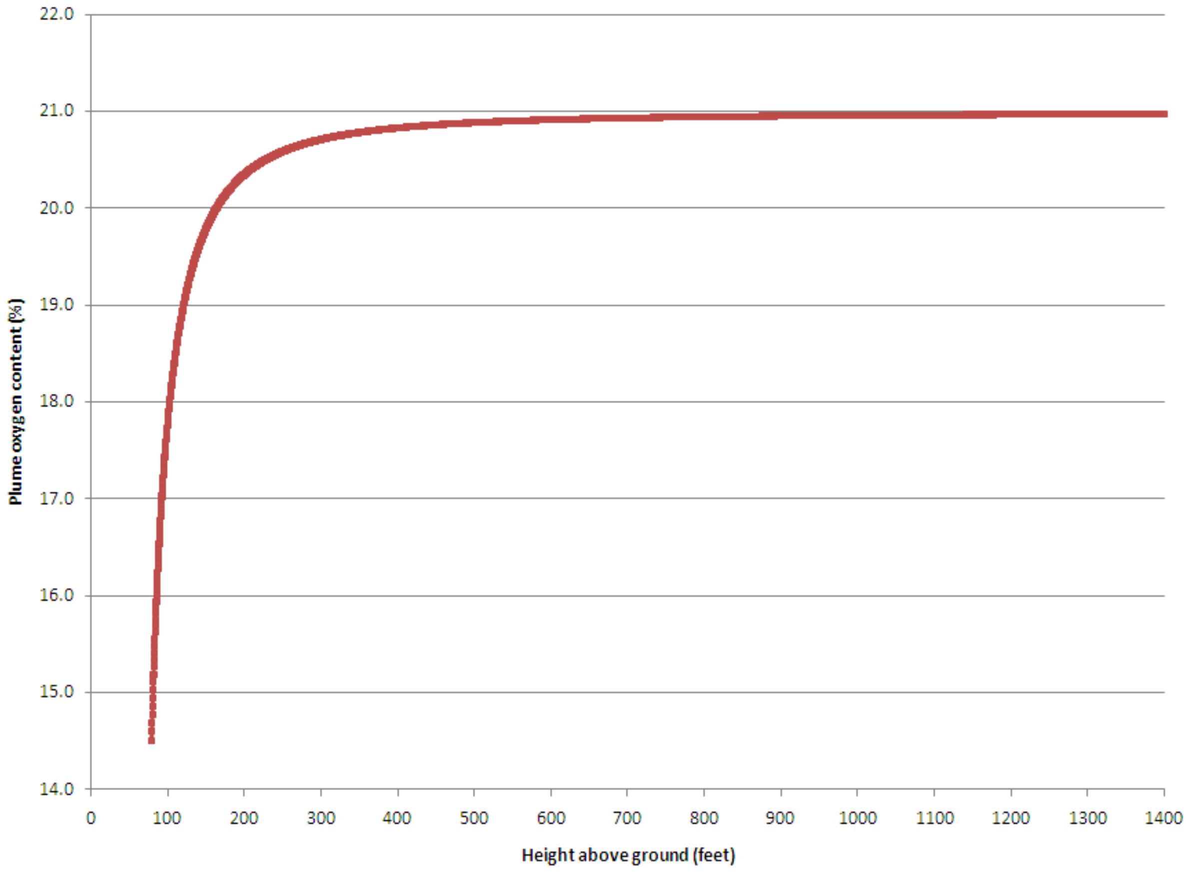


Figure B6 Plume oxygen content versus height above ground for the hour when the maximum threshold plume height of 1309 feet above ground level occurs

Location: Mariposa	**Data source:** TAPM	**Units:** Fahrenheit and feet
Type: X-Y Plot	**Prepared by:** F. Quintarelli and A. Schloss	**Date:** April 2010

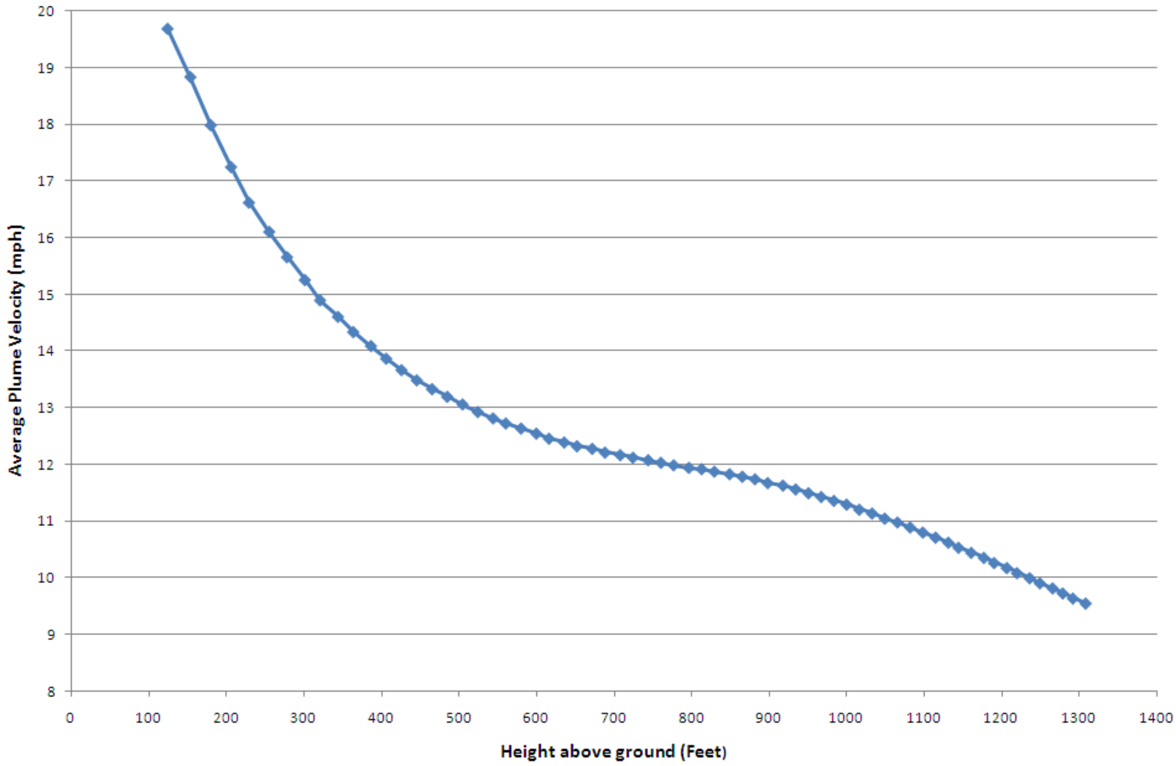


Figure B7 **Average plume vertical velocity versus height above ground for the hour when the maximum threshold plume height of 1309 feet above ground level occurs**

Location:	**Data source:**	**Units:**
Mariposa	TAPM	Miles per hour and feet
Type:	**Prepared by:**	**Date:**
X-Y Plot	A. Schloss	April 2010

Table B8 Temperature range of the plume for the hour when the maximum threshold plume height of 1309 feet above ground level occurs

Temperature	Units
294 - 299	Kelvin
70 - 78	Fahrenheit
21 - 26	Celsius

Appendix C

THE EVALUATION OF MAXIMUM UPDRAFT SPEEDS FOR CALM CONDITIONS AT VARIOUS HEIGHTS IN THE PLUME FROM A GAS-TURBINE POWER STATION AT OAKEY, QUEENSLAND, AUSTRALIA

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Contents

Tables

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C1 Introduction

This report evaluates the core velocity of a forced-plume discharged vertically from a gas-turbine power station in a calm neutral environment. It is in such an environment that maximum (relative) updrafts occur and such updrafts are of interest to aircraft that may traverse the plume core.

The forced-plume model adopted here is based on the review of literature and experimental observations outlined in Spillane (1980). The so-called top-hat profile of a plume with Gaussian distributed properties is used herein. Such top-hat profiles assume that cross-sectional area integrals can be expressed as averaged values $\overline{C}$ over a cross-section of equivalent circular radius, b, and also that the integral of products can be treated as the product of averaged quantities. For a Gaussian profile of a property with standard deviation σ (i.e. a decay from a core value of C_{MAX} proportional to exp $(-r^2/2\sigma^2)$ in any radial r direction), we have that

The equivalent radius is

$$b = 2\sigma \qquad (1)$$

The maximum value is

$$C_{MAX} = 2\overline{C} \qquad (2)$$

and the transverse gradient of the property is closely given by

$$C_{MAX} / b = 2\overline{C} / b \qquad (3)$$

C2 Method (model)

In a calm neutral (uniform) atmosphere the jet-plume integral equations in top-hat parameterisation are;

Radius growth: $$\frac{da}{dz} = \beta = 2\alpha - \frac{\lambda^2}{2F_r^2} \qquad (4)$$

Flux of buoyancy: $$\frac{dF}{dz} = 0 \rightarrow F = F_o \qquad \text{(i.e. } F \neq F(z)\text{)} \qquad (5)$$

Momentum flux: $$\frac{d(Va)^2}{dz} = \frac{Fa}{Va} = \frac{F_o a}{Va} \qquad \text{(using (5))} \qquad (6)$$

Flux of heat: $$\frac{d}{dz}(Va^2 \lambda^2 \Delta\theta / \theta_E) = 0 \qquad (7)$$

wherein, after Morton (1965),

$$\rho b^2 = \rho_e a^2, \quad \text{i.e.} \quad b = a\left(\frac{\theta_p}{\theta_E}\right)^{1/2} \qquad (7b)$$

where

θ_E = virtual potential temperature of environment (in ^{o}K)

θ_p = virtual potential temperature of plume.

$\Delta\,\theta_E = (\theta_p - \theta_E)$

Now the buoyancy is given by

$$F = V\lambda^2 a^2 g \frac{\Delta\theta}{\theta_E}, \tag{7c}$$

where V is the velocity in the plume at height z. Using that at the outlet (with diameter D)

$$a = a_o = \left(\frac{D}{2}\right)\left(\frac{\theta_{Eo}}{\theta_{p_o}}\right)^{1/2}$$

and that:

$\lambda \approx 1.11\lambda$ for an established Gaussian profile

with

$\lambda = \lambda_o \approx 1.0$ at the outlet,

the buoyancy at the outlet may be calculated using

$$F = F_o = V\lambda_o^2 a_o^2 g \frac{(\Delta\theta)_o}{\theta_{Eo}} = V(1)^2\left[\left(\frac{D}{2}\right)\left(\frac{\theta_{E_o}}{\theta_{p_o}}\right)^{1/2}\right]^2 g\frac{(\Delta\theta)_o}{\theta_{Eo}} = Vg\frac{D^2}{4}\frac{(\Delta\theta)_o}{\theta_{po}}$$

or

$$F_o = Vg\frac{D^2}{4}\frac{(\Delta\theta)_o}{\theta_{po}} \tag{7d}$$

Finally, the Froude number (Fr^2) is defined by

$$Fr^2 = \frac{V^2}{(ag\Delta\theta/\theta_E)}$$

which for a non-buoyant $(\Delta\theta = 0)$ jet is infinite.

From Schlicting (1955), Ricou and Spalding (1961), Hill (1972), Turner (1973) and Briggs (1975), a jet in a calm neutral atmosphere has a radius growth of:-

$$\frac{da}{dz} = \frac{db}{dz} = 2\,\alpha = 0.16, (\alpha = 0.08) \tag{8}$$

After Schmidt (1941), Rouse et al (1952), Morton et al (1956), Turner (1973) and Briggs (1975), a plume in a calm neutral atmosphere has a radius growth of:

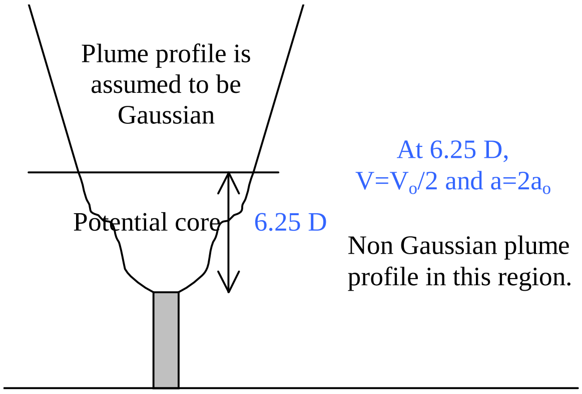
$$\frac{da}{dz} \approx \frac{db}{dz} = 6\alpha/5 = 0.15, (\alpha = 0.125) \tag{9}$$

We note from the transformation (8) above that $\frac{da}{dz}$ is (slightly) greater than $\frac{db}{dz}$ for plumes and, as noted by Scorer (1959) and Abrahams (1963, 1965), $\frac{da}{dz}$ for a plume is almost indiscernible from that of the jet. It follows the best practical relationship is:

$$\frac{da}{dz} = 0.16 \qquad (10)$$

for both forced plumes and jets.

However, near the outlet the radial profiles are not Gaussian. A potential core, in which the maximum core velocity and temperature remain constant, extends approximately 6.25 times the outlet diameter, D, above the outlet (see Forstall and Shapiro (1950), Pratte and Baines (1967)).



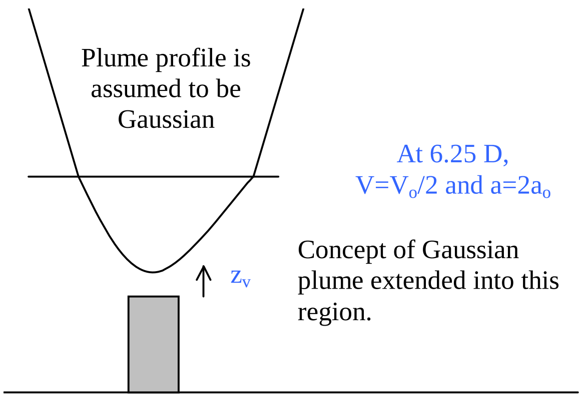
In this potential core zone the flux of momentum of jet-plume is approximately constant. Adopting a Gaussian profile with its core maximum = V_o at 6.25 D above the outlet, the average plume velocity is given by:

$$V = \frac{V_o}{2} \qquad \text{(at } z = 6.25D\text{)} \qquad (11)$$

and

$$a = 2a_o = D\left(\frac{\theta_E}{\theta_{p_o}}\right)^{1/2} \qquad \text{(at } z = 6.25D\text{)} \qquad (12)$$

It is convenient to introduce the concept of a 'virtual' plume point source which is located at a height z_v above the stack. The origin of the 'virtual' source is determined by extending the Gaussian profile below the height of 6.25 D to its origin i.e. z_v.



The "virtual" point source of a forced-plume, from (12) and (9), is thus located at a height above the outlet of:

$$z_v = 6.25D\left(1-\left(\frac{\theta_E}{\theta_{p_o}}\right)^{1/2}\right) \qquad (13)$$

Note that from (10) this implies that the variation of the radius of the plume with height is given by:

$$a = 0.16(z - z_v) \qquad \text{(for } z \geq 6.25D\text{)} \qquad (14)$$

For a neutral environment, i.e. one for which

$$\left(\frac{d\theta_E}{dz}\right) = 0 \qquad \text{or} \qquad \theta_E = \text{constant} = \theta_{Eo}$$

the solution of (5) that satisfies (11) and (12) with plume radius 'a' given by (14) is:

$$(Va)^3 = (Va)_o^3 + 0.12F_o\left[(z - z_v)^2 - (6.25D - z_v)^2\right] \qquad \text{(For } z \geq 6.25D\text{)} \qquad (15)$$

Conservation of heat flux equation (i.e. equation 7) yields:

$$Va^2\lambda^2\frac{\Delta\theta}{\theta_E} = \text{constant} = V_o a_o^2 \lambda_o^2\left(\frac{(\Delta\theta)_o}{\theta_{Eo}}\right)$$

and since $\lambda_o^2 \approx 1.0$, with $a_o = \left(\frac{D}{2}\right)\left(\frac{\theta_{Eo}}{\theta_{p_o}}\right)^{1/2}$ this may be written:

$$Va^2\lambda^2\frac{\Delta\theta}{\theta_E} = V_o\left(\frac{D^2}{4}\right)\frac{(\Delta\theta)_o}{\theta_{po}} \qquad (16)$$

This may be rewritten for the plume potential temperature as a function of height as:

$$\theta_p(z) = \theta_E\left[1 + \left(\frac{\theta_{po} - \theta_E}{\theta_{po}}\right)\left(\frac{(V_o D^2)}{4(Va^2\lambda^2)}\right)\right] \qquad (17)$$

The product (Va^2) is evaluated from (15) with (14) and (13).

C3 Summary of equations for a(z), V(z) and θ_p (z).

At height z above the outlet and $z \geq 6.25D \geq z_v$;

$$a = 0.16(z - z_v)$$

$$(Va)^3 = (Va)_o^3 + 0.12F_o\left[(z - z_v)^2 - (6.25D - z_v)^2\right]$$

$$\theta_p(z) = \theta_E\left[1 + \left(\frac{\theta_{po} - \theta_E}{\theta_{po}}\right)\left(\frac{(V_o D^2)}{4(Va^2 \lambda^2)}\right)\right]$$

where

$$z_v = 6.25D\left(1 - \left(\frac{\theta_E}{\theta_{P_o}}\right)^{1/2}\right)$$

$$F_o = Vg\,\frac{D^2}{4}\,\frac{(\Delta\theta)_o}{\theta_{Po}}$$

$$a_o = \left(\frac{D}{2}\right)\left(\frac{\theta_{Eo}}{\theta_{P_o}}\right)^{1/2}$$

$$(Va)_o = V_o a_o = V_o\left(\frac{D}{2}\right)\left(\frac{\theta_{Eo}}{\theta_{P_o}}\right)^{1/2} \qquad (18)$$

C4 Sample solution flow chart

INPUT VARIABLES →

Stack height (**H**)
Stack diameter (**D**)
Exit velocity (**V_o**)
Plume Temp (K) (**θ_{Po}**)
Ambient Temp (K) (**θ_E**)

Calculate initial parameters

↓

Height above stack of virtual point source (**z_v**)
Initial buoyancy (**F_o**)
Calculate the initial value of **$((Va)_o)^3$**

↓

Determine the starting height for calculations i.e. (**6.25D**)

↓

Calculate the plume radius (a) at all heights greater than 6.25D using

$$a = 0.16(z - z_v)$$

↓

Calculate the velocity (V) at all heights greater than 6.25D using

$$V = \frac{1}{a}\left[(Va)_o^3 + 0.12F_o\left[(z - z_v)^2 - (6.25D - z_v)^2\right]\right]^{1/3}$$

↓

(If required) calculate the plume potential temperature profile (θ_p) at all heights greater than 6.25D using

$$\theta_p(z) = \theta_E\left[1 + \left(\frac{\theta_{po} - \theta_E}{\theta_{po}}\right)\left(\frac{(V_o D^2)}{4(Va^2\lambda^2)}\right)\right]$$

C5 Example: Calculations for Oakey Power Station

Evaluations of V, a and θ_p at 100 m intervals are presented below for the Oakey Power Station with unit characteristics:

Stack height	Z_o = 35 m
Stack diameter	D = 6.2 m
Exit velocity, full load	V_o = 38.9 ms^{-1}
Exit Temperature	θ_{po} = 835 ^{o}K
Buoyancy Flux	F_o = 2300 m^4 s^{-3}

Environmental virtual potential temperature, θ_E = 300 ^{o}K (independent of height for a neutral atmosphere).

It follows that $(Va)_o$ = 72.28 $m^2 s^{-1}$ and

z_v = 15.52 m above outlet.

Height of potential core is 6.25D = 38.8 m above the outlet.

Minimum starting height above ground level for calculations is (38.8+35 = 73.8 m)

Presented in Table C1 and plotted in Figure C1 through Figure C3 are the results for the plume radius, average vertical velocity, and plume potential temperature as a function of height for the Oakey power station.

C6 Conclusions

It is concluded that in the (rare) event of a calm uniform and neutral atmosphere (the situation most favourable to the rise of the vertically forced buoyant plume discharged from the outlet of a unit stack of the Oakey power station), a plume will extend above 1000 m with vertical velocities averaged across the plume area equal to 4.14 ms^{-1}, over a plume width of approximately 300 m. In a Gaussian radial profile with an average vertical velocity of 4.14 ms^{-1}, the core maximum is close to 8.3 ms^{-1}.

Table C1 Calculations at various heights above ground

Height above ground (m)	Plume radius (m)	Plume average vertical velocity (m/s)	Plume potential temperature (K)
100	7.92	12.26	375.93
125	11.92	10.18	340.35
150	15.92	9.07	325.39
175	19.92	8.34	317.63
200	23.92	7.81	313.06
225	27.92	7.39	310.13
250	31.92	7.05	308.12
275	35.92	6.77	306.68
300	39.92	6.53	305.60
325	43.92	6.32	304.78
350	47.92	6.14	304.14
375	51.92	5.97	303.62
400	55.92	5.83	303.20
425	59.92	5.69	302.85
450	63.92	5.57	302.56
475	67.92	5.46	302.32
500	71.92	5.35	302.11
525	75.92	5.26	301.93
550	79.92	5.17	301.77
575	83.92	5.08	301.63
600	87.92	5.00	301.51
625	91.92	4.93	301.40
650	95.92	4.86	301.30
675	99.92	4.79	301.22
700	103.92	4.73	301.14
725	107.92	4.67	301.07
750	111.92	4.62	301.01
775	115.92	4.56	300.95
800	119.92	4.51	300.90
825	123.92	4.46	300.85
850	127.92	4.41	300.81
875	131.92	4.37	300.77
900	135.92	4.32	300.73
925	139.92	4.28	300.70
950	143.92	4.24	300.66
975	147.92	4.20	300.63
1000	151.92	4.17	300.61

Figure C1 Plume radius as a function of the height above the ground

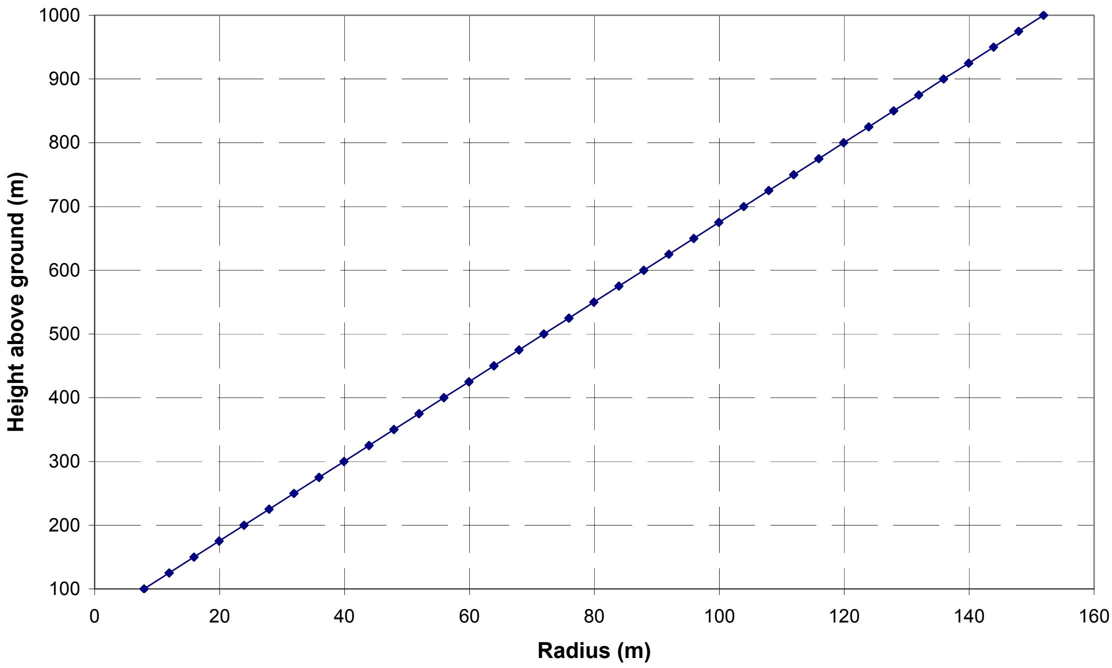


Figure C2 Plume average vertical velocity as a function of the height above the ground. (A vertical velocity of 4.3 m/s is also highlighted in the figure)

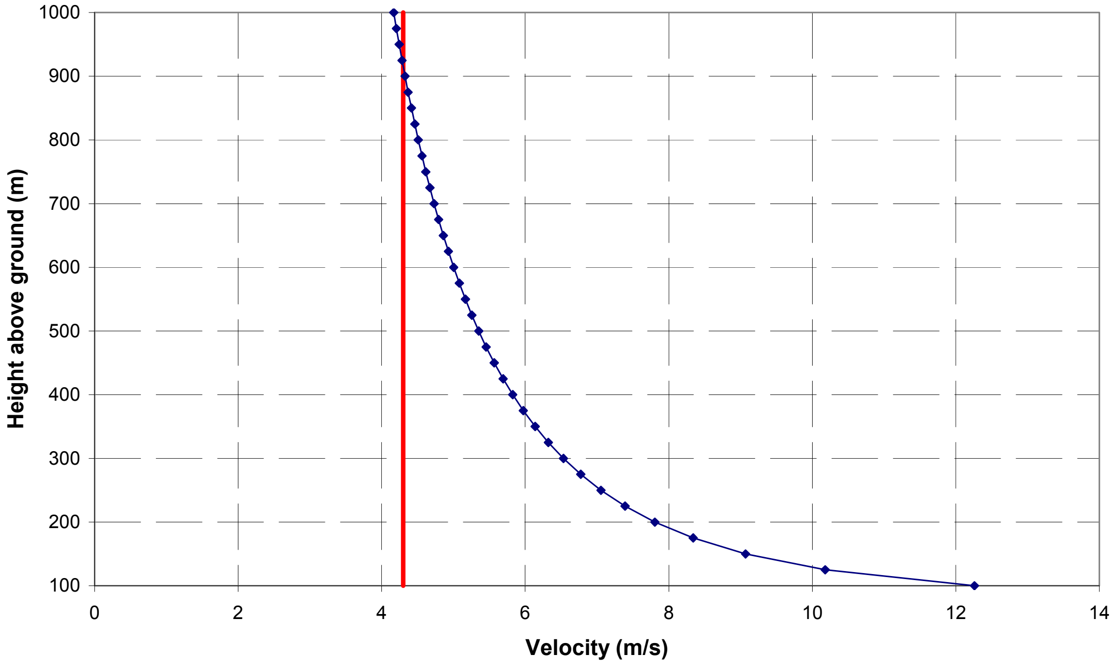
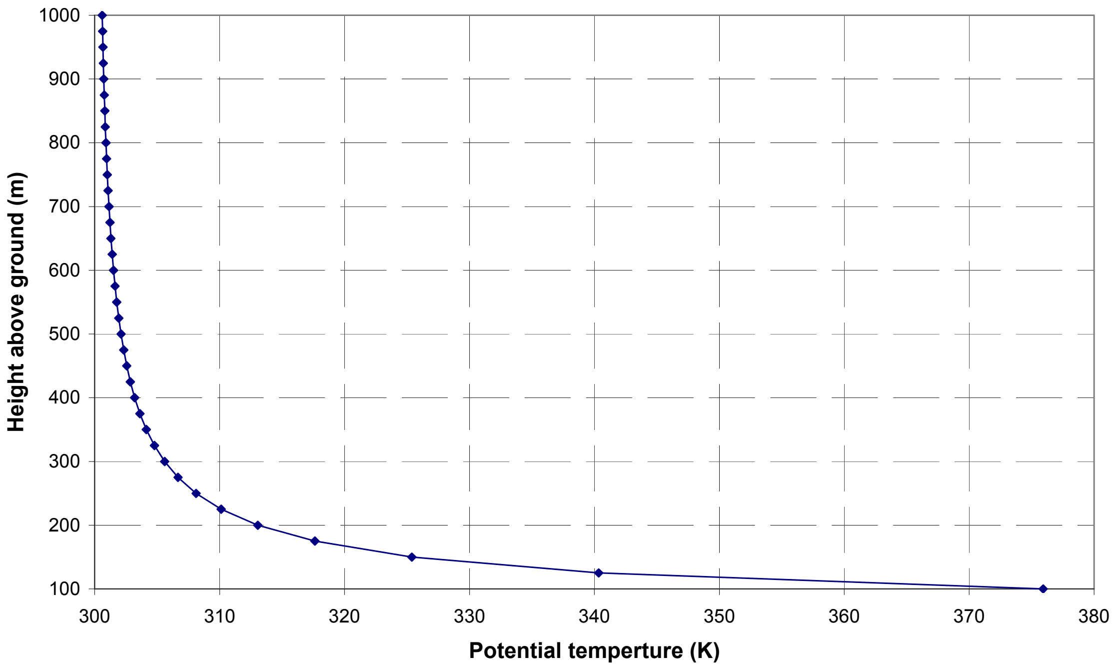


Figure C3 Plume potential temperature as a function of the height above the ground



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Appendix D

THE EVALUATION OF UPDRAFT SPEEDS AT VARIOUS HEIGHTS IN THE MERGED PLUME FROM TWO GAS-TURBINE POWER UNITS AT OAKEY, QUEENSLAND IN A CALM NEUTRAL ENVIRONMENT

Contents

D1 Introduction

The forced-plume model adopted here has been detailed in Appendix C and is based on that review of literature and experiments discussed in Spillane (1980). The so-called "top-hat" parameterisation of a plume with Gaussian distributed properties in a calm neutral environment leads to the jet-plume (integral) equations;

Radius growth: $$\frac{da}{dz}=\beta=2\alpha-\frac{\lambda^2}{2F_r^2} \quad (1)$$

Flux of buoyancy: $$\frac{dF}{dz}=0\rightarrow F=F_o \qquad \text{(i.e. } F\neq F(z)\text{)} \quad (2)$$

Momentum flux: $$\frac{d(Va)^2}{dz}=\frac{Fa}{Va}=\frac{F_oa}{Va} \qquad \text{(using (5))} \quad (3)$$

Flux of heat: $$\frac{d}{dz}(Va^2\lambda^2\Delta\theta/\theta_E)=0 \quad (4)$$

All above symbols are as defined in Appendix C. As discussed in Appendix C, $\frac{da}{dz}=0.16$ is the best practical relationship of both plumes and jets and the virtual point source of the forced-plume from a single unit, of outlet diameter D, is located at a height above the outlet of:

$$z_v=6.25D\left(1-\left(\frac{\theta_E}{\theta_{p_o}}\right)^{1/2}\right) \quad (5)$$

In summary the equations for a single plume's radius (a), average vertical velocity (V) and potential temperature (θ_p) at a height z above the outlet, (valid for z ≥ 6.25 D, the core height), are:

$$(Va)^3=(Va)_o^3+0.12F_o\left[(z-z_v)^2-(6.25D-z_v)^2\right] \quad (6)$$

$$a=0.16(z-z_v) \quad (7)$$

$$\theta_p(z)=\theta_E\left[1+\left(\frac{\theta_{po}-\theta_E}{\theta_{po}}\right)\left(\frac{(V_oD^2)}{4(Va^2\lambda^2)}\right)\right] \quad (8)$$

D2 Merging of identical plumes

Equation 1 is based on Morton et al (1956) with the integral-plumes entrainment velocity proportional to the plume's top-hat velocity, in combination with the momentum flux equation (2), and the plume Froude number, F_r^2, defined by

$$Fr^2=\frac{V^2}{(ag\Delta\theta/\theta_E)} \quad (9)$$

We note that, for a forced plume, while constant radial growth is adopted above the potential-core, the classical plume behaviour consistent also with constant radial growth is given by:

$$\frac{da}{dz} = \beta = \frac{6\alpha}{5} \qquad (10)$$

This is only attained when the Froude Number becomes constant with height; i.e. from equation (1);

$$Fr^2 = \frac{5\lambda^2}{8\alpha} \qquad (11)$$

For λ = 1.11, β = 0.16 or α = 0.133, F_r^2 = 5.78 while for α = 0.125, β = 0.15, F_r^2 = 6.16.

As we have adopted the practical value of β = 0.16, F_r^2 will be 5.78 and constant with height. The relationship $F_r^2 / \lambda^2 = 5/8\alpha$ throughout a point-source plume with boundary conditions of zero momentum and mass flux can be seen directly from the classical solutions (given by set 6.16, p172, of Turner's 1973 text).

For our purposes it is convenient to note, from equation 9, that in a neutral environment

$$Fr^2 F_o = \lambda^2 \left(V^3 a\right) \qquad (12)$$

Thus V^3a becomes constant above that level where the Froude number of the forced plume falls to its constant buoyancy-dominated value (i.e. approximately 5.78).

D3 Assumptions and consequences: The merging of two plumes

Note that the subscript m refers to the merged plume, the subscript s to results for the single plume as outlined in Appendix C.

- The two plumes initially 'touch' at a height (z_{touch}) when the radius of the single plume is equal to half the separation distance, i.e. $a_s = d/2$.
- The plumes have finished merging at a height (z_{full}) corresponding to when the single plume radius is equal to the separation distance, i.e $a_s = d$.
- The flux of buoyancy is conserved when plumes merge. Thus when (z_{full}) we have that $F_m = 2F_s = 2F_o$. According to (12), this may also be written:

$$V_m^3 a_m = 2\left(V_s^3 a_s\right)\Big|_{z=z_{full}} = 2V_{full}^3 a_{full} \qquad (13)$$

- Momentum flux is conserved at the height where merging is assumed to be complete (i.e. at (z_{full})), i.e.

$$(Va)_m^2 = 2(Va)_s^2\Big|_{z=z_{full}}$$

or

$$V_m^2 a_m^2 = 2V_{full}^2 a_{full}^2 \qquad (14)$$

where

$$V_{full} = V_s\big|_{z=z_{full}} \quad \text{and} \quad a_{full} = a_s\big|_{z=z_{full}}$$

- Combining equations (13) and (14) we find that at a height of $z = z_{full}$:

$$a_m = 2^{1/4} a_{full} \quad \text{and} \quad V_m = 2^{1/4} V_{full} \qquad (15)$$

- Above this height, it is assumed that the plume behaves as a single plume and therefore that the radius of the merged plume is given by

$$a_m = (2^{1/4} a_{full}) + 0.16(z - z_{full}) \qquad \text{for } z \geq z_{full} \qquad (16)$$

- Above $z = z_{full}$ the average vertical velocity of the merged plume may be found using:

$$V_m = \left[\frac{\left(2V_{full}^3 a_{full}\right)}{a_m} \right]^{1/3} \qquad (17)$$

- As the flux of buoyancy is conserved, the following relationships hold

$$F_m = \left[V_m a_m^2 \lambda^2 g \frac{\Delta\theta_m}{\theta_E} \right] = 2\left[V a^2 \lambda^2 g \frac{\Delta\theta}{\theta} \right]$$

and substituting for V_m and a_m from (15) gives

$\Delta\theta_m = 2^{1/4}\, \Delta\theta$. (18)

D4 Sample solution flow chart: 2 plumes

INPUT VARIABLES

Stack height (**H**)
Stack diameter (**D**)
Exit velocity (V_o)
Plume Temp (K) (θ_{Po})
Ambient Temp (K) (θ_E)
Stack separation distance (**d**)

Calculate initial parameters

Height above stack of virtual point source (z_v)
Initial buoyancy (F_o)
Calculate the initial value of $((Va)_o)^3$

Calculate the single plume vertical profile for plume radius, vertical velocity, as well as the parameter V^3a at each height. See appendix 1 for details.

Determine the value of z_{touch} which is the height at which the single plume radius is $a_s=d/2=a_{touch}$
Determine the value of z_{full} which is the height at which the single plume radius is $a_s=d=a_{full}$.
Determine the value of V_{full} which is the value of V_s at the height when is a_{touch}.

Determine the value of the merged plume radius a_m at z_{full},
i.e. $a_m=2^{1/4}a_{full}$
Determine the value of the merged plume average velocity V_m at z_{full},
i.e. $V_m=2^{1/4}V_{full}$

Calculate the plume radius (a_m) at all heights greater than z_{full}
using $a_m=(2^{1/4}a_{full})+0.16(z-z_{full})$

Calculate the average vertical velocity of the merged plume (V_m) at all heights greater than z_{full} using

$$V_m=\left[\frac{\left(2V_{full}^3a_{full}\right)}{a_m}\right]^{1/3}=\left[\frac{\left(2F_o\right)}{a_m}\right]^{1/3}$$

Note: for values of the merge plume radius and average vertical velocity at heights between $z=z_{touch}$ and $z=z_{full}$, use linear interpolation between the values of the parameters at these two heights.

D5 Example: Calculations for Oakey Power Station

Recall from Appendix C the characteristics of the Oakey power station:

Stack height	Z_o = 35 m
Stack diameter	D = 6.2 m
Exit velocity, full load	V_o = 38.9 ms^{-1}
Exit temperature	θ_{po} = 835 ^{o}K
Buoyancy Flux	F_o = 2300 m^4 s^{-3}

Environmental virtual potential temperature, θ_E = 300 ^{o}K (independent of height for a neutral atmosphere).

It follows that $(Va)_o$ = 72.28 m^2 s^{-1} and

z_v = 15.52 m above outlet.

Height of potential core is 6.25D = 38.8 m above the outlet.

Minimum starting height above ground level for calculations is (38.8+35 = 73.8 m)

Now, assume that there are two stacks separated by a distance of 25 m. Then it follows that:
a_{touch} = 12.5 m and a_{full} = 25.0 m

Solution:

- For $z < z_{touch}$, there is no overlap of the plumes and therefore the value of the plume radius, velocity etc, correspond to the single plume solution, i.e.

$$a = a_s = 0.16(z - 15.52)$$

and

$$V = V_s = \frac{1}{a}\left[(72.28)^3 + 0.12(2300)\left[(z-15.52)^2 - (38.8-15.52)^2\right]\right]^{1/3}$$

- For $z = z_{touch}$ we have that

$$a = a_{touch} = 12.5 \text{ and } z = z_{touch} = \left[15.52 + \left(\frac{12.5}{0.16}\right)\right] = 93.64 \text{ m}$$

giving

$$V = V_{touch} = \frac{1}{12.5}\left[(72.28)^3 + 0.12(2300)\left[(93.64-15.52)^2 - (38.8-15.52)^2\right]\right]^{1/3}$$

or $V_{touch} = 9.93$ m/s

- For $z = z_{full}$, the single plume radius is

$$a_{full} = 25.0 \text{ and } z = z_{full} = \left[15.52 + \left(\frac{25}{0.16}\right)\right] = 171.8 \text{ m}$$

Giving

$$V_{full} = \frac{1}{25.0}\left[(72.28)^3 + 0.12(2300)\left[(171.8-15.52)^2 - (38.8-15.52)^2\right]\right]^{1/3}$$

or $V_{full} = 7.64$ m/s

Giving a value for $V_{full}^3 a_{full} = (7.64)^3(25) = 11{,}149$.

The merge plume radius and vertical velocity are therefore given by:

$$a = a_m = 2^{1/4} a_{full} = 29.7 \text{ m}$$

and

$$V = V_m = 2^{1/4} V_{full} = 9.1 \text{ m/s}$$

- Above $z > z_{full}$, the plumes are assumed to be fully merged and the value of the merge plume radius and vertical velocity are given by

$$a = a_m = 29.7 + 0.16(z - 171.8)$$

and

$$V = V_m = \left[\frac{11{,}149}{(29.7 + 0.16(z - 171.8))}\right]^{1/3}$$

- For values of z between $z = z_{touch}$ and $z = z_{full}$, linear interpolation can be used to calculate the value of the (partially) merged plume radius and vertical velocity, i.e. between $a = 12.5$ m and $a = 29.7$ m as well as $V = 9.93$ m/s and $V = 9.1$ m/s.

- Note that for this example, the critical velocity of 4.3 m/s occurs at a height that is greater than 171.8 m above the stack height. Therefore to find the height above the stack that corresponds to the critical value of the vertical velocity we use the equations for $z > z_{full}$ and solve for $V_m = 4.3$ m/s.

$$z_{critical} = \frac{1}{0.16}\left[\frac{11{,}502}{(4.3)^3} - 29.7\right] + 171.8 = 890.3 \text{ m}$$

above the stack, or 925 m above the ground. At this height the plume radius is:

$$a_{critical} = 29.7 + 0.16(890.3 - 171.8) = 144.7 \text{ m}$$

D6 Possible extension to N identical plumes

The model for outlined in the previous sections could be extended to include multiple plumes by applying the same assumptions of buoyancy flux conservation and momentum flux conservation at the height at which the plumes are assumed to be fully merged. In this case, however, we would have that at $z = z_{full}$, the merged plume radius would be given by $a_m = N^{1/4} a_{full}$ and the merged plume vertical velocity would be given by $V_m = N^{1/4} V_{full}$ where N is the number of identical stacks and a_{full} and V_{full} correspond to the value of the single plume radius and vertical velocity at z_{full}.

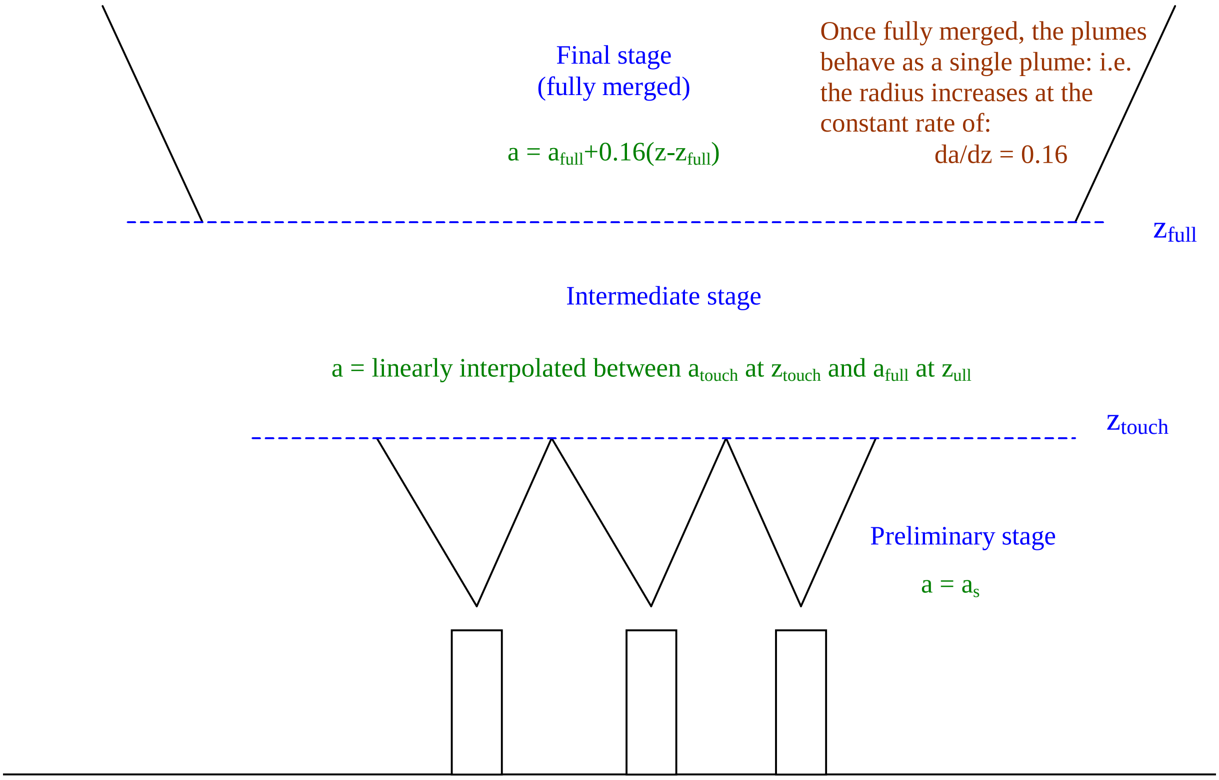
Although it may not be difficult to argue that the value of z_{touch} corresponds to $a_s = d/2$ (where d is the stack separation distance), the height at which the multiple plumes may assume to be fully merged is not so apparent.

It has been suggested (Katestone, 2003) that multiple plumes may be assumed to have fully merged at a height that corresponds to a single plume radius of $\frac{1}{2} d(N-1)$ for $N \geq 3$. This expression suggests that 3 identical plumes will have fully merged before $a_s = D$, with the required radial distance increasing at a rate of d/2 for each additional stack.

Assuming that all plumes will be fully merged by the time $a_s = D$ regardless of the number of plumes assessed will result in a conservative estimate for the critical height (i.e the height at which $V_m = 4.3$ m/s).

A more realistic estimate of the critical height would require a more accurate estimate of the height at which buoyancy enhancement of the plume as they merge is applied i.e. z_{full}.

During the three stages of plume growth the equations for the radius of the plume are as indicated in the figure in green.


Final stage
(fully merged)
a = a_full+0.16(z-z_full)
Once fully merged, the plumes behave as a single plume: i.e. the radius increases at the constant rate of:
da/dz = 0.16
z_full
Intermediate stage
a = linearly interpolated between a_touch at z_touch and a_full at z_ull
z_touch
Preliminary stage
a = a_s

Attachment DR52-7
Computational Fluid Dynamics Turbine Exhaust Velocity Characterization
CH2M HILL, May 2010

Mariposa Energy Project
Turbine Exhaust Velocity Characterization

14 May 2010

Prepared for: **Diamond Generating Corporation**

Prepared by: **Advanced Design and Simulation Group**

Diamond Generating Corporation
A Subsidiary of Mitsubishi Corporation

CH2MHILL

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Report

Figures

Executive Summary

This study predicts general exhaust plume characteristics associated with a simple-cycle natural gas power plant that is proposed for the in Northern California's San Joaquin Valley. The proposed simple cycle power plant discharges hot exhaust from four GE LM6000 turbines through four exhaust stacks. The plant is a peaking plant and therefore will only operate occasionally during periods of high energy demand. There is concern that the momentum of the hot exhaust plumes may cause localized turbulence and possibly affect aircraft operating in the vicinity of the power plant. The objective of this study is to computationally determine the exhaust plume's vertical velocity, temperature, and oxygen concentrations under a variety of wind conditions.

The exhaust plumes were characterized with airflow modeling software that is based on computational fluid dynamics (CFD). CFD is a mathematical modeling procedure whereby the fluid parameters of pressure, velocity, temperature, and turbulence are calculated by solving the governing partial differential equations for fluid flow and turbulence. The CFD used for the analysis was ANSYS Fluent which is the world's leading CFD software used by both private industry and researchers. The model input and assumptions are based on the latest design information available at the time of the study, as well as external flow modeling standard practices. See the Technical Approach section for more information on CFD software and modeling approach. The report section "General Assumptions" and "References" provides a complete basis for the model input and modeling basis.

The exhaust plumes were simulated with all four turbines operating at 100% load during both a 5 mph wind and a 10 mph wind at two ambient conditions of 59 deg F and 112 deg F. Exhaust plume vertical velocities, temperatures, and oxygen concentrations were calculated 3-dimensionally for each case.

A vertical velocity of 9.62 mph was used to as the midrange limit of light atmospheric turbulence, and a vertical velocity limit of 13.6 mph was used as an upper limit for light turbulence. The maximum height where these vertical velocities are predicted to occur are listed to the right for the various cases. For example in Case #1 the maximum height where the vertical velocity was 9.62 MPH was found to be approximately 760 ft AGL.

The plume temperatures were found to cool to within 20 deg F of the ambient temperature within 361 ft AGL. Oxygen level at the stack discharge was given as 14.5% (70% of ambient levels), and was found to be 20% (95% of ambient) within 160 ft AGL.

Maximum heights for the various cases are listed to the right, on this page, and graphical results are presented for each case with the report.

Maximum heights Above Ground Level (AGL) for the four cases:

Case #1 – 5 MPH Wind, 59 degF Ambient		
Maximum elevation at which the midrange of light turbulence (9.62 MPH) is observed	~	760 ft AGL
Maximum elevation at which the upper limit of light turbulence (13.6 MPH) is observed	~	142 ft AGL
Maximum elevation at which the temperature is at least 20 degF above ambient	~	361 ft AGL
Maximum elevation at which the Oxygen level is less than 20% (95% of ambient)	~	135 ft AGL
Case #2 – 10 MPH Wind, 59 degF Ambient		
Maximum elevation at which the midrange of light turbulence (9.62 MPH) is observed	~	122 ft AGL
Maximum elevation at which the upper limit of light turbulence (13.6 MPH) is observed	~	111 ft AGL
Maximum elevation at which the temperature is at least 20 degF above ambient	~	244 ft AGL
Maximum elevation at which the Oxygen level is less than 20% (95% of ambient)	~	113 ft AGL
Case #3 – 5 MPH Wind, 112 degF Ambient		
Maximum elevation at which the midrange of light turbulence (9.62 MPH) is observed	~	622 ft AGL
Maximum elevation at which the upper limit of light turbulence (13.6 MPH) is observed	~	132 ft AGL
Maximum elevation at which the temperature is at least 20 degF above ambient	~	325 ft AGL
Maximum elevation at which the Oxygen level is less than 20% (95% of ambient)	~	139 ft AGL
Case #4 – 10 MPH Wind, 112 degF Ambient		
Maximum elevation at which the midrange of light turbulence (9.62 MPH) is observed	~	111 ft AGL
Maximum elevation at which the upper limit of light turbulence (13.6 MPH) is observed	~	103 ft AGL
Maximum elevation at which the temperature is at least 20 degF above ambient	~	208 ft AGL
Maximum elevation at which the Oxygen level is less than 20% (95% of ambient)	~	112 ft AGL

Technical Approach

The purpose of this study was to provide the best approximation of plume formation from the proposed power plant using Computational Fluid Dynamics (CFD). This study began by determining the most appropriate Computational Fluid Dynamic (CFD) software package. The CFD packages considered were ANSYS FLUENT (ANSYS Inc., Canonsburg, Pa), Star-CCM+ (CD-Adapco, Melville, NY), Flovent (Mentor Graphics, Wilsonville, OR), and FDS (NIST).

ANSYS FLUENT (release 12.1) was chosen for this study for several reasons. ANSYS FLUENT has been validated within numerous peer-reviewed journal publications for external flow simulations and buoyant plume studies (ref 1, 3, 4, 7). In addition, ANSYS FLUENT is the leading CFD software provider with more than 400 Ph.D. level experts contributing to the advancement and development of the software. ANSYS FLUENT provides the most modern turbulence closure models combined with second-order solution approximations for increased accuracy. Finally, ANSYS Fluent has a robust and accurate solver which can accommodate large models for improved accuracy.

The latest best practices for external flow simulation were referenced during the model creation (ref. 2,3,6,8). Both peer-reviewed articles and reports from experts in the field of CFD simulation of flows were used to verify model assumptions and settings.

General Assumptions

- Models are based on layout "091215_MEP_Flight_Model.kmz" December 2009 and flow rates specified in spreadsheets "Kelso LM6000 Performance 3.xls" February 2009, "Kelso LM6000 Performance.xls" February 2009, and "MEP_StackConditions_07_14_2009.xls" July 2009.
- Model domain dimensions are 5000 ft x 5000 ft x 3000 ft (length x width x height)
- Atmospheric pressure is assumed to be 14.7 psi
- The turbulence model chosen for the analysis is the Realizable k-epsilon model because it is suitable for complex shear flows involving rapid strain, moderate swirl and locally transitional flows. This turbulence model has been shown to have better performance for external flow simulations when compared to the standard k-epsilon turbulence model (Ref. 4).
- Although the nature of wind blowing over a building is essentially dynamic, (i.e. it varies continually with time) the approach taken in this study is a steady state approach. Hence, for a particular wind direction it is assumed that the airflow reaches steady state conditions (i.e. pressures and velocity etc., do not change with time).
- The oncoming wind profiles are assumed to be in a rural setting for the wind directions considered. Velocity changes with height as shown in the profiles on Page #4. The equation defining the 5 and 10 MPH wind cases correspond to the logarithmic law for rough surfaces (best practice for modeling the atmospheric boundary layer (ABL)):

$$U(z) = \frac{u_\tau(10)}{K} Log_e\left(\frac{z}{z_0}\right)$$

$U(z)$ = wind speed as a function of height

z = height above ground

z_0 = roughness length (constant for a given ground surface)

z_0 = 0.0984 ft (0.03 m), value used for "open", rural landscape (Ref. 1-4)

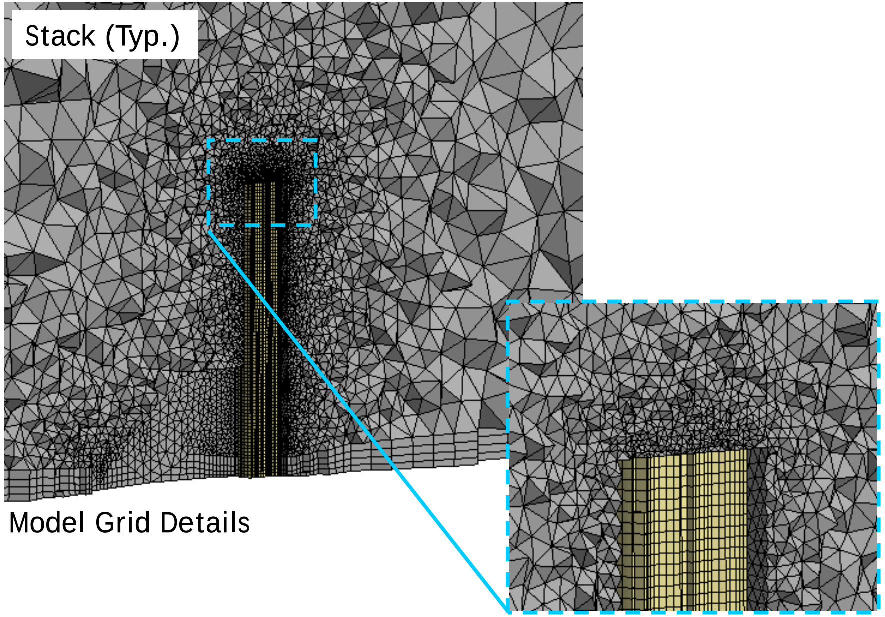
K = von Karman's constant (constant for all surfaces)

$u_t(10)$ = friction velocity $\equiv \sqrt{(\tau_w/\rho_a)}$ (based on a wind speed at a reference height of 10 m)

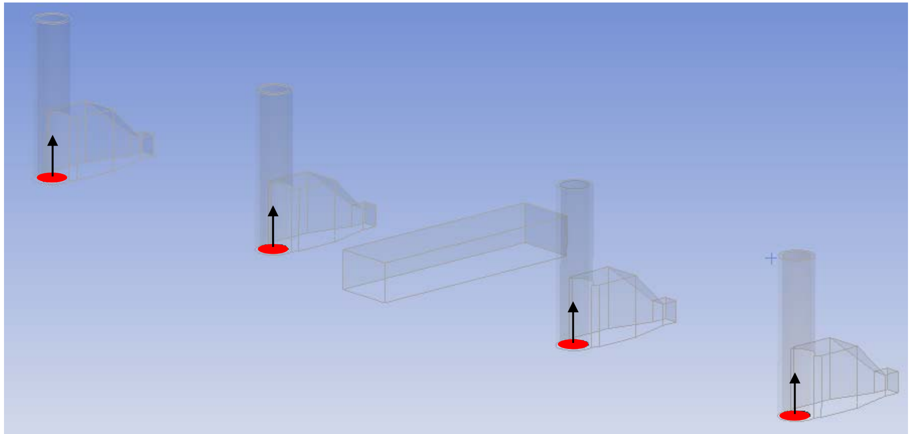
τ_w - wall shear stress , ρ_a - air density

- The downwind model domain sides are assumed to be open to the atmosphere, allowing airflow and heat to freely move in all directions across this boundary
- The exhaust mass flow rate is defined at the bottom surface of each stack. This allows the exhaust stack flow to exit into the atmosphere with an approximation of the real velocity profile (see figure to the lower right).
- An unstructured tetrahedral mesh was used for all models with the total model domain consisting of approximately 5 million cells. Details of grid around the exhaust stacks are shown to the right.

- Continued



Model Grid Details



Mass-flow supply points (4 stacks)

General Assumptions - *Continued*

- Radiation heat transfer is a function of absolute temperature to the fourth power, and its significance increases rapidly as temperature increases. In most cases, radiation can be safely ignored at temperatures below 500F. Results for this analysis show the plume is well below a temperature where radiation would have a significant contribution to heat transfer. The maximum plume temperature is less than 500F at 88 ft AGL (8 ft above stack discharge) and 120F at 165 ft AGL, for the cases considered. Thus radiation is a negligible heat transfer mechanism and is therefore ignored. (Ref.6)
- Stack exhaust is considered to have a molecular weight of 28.0 g/mol with temperature dependent viscosity (Sutherland's approximation)

- The turbulent kinetic energy is approximated as [m2/s2]:

$$k = \frac{u_\tau^2}{\sqrt{C_\mu}}$$

C_μ = turbulent-viscosity constant

- The turbulent dissipation rate is assumed as [m2/s3]:

$$\varepsilon(z) = \frac{1}{\mathrm{K}}\frac{u_\tau^3}{z}$$

General Assumptions – *Continued*

- Fluent model input parameters:

Models Settings

Space	3D
Time	Steady
Viscous	Realizable k-epsilon turbulence model
Wall Treatment	Standard Wall Functions
Heat Transfer	Enabled
Solidification and Melting	Disabled
Radiation	None
Species Transport	Non-Reacting (2 species)
Coupled Dispersed Phase	Disabled
Pollutants	Disabled
Pollutants	Disabled
Soot	Disabled

Material: mixture-air-exhaust (mixture)

Property	Units	Method	Value(s)
Mixture	Species	names	air-exhaust air
Density	kg/m3	incompressible-ideal-gas	#f
Cp (Specific Heat)	j/kg-k	constant	1006.43
Thermal Conductivity	w/m-k	constant	0.0454
Viscosity	kg/m-s	constant	1.72E-05
Mass Diffusivity	m2/s	constant-dilute-appx	2.88E-05
Molecular Weight	kg/kmol	constant	28.966

Boundary Conditions

Name	Type	Material name
outlet	pressure-outlet	
inlet_stack1	mass-flow-inlet	mixture-air-exhaust
inlet_stack2	mass-flow-inlet	mixture-air-exhaust
inlet_stack3	mass-flow-inlet	mixture-air-exhaust
inlet_stack4	mass-flow-inlet	mixture-air-exhaust
ceiling	symmetry	
wall_1	symmetry	
wall_2	symmetry	
floor	wall	
inlet	velocity-inlet	mixture-air-exhaust

Boundary Conditions - *Continued*

Setup Conditions – 59F Ambient

Outlet	
Gauge pressure (pascal)	0
Backflow Total Temperature (f)	59
Backflow Turbulent Kinetic Energy	(profile udf k_profile)
Backflow Turbulent Dissipation Rate	(profile udf dissip_profile)
stack inlets	
Mass Flow Rate (lbm/hr)	1051375
Total Temperature (f)	848
Turbulent Intensity (%)	2
Hydraulic Diameter (ft)	12
Mass fraction (air-exhaust)	1
floor	
Temperature (f)	59

Setup Conditions – 112F Ambient

Outlet	
Gauge pressure (pascal)	0
Backflow Total Temperature (f)	112
Backflow Turbulent Kinetic Energy	(profile udf k_profile)
Backflow Turbulent Dissipation Rate	(profile udf dissip_profile)
stack inlets	
Mass Flow Rate (lbm/hr)	845007
Total Temperature (f)	863
Turbulent Intensity (%)	2
Hydraulic Diameter (ft)	12
Mass fraction (air-exhaust)	1
floor	
Temperature (f)	112

Case Specific Assumptions

Case #1 - 5 MPH Wind, 59F Ambient, Case Design Basis and Assumptions

- "Velocity inlet" domain boundary condition at upwind sides of the model domain to create a 5 mph wind, at 33 ft AGL, towards the Airport Approach path (see profile to the right)
- Ambient and stack conditions are detailed in the table below:

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
59	60	100	848	1,051,375	597,341	79.5	12.0	14.5	60.0

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)

Case #2 - 10 MPH Wind, 59F Ambient, Case Design Basis and Assumptions

- "Velocity inlet" domain boundary condition at upwind sides of the model domain to create a 10 Mile per Hour wind, at 33 ft AGL, towards the Airport Approach path (see profile to the right)
- Ambient and stack conditions are detailed in the table below:

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
59	60	100	848	1,051,375	597,341	79.5	12.0	14.5	60.0

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)

Case #3 - 5 MPH Wind, 112F Ambient, Case Design Basis and Assumptions

- "Velocity inlet" domain boundary condition at upwind sides of the model domain to create a 5 Mile per Hour wind, at 33 ft AGL, towards the Airport Approach path (see profile to the right)
- Ambient and stack conditions are detailed in the table below:

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
112	15	100	863	845,007	485,749	79.5	12.0	15.3	48.8

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)

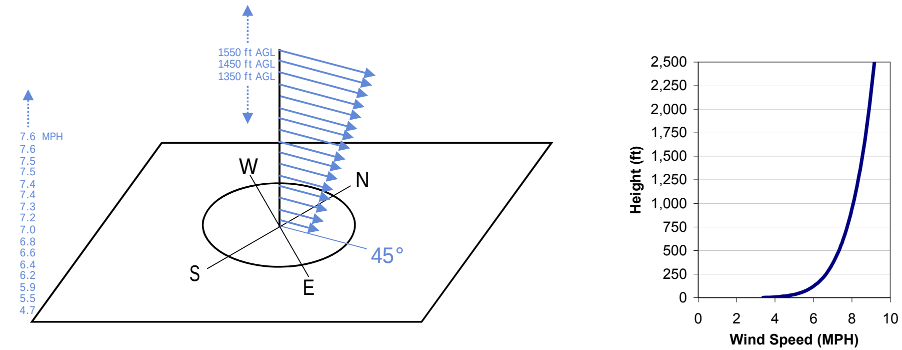
Case #4 - 10 MPH Wind, 112F Ambient, Case Design Basis and Assumptions

- "Velocity inlet" domain boundary condition at upwind sides of the model domain to create a 10 Mile per Hour wind, at 33 ft AGL, towards the Airport Approach path (see profile to the right)
- Ambient and stack conditions are detailed in the table below:

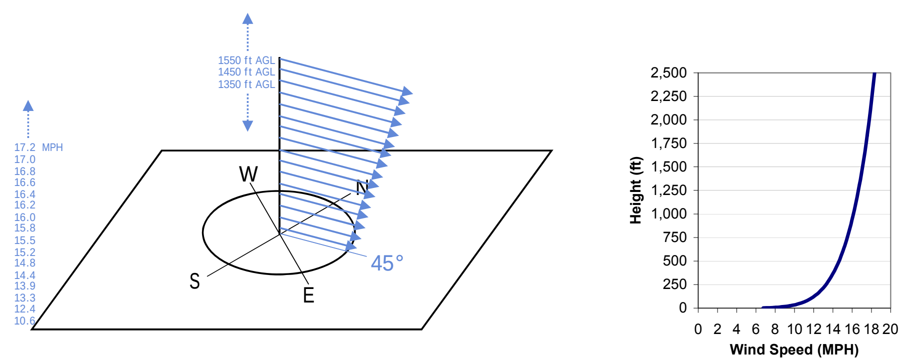
Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
112	15	100	863	845,007	485,749	79.5	12.0	15.3	48.8

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)

5 MPH Wind Profile



10 MPH Wind Profile



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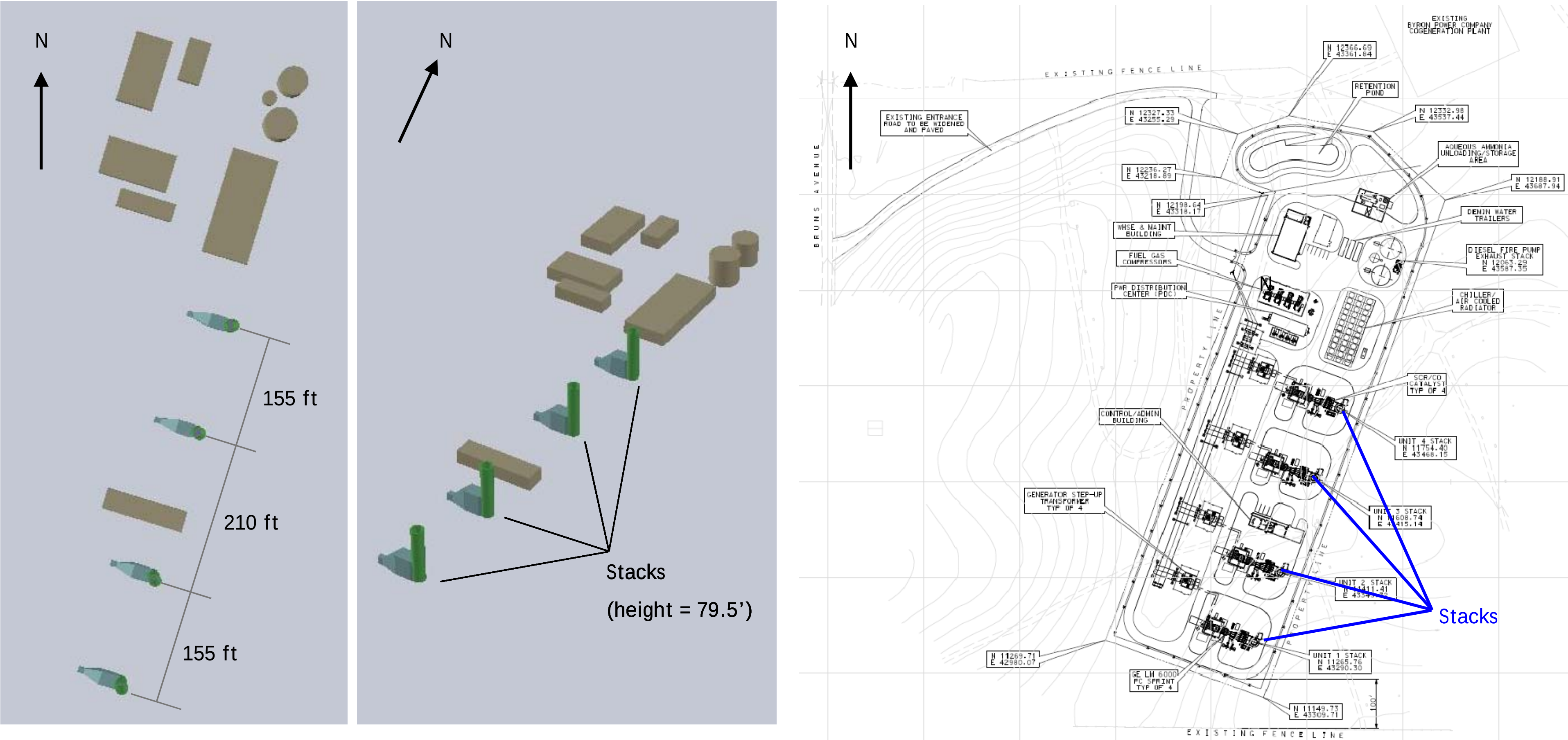


Site Layout - Perspective & Plan Views of on-site equipment

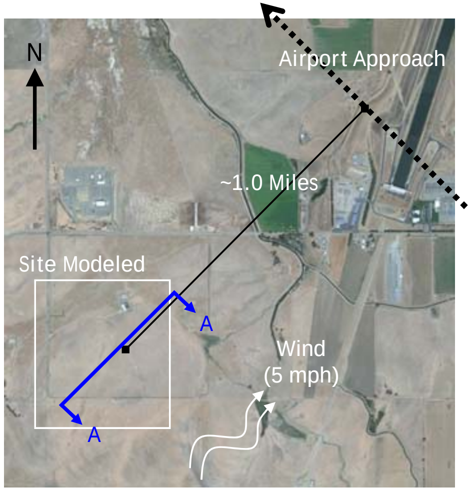
CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project	A
	Date: 14 May 2010		Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10		Table Of Contents	

Case #1

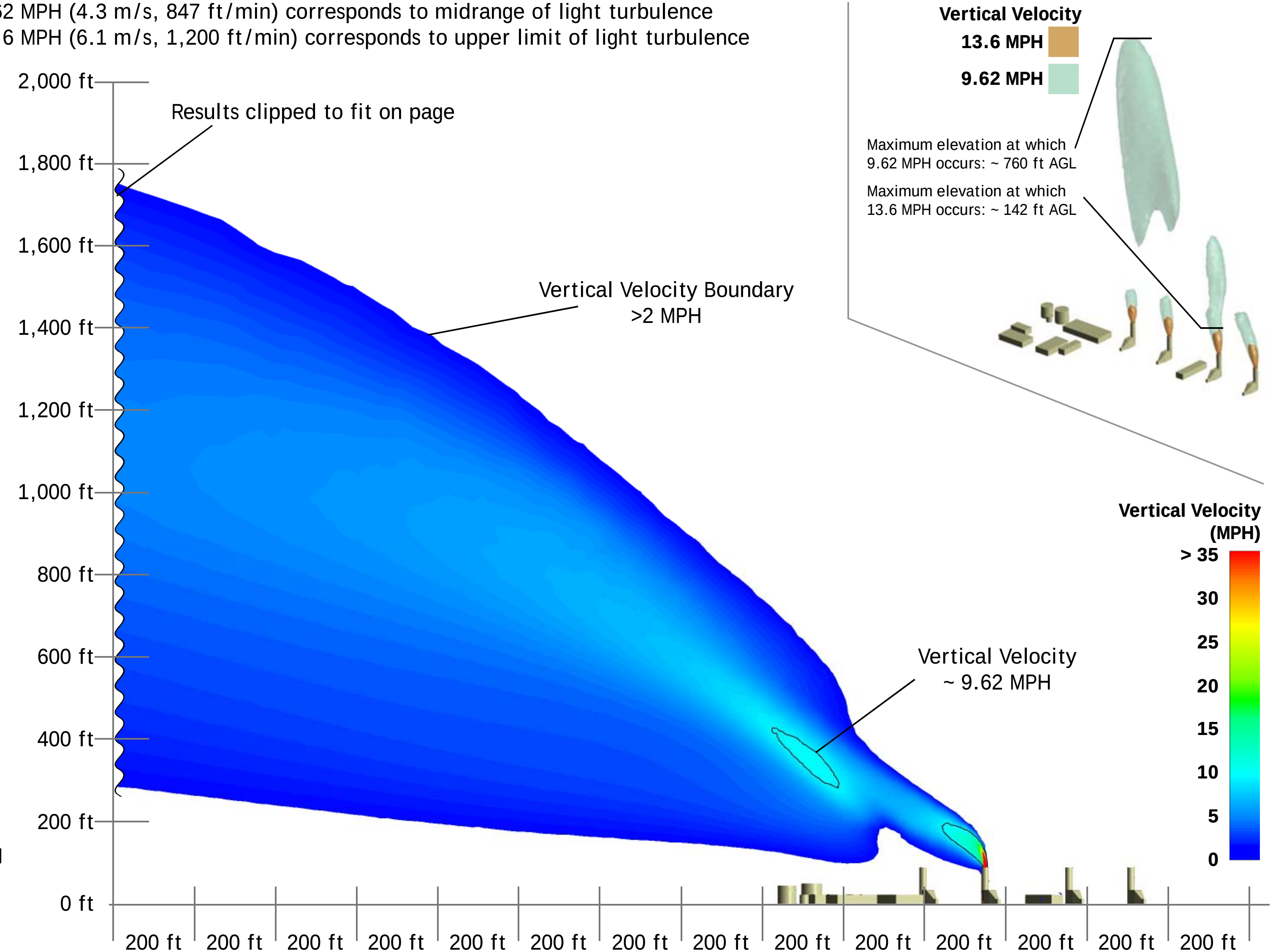
5 MPH Wind Speed – 59F Ambient Conditions

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
59	60	100	848	1,051,375	597,341	79.5	12.0	14.5	60.0

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)



9.62 MPH (4.3 m/s, 847 ft/min) corresponds to midrange of light turbulence
13.6 MPH (6.1 m/s, 1,200 ft/min) corresponds to upper limit of light turbulence



Results Summary:

Maximum elevation at which 9.62 MPH occurs: ~ 760 ft AGL

Maximum elevation at which 13.6 MPH occurs: ~ 142 ft AGL

Maximum horizontal distance at which the velocity of 9.62 MPH occurs: ~ 663 ft

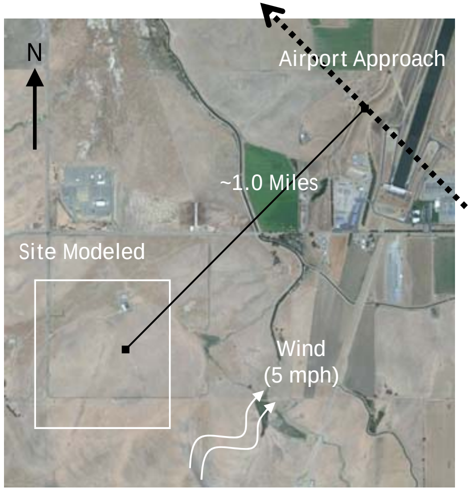
Maximum horizontal distance at which the velocity of 13.6 MPH occurs: ~ 44 ft

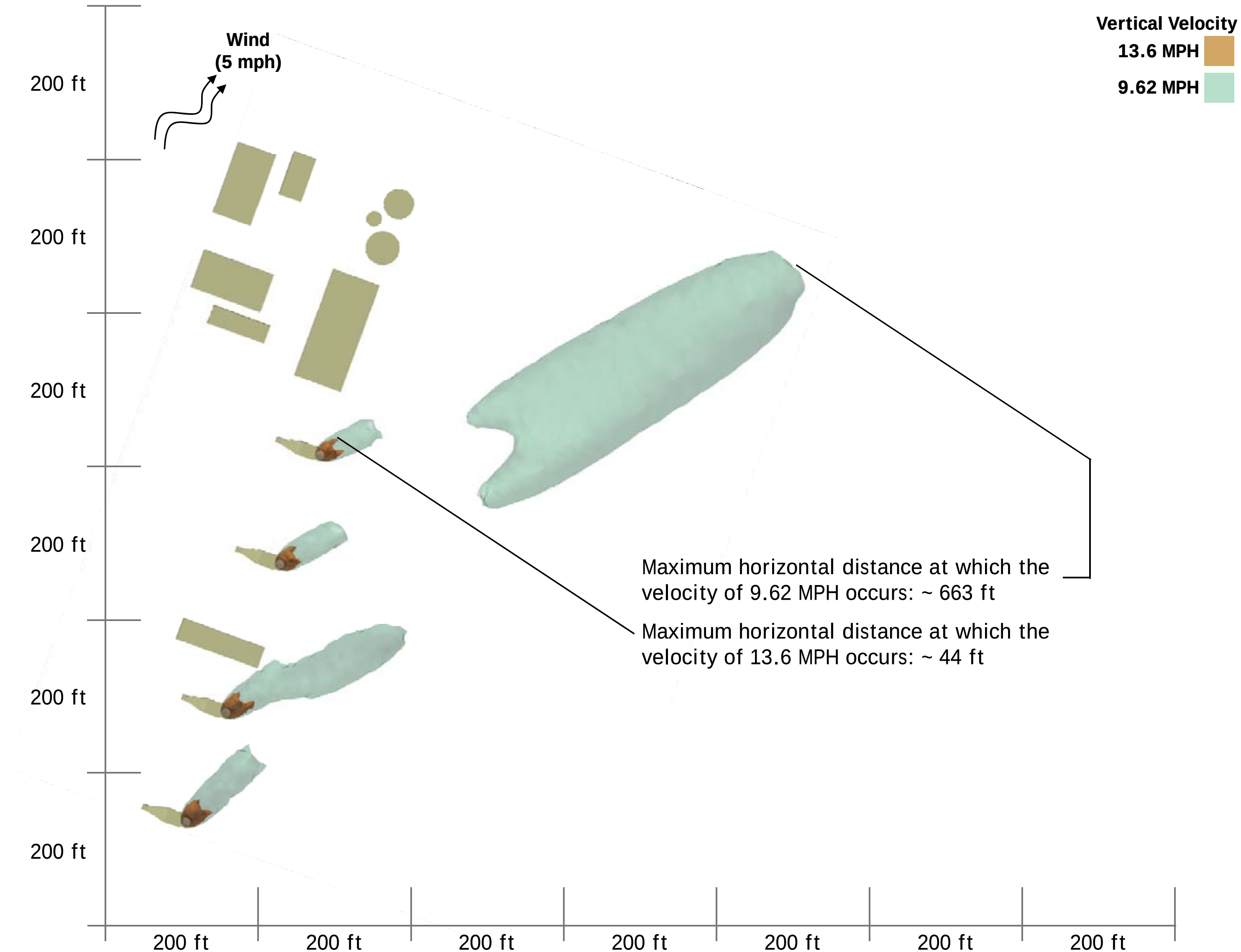
Ambient Wind Speed: 5 MPH

Case #1 (5 mph, 59F Ambient):

- Section A-A showing Vertical Velocity

CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project	**Figure 1.0**
	Date: 14 May 2010		Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10		Table Of Contents	



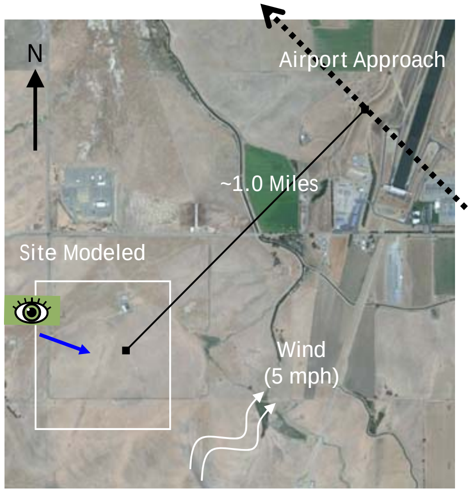


Ambient Wind Speed: 5 MPH

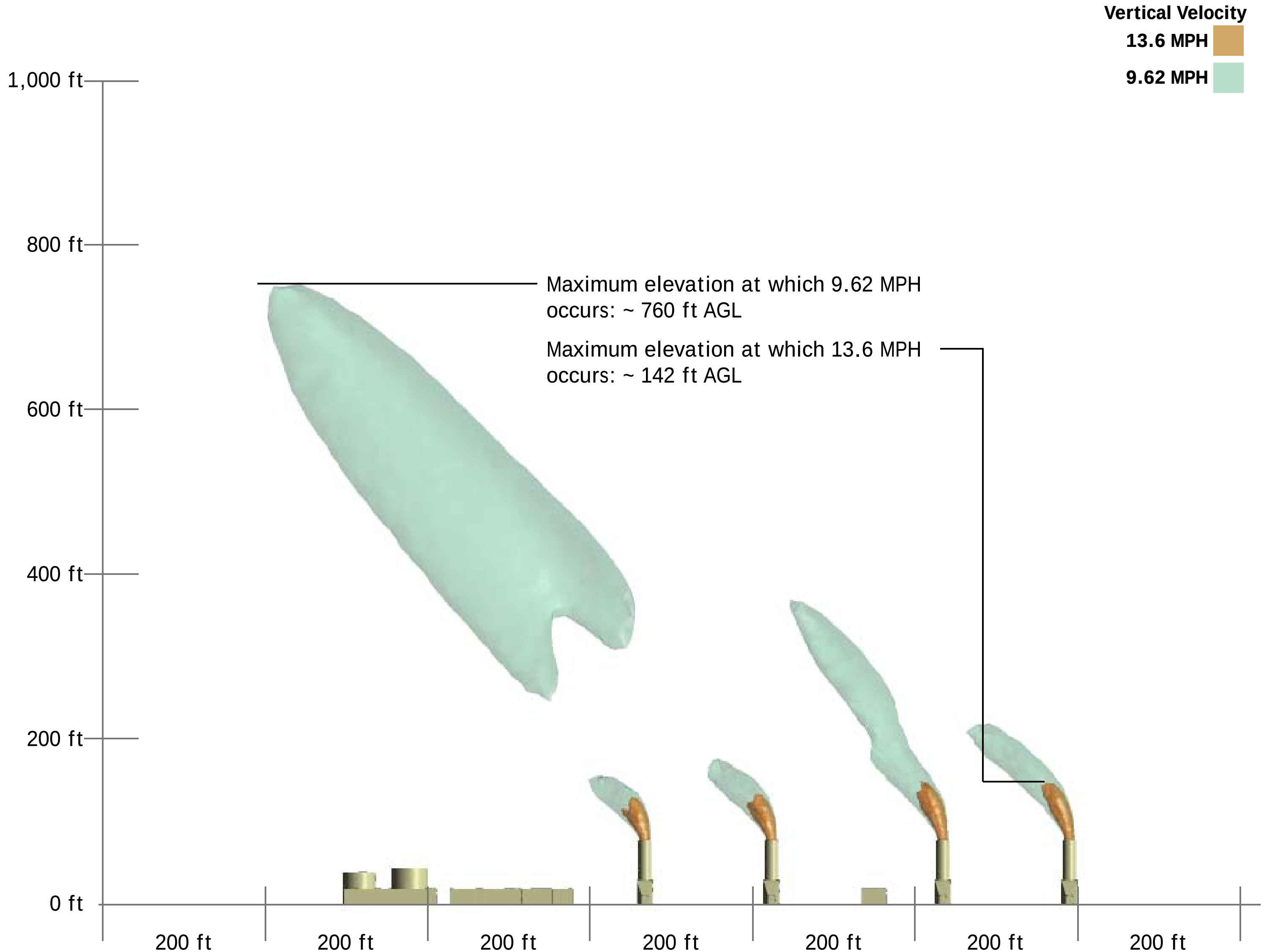
Case #1 (5 mph, 59F Ambient):

- Plan view showing Vertical Velocity Isosurfaces

CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project	Figure 1.1
	Date: 14 May 2010		Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10		Table Of Contents	



* Blue arrow indicates the image viewpoint

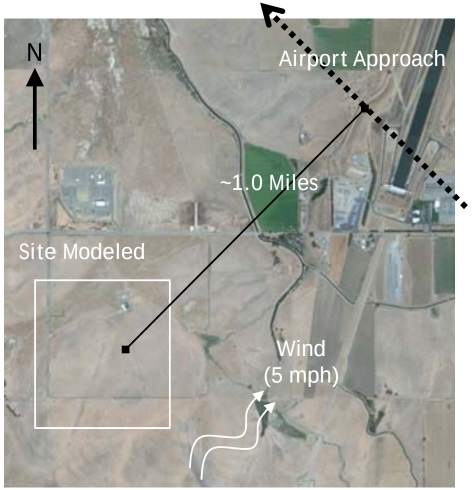


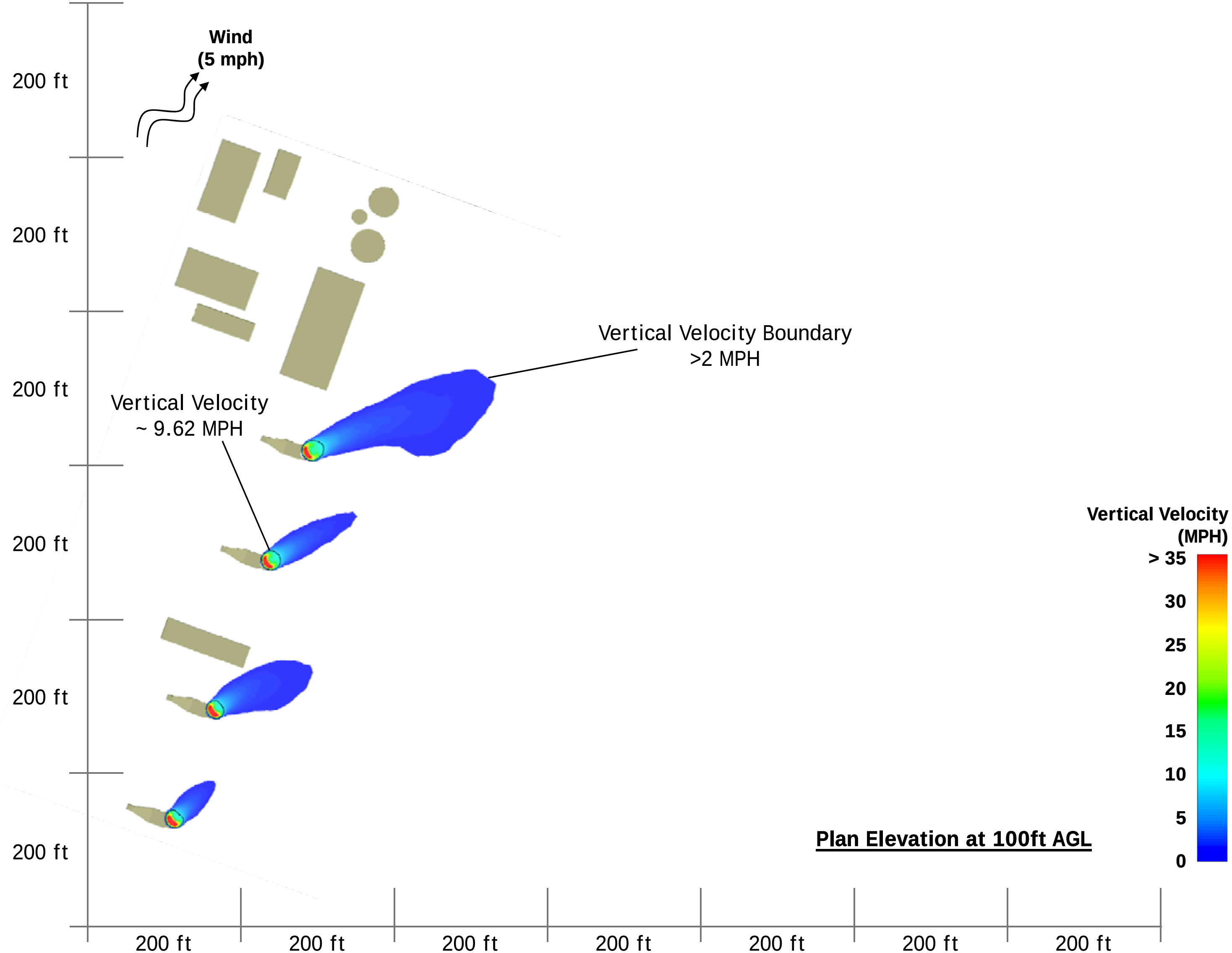
Ambient Wind Speed: 5 MPH

Case #1 (5 mph, 59F Ambient):

- Elevation view showing Vertical Velocity Isosurfaces

CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project Turbine Exhaust Velocity Characterization	Table Of Contents	**Figure 1.2**
	Date: 14 May 2010				
	File: Diamond Exh CFD_5-14-10				



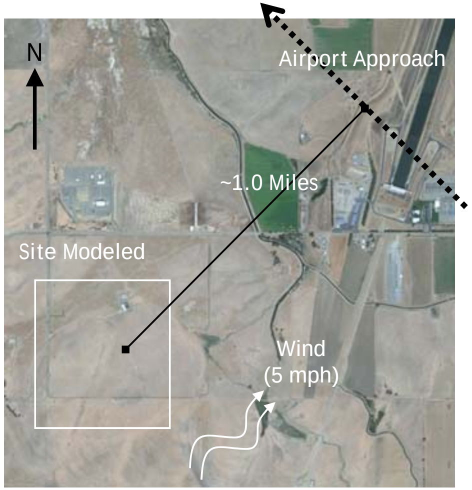


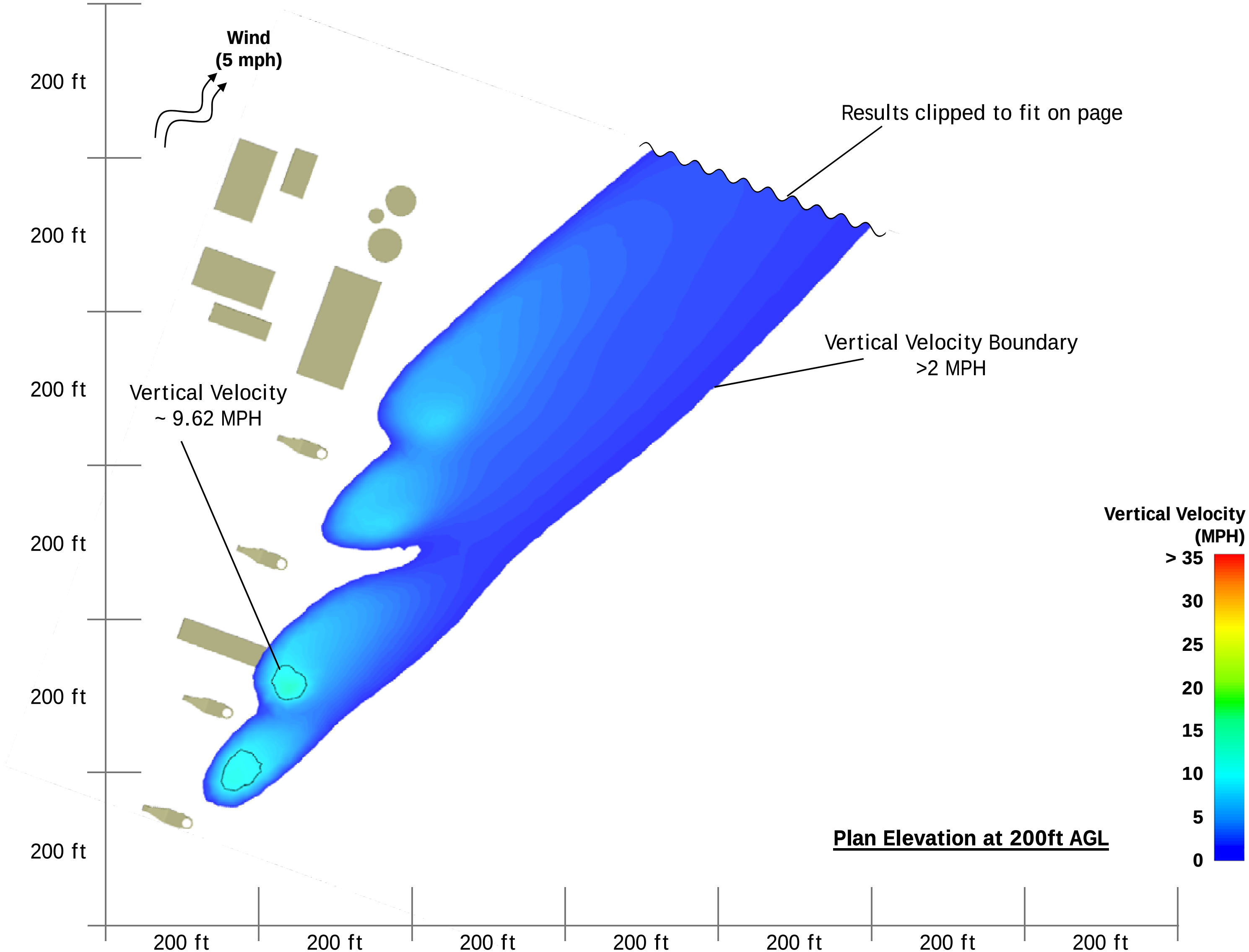
Ambient Wind Speed: 5 MPH

Case #1 (5 mph, 59F Ambient):

- Plan showing Vertical Velocity @ 100 ft AGL

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization	Table Of Contents	**Figure 1.3**



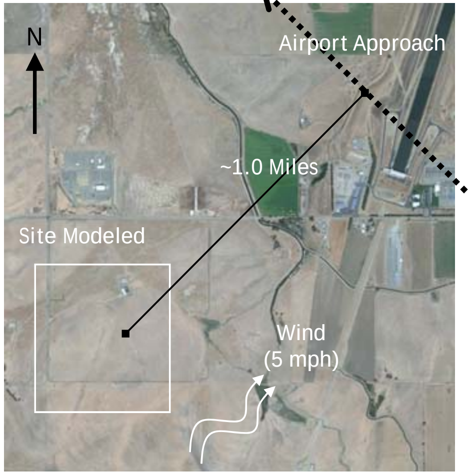


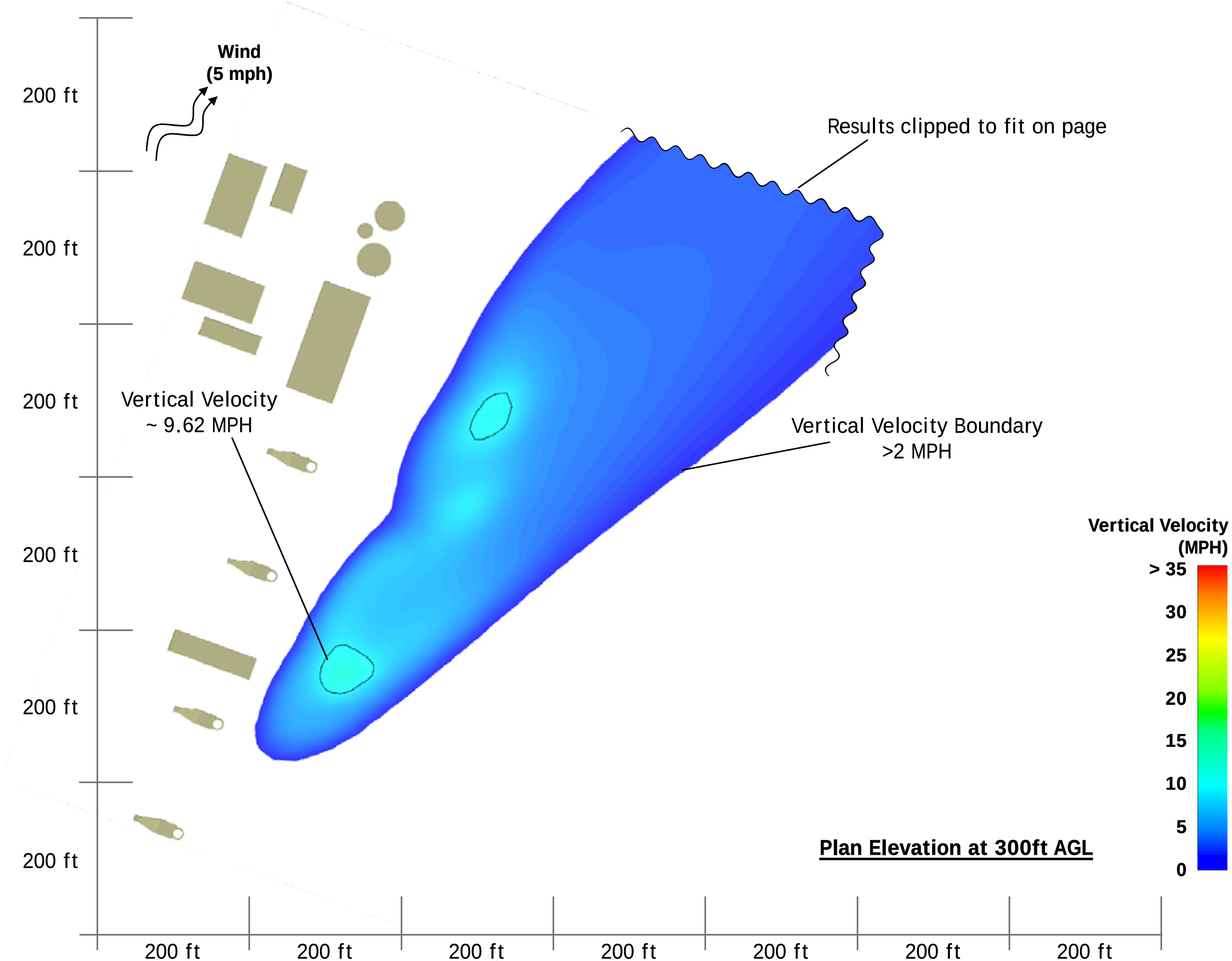
Ambient Wind Speed: 5 MPH

Case #1 (5 mph, 59F Ambient):

- Plan showing Vertical Velocity @ 200 ft AGL

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization Table Of Contents	**Figure 1.4**





Ambient Wind Speed: 5 MPH

Case #1 (5 mph, 59F Ambient):

- Plan showing Vertical Velocity @ 300 ft AGL

CH2MHILL	Project #: 382914	*CONFIDENTIAL*
	Date: 14 May 2010	Mariposa Energy Project
	File: Diamond Exh CFD_5-14-10	Turbine Exhaust Velocity Characterization

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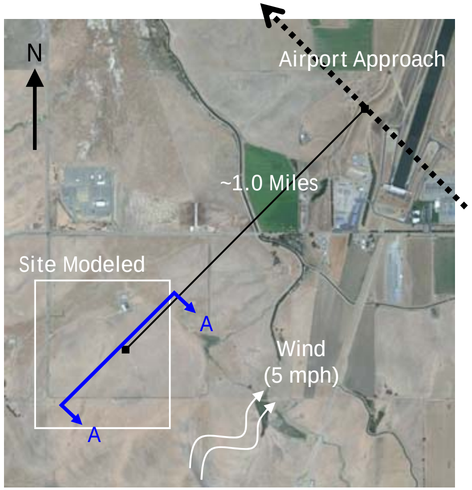
Figure 1.5



Results Summary:

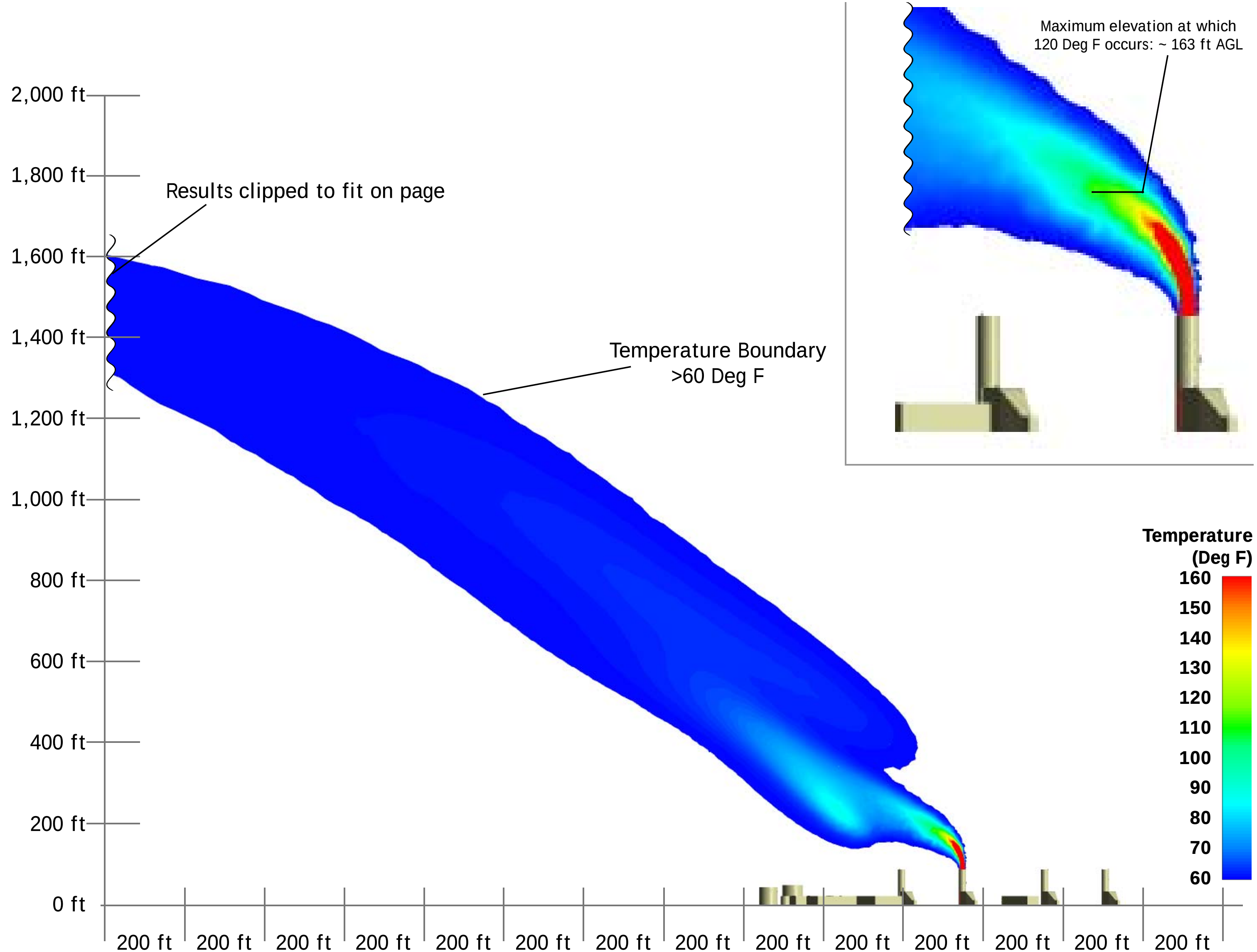
Maximum elevation at which 70 Deg F occurs: ~ 530 ft AGL

Maximum elevation at which 80 Deg F occurs: ~ 361 ft AGL

Maximum horizontal distance at which the temperature of 70 Deg F occurs: ~ 507 ft

Maximum horizontal distance at which the temperature of 80 Deg F occurs: ~ 302 ft

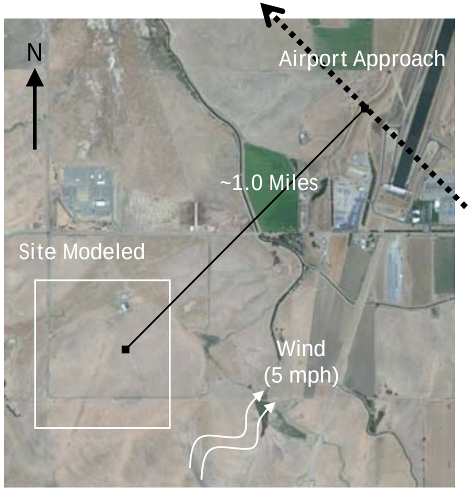
Ambient Temperature: 59 Deg F

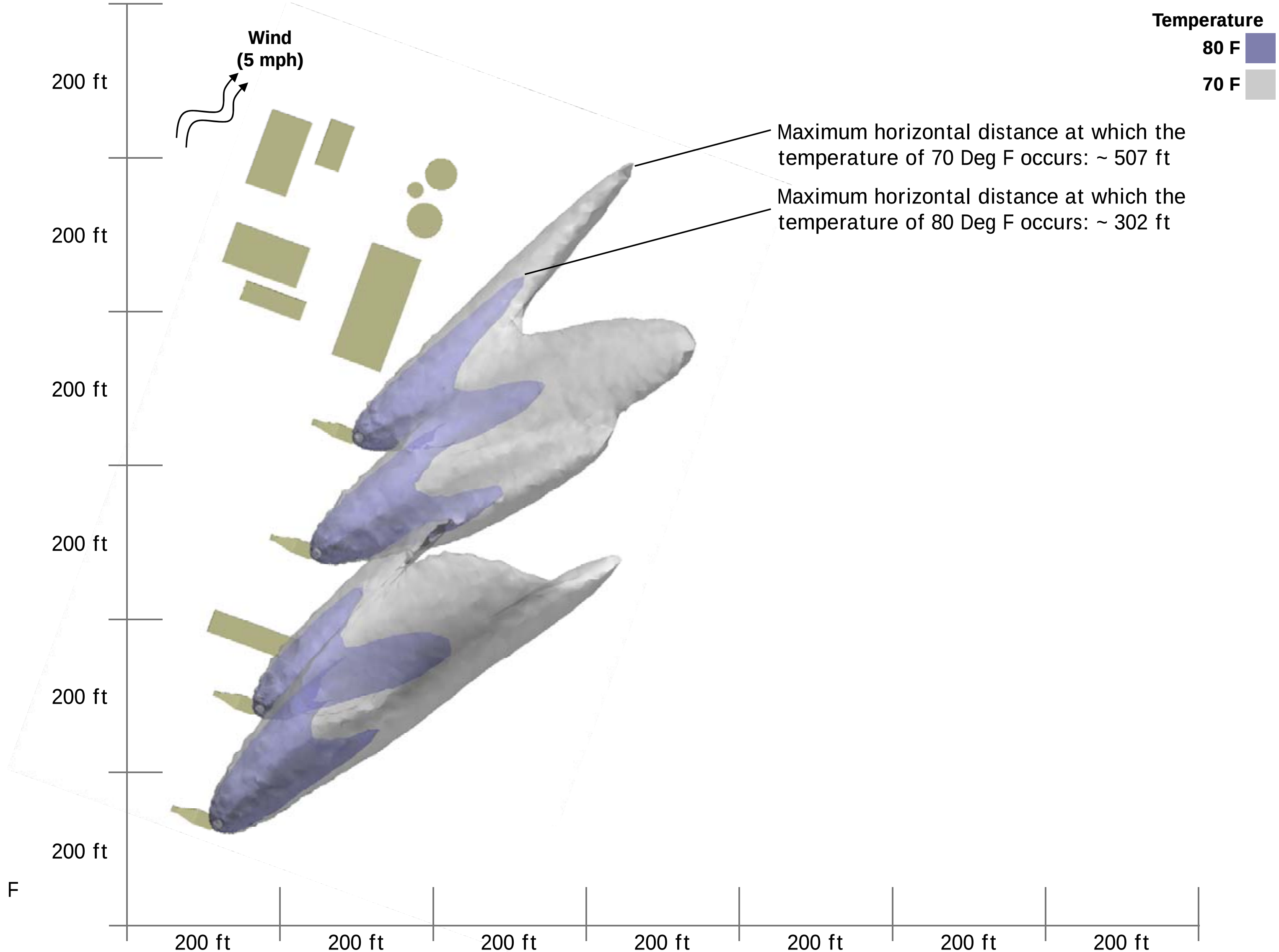


Case #1 (5 mph, 59F Ambient):

- Section showing Temperature

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization Table Of Contents	**Figure 1.6**



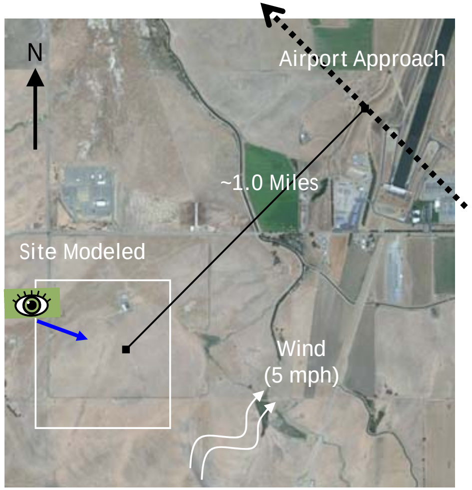


Ambient Temperature: 59 Deg F

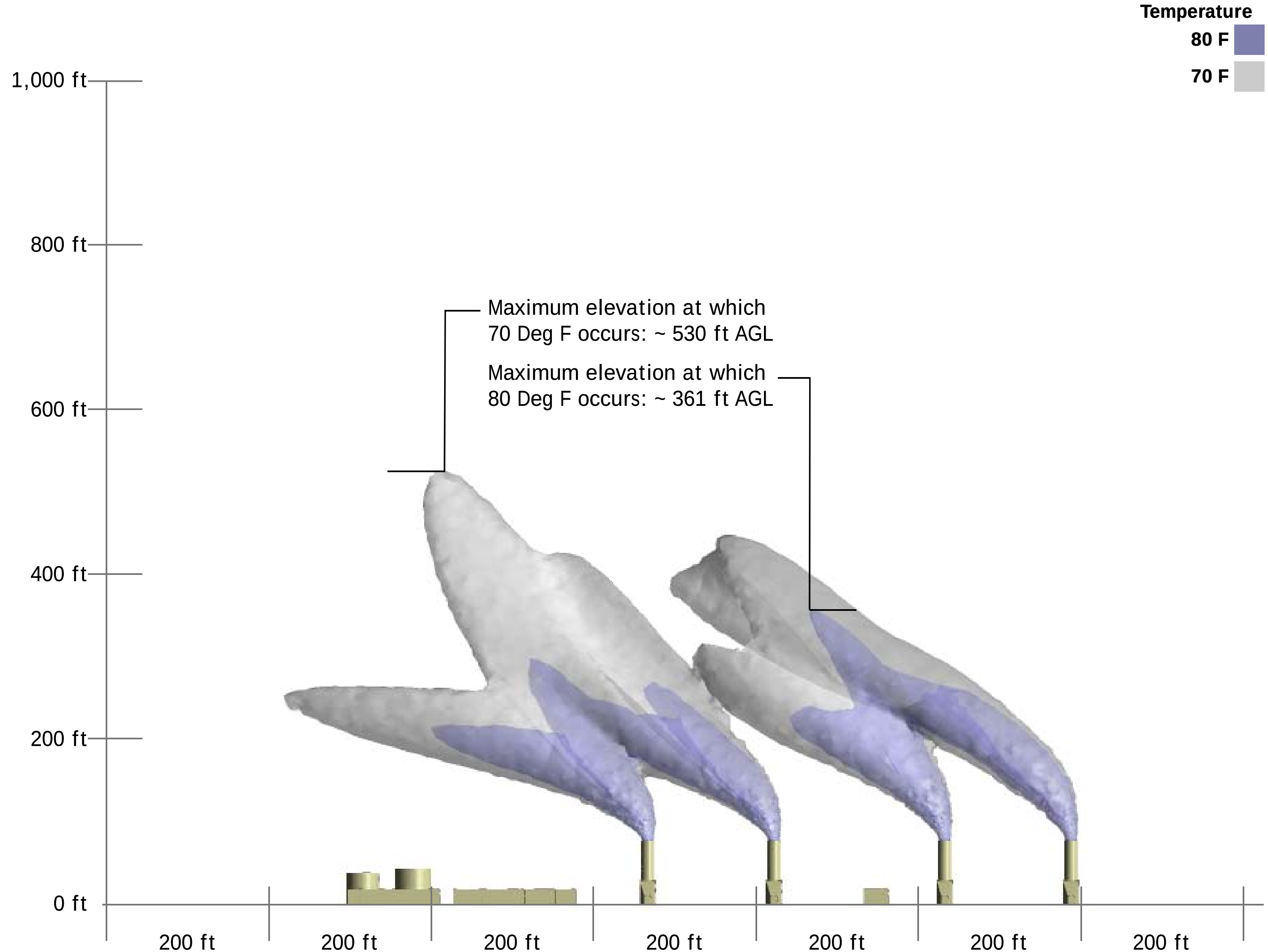
Case #1 (5 mph, 59F Ambient):

- Plan view showing Temperature Isosurfaces

CH2MHILL	Project #: 382914	*CONFIDENTIAL* Mariposa Energy Project	**Figure 1.7**
	Date: 14 May 2010	Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10	Table Of Contents	



* Blue arrow indicates the image viewpoint

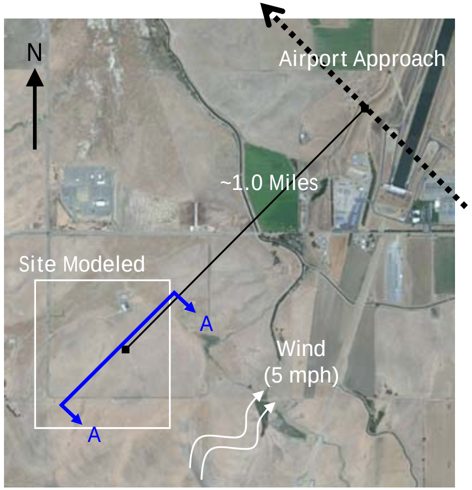


Ambient Temperature: 59 Deg F

Case #1 (5 mph, 59F Ambient):

- Elevation view showing Temperature Isosurfaces

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization	Table Of Contents	**Figure 1.8**



Results Summary:

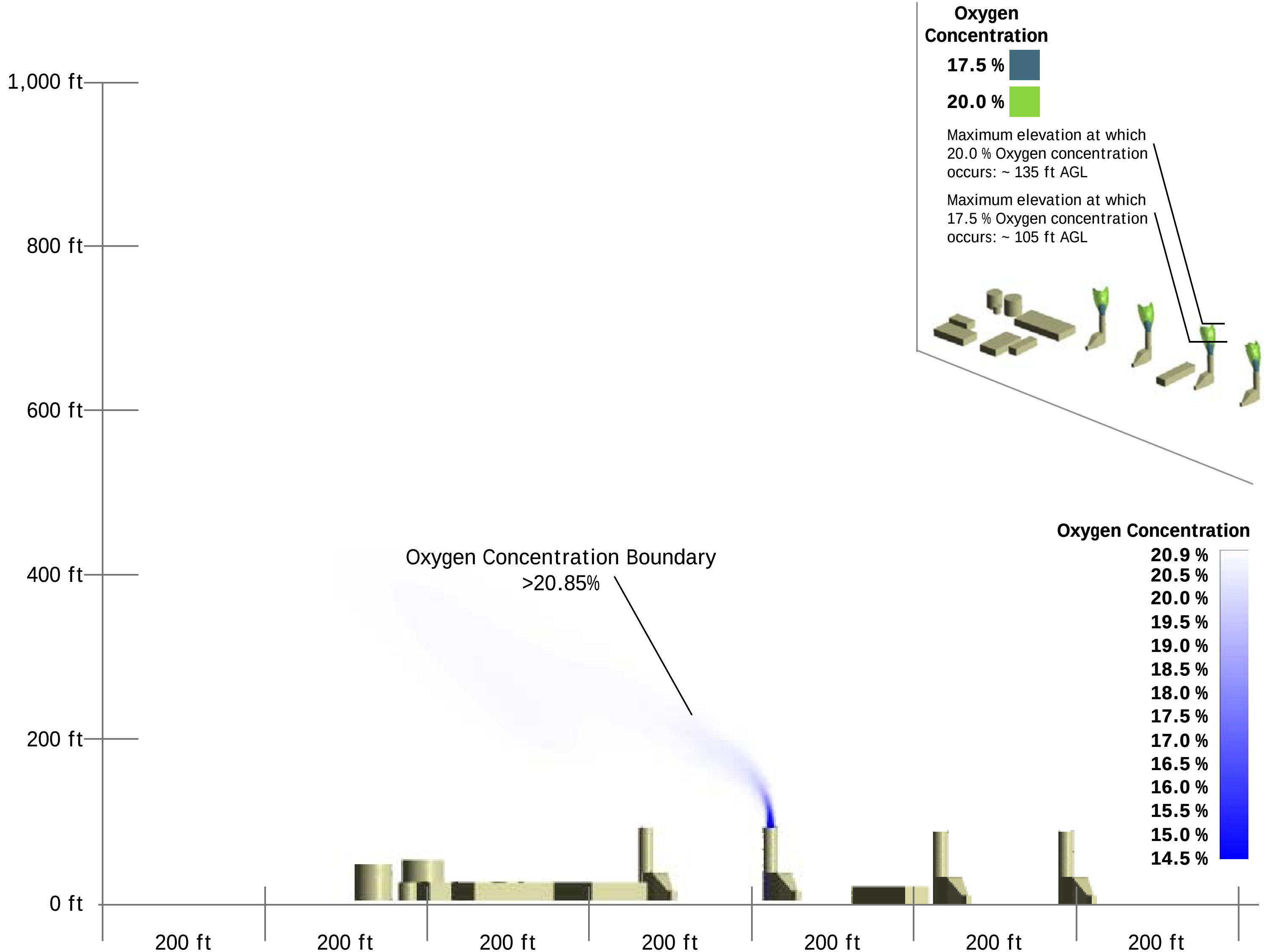
Maximum elevation at which 17.5 % Oxygen concentration occurs: ~ 105 ft AGL

Maximum elevation at which 20.0 % Oxygen concentration occurs: ~ 135 ft AGL

Maximum horizontal distance at which the concentration of 17.5 % occurs: ~ 16 ft

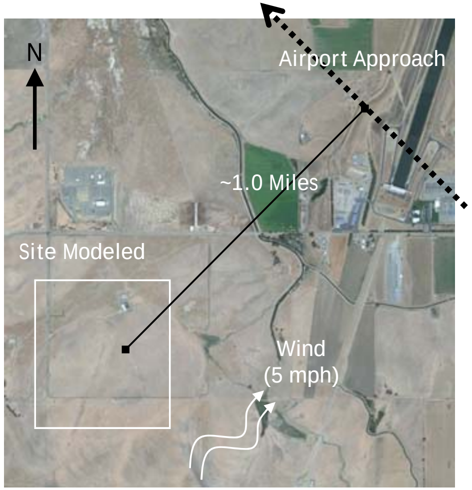
Maximum horizontal distance at which the concentration of 20.0 % occurs: ~ 48 ft

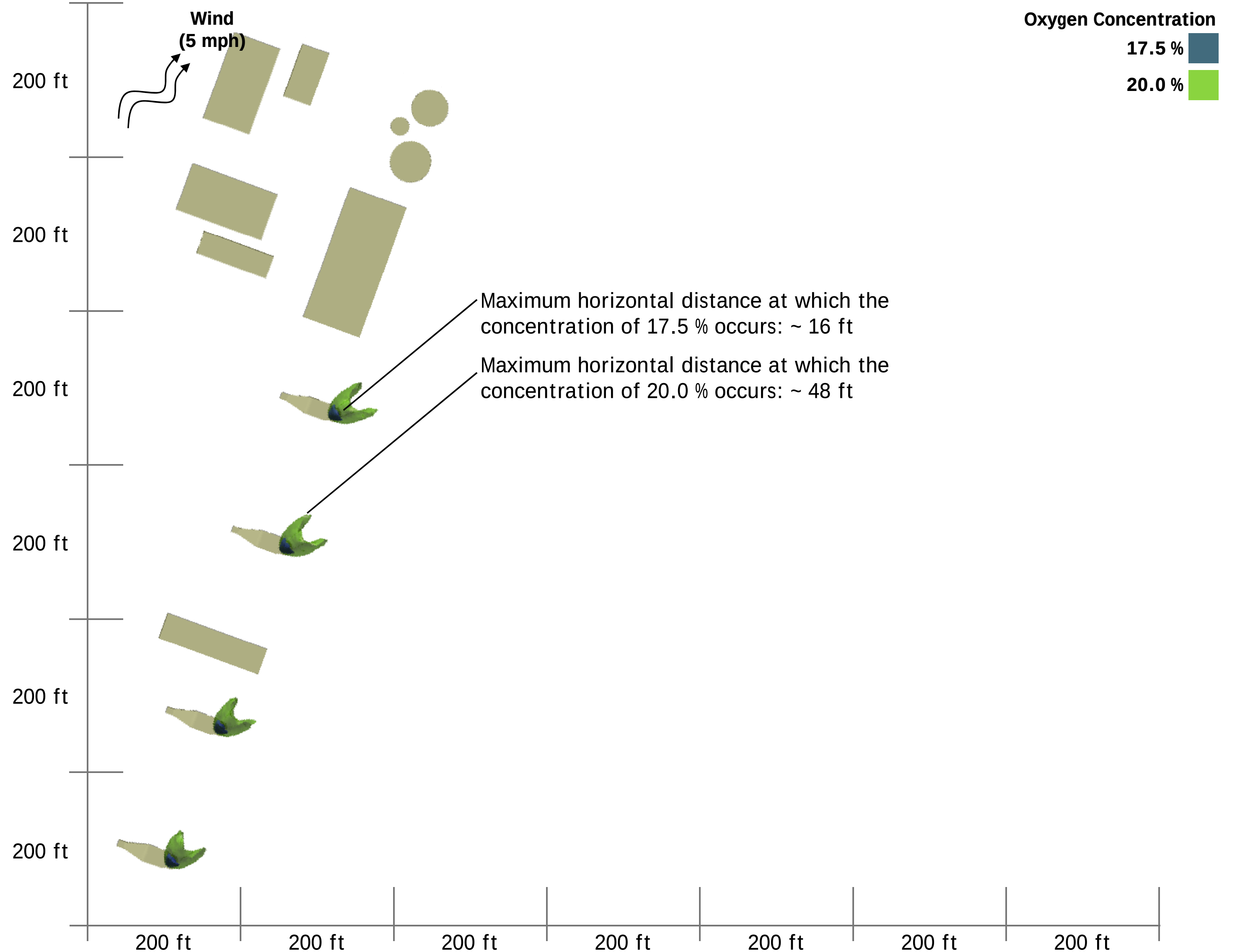
Ambient Oxygen: 20.9 %
Stack Exhaust Oxygen: 14.5 %



Case #1 (5 mph, 59F Ambient):
- Section showing Oxygen Concentrations

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization Table Of Contents	**Figure 1.9**





Ambient Oxygen: 20.9 %
Stack Exhaust Oxygen: 14.5 %

Case #1 (5 mph, 59F Ambient):

- Plan view showing Oxygen concentration Isosurfaces

CH2MHILL

Project #: 382914
Date: 14 May 2010
File: Diamond Exh CFD_5-14-10

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Mariposa Energy Project
Turbine Exhaust Velocity Characterization

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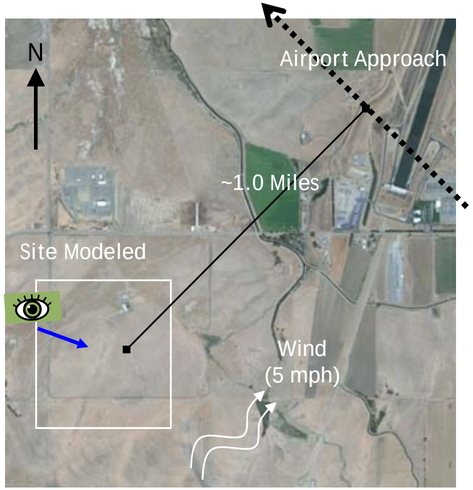
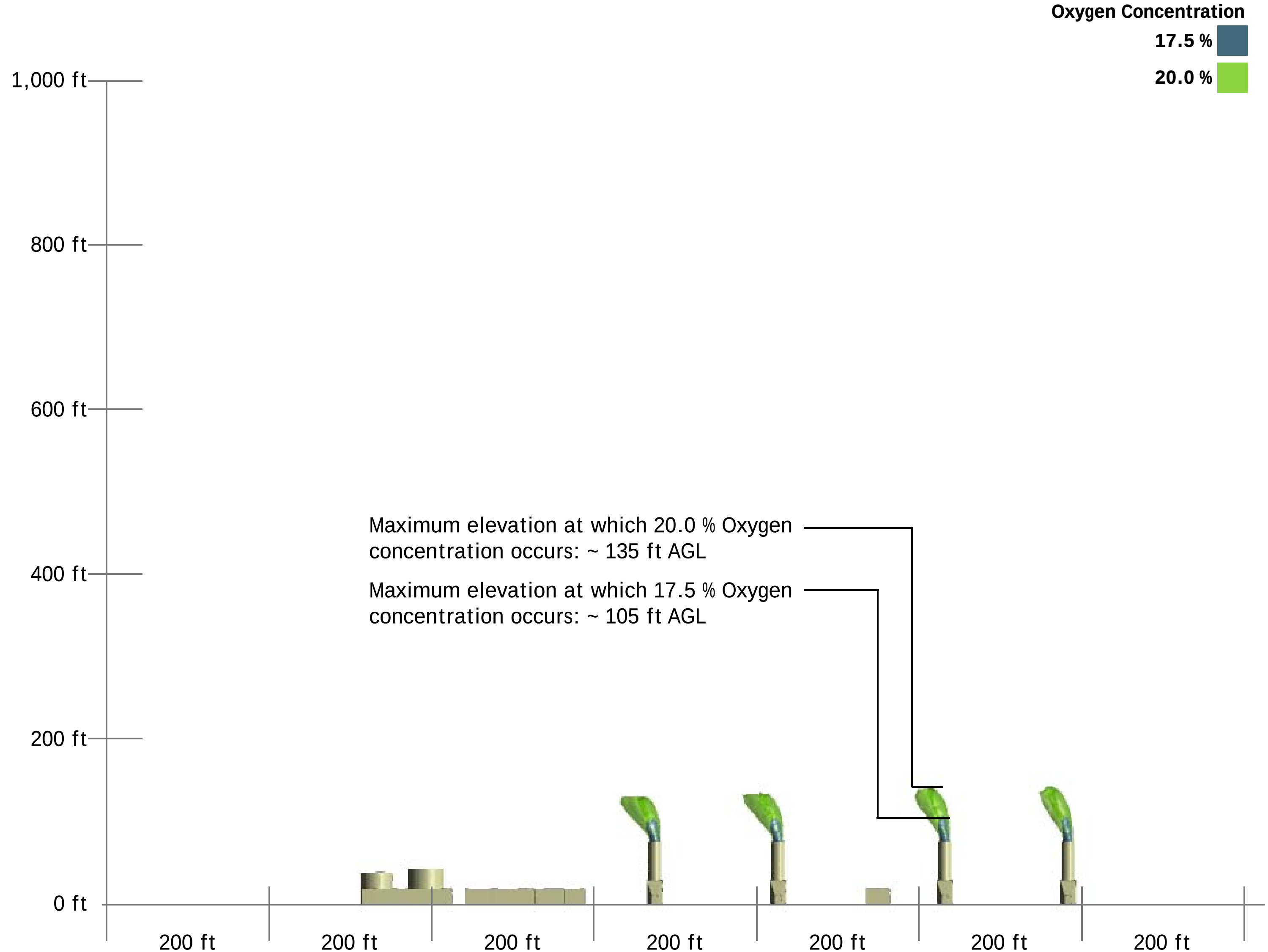
Figure 1.10



* Blue arrow indicates the image viewpoint



Ambient Oxygen: 20.9 %
Stack Exhaust Oxygen: 14.5 %

Case #1 (5 mph, 59F Ambient):

- Elevation view showing Oxygen concentration Isosurfaces

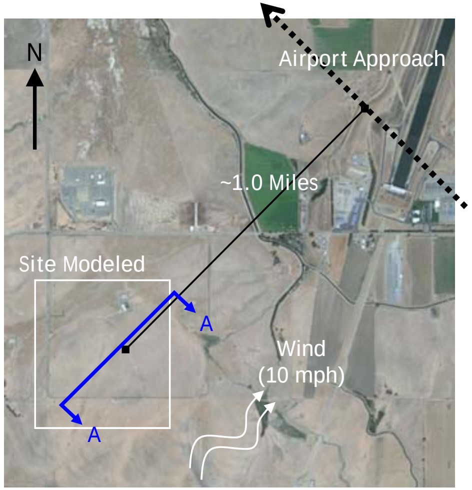
CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project	Figure 1.11
	Date: 14 May 2010		Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10		Table Of Contents	

Case #2

10 MPH Wind – 59F Ambient Conditions

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
59	60	100	848	1,051,375	597,341	79.5	12.0	14.5	60.0

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)



Results Summary:

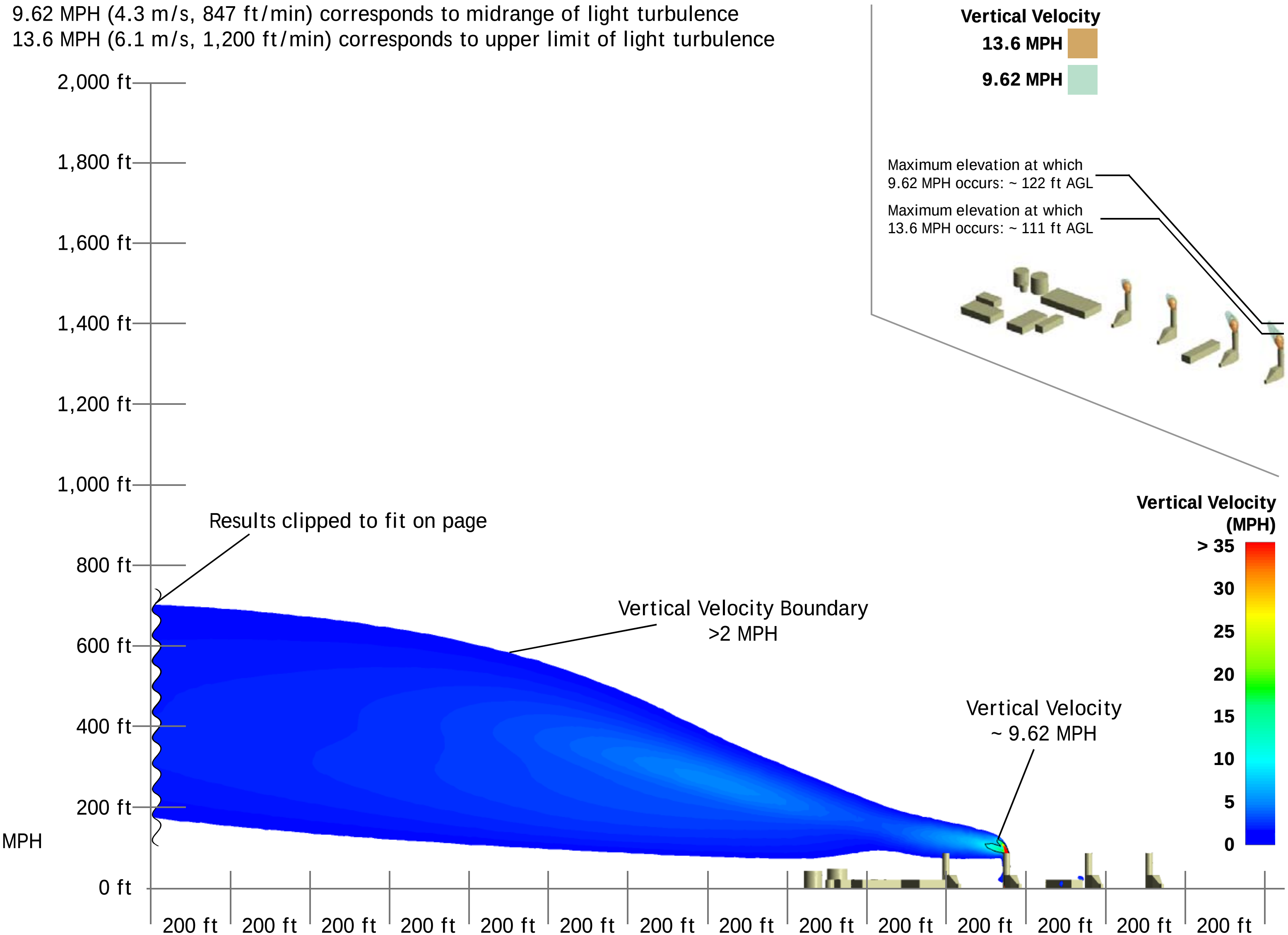
Maximum elevation at which 9.62 MPH occurs: ~ 122 ft AGL

Maximum elevation at which 13.6 MPH occurs: ~ 111 ft AGL

Maximum horizontal distance at which the velocity of 9.62 MPH occurs: ~ 76 ft

Maximum horizontal distance at which the velocity of 13.6 MPH occurs: ~ 23 ft

Ambient Wind Speed: 10 MPH



Case #2 (10 mph, 59F Ambient):

- Section A-A showing Vertical Velocity

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization	**Figure 2.0**

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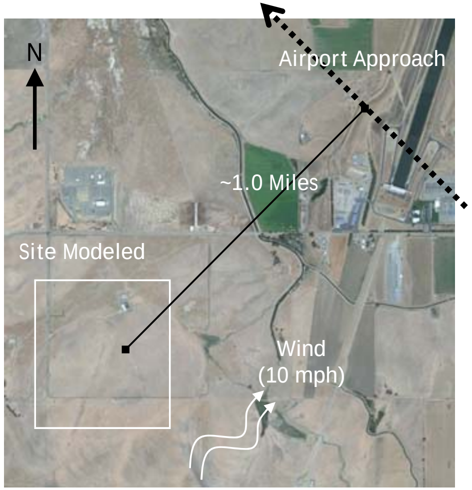
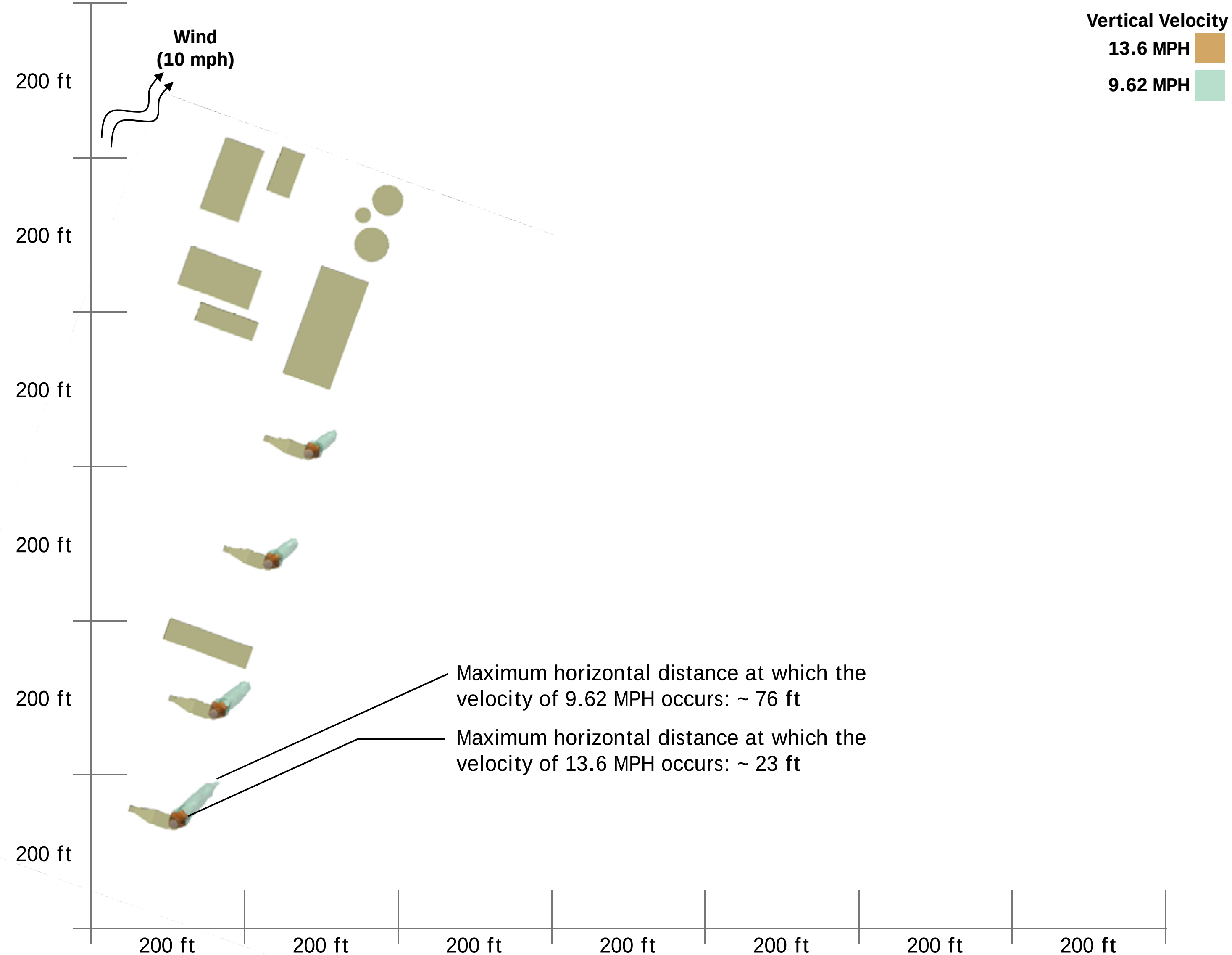
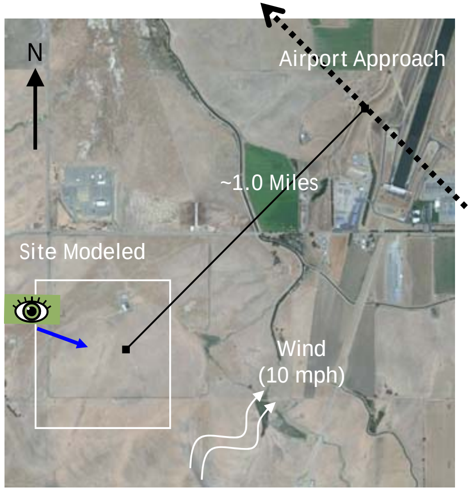




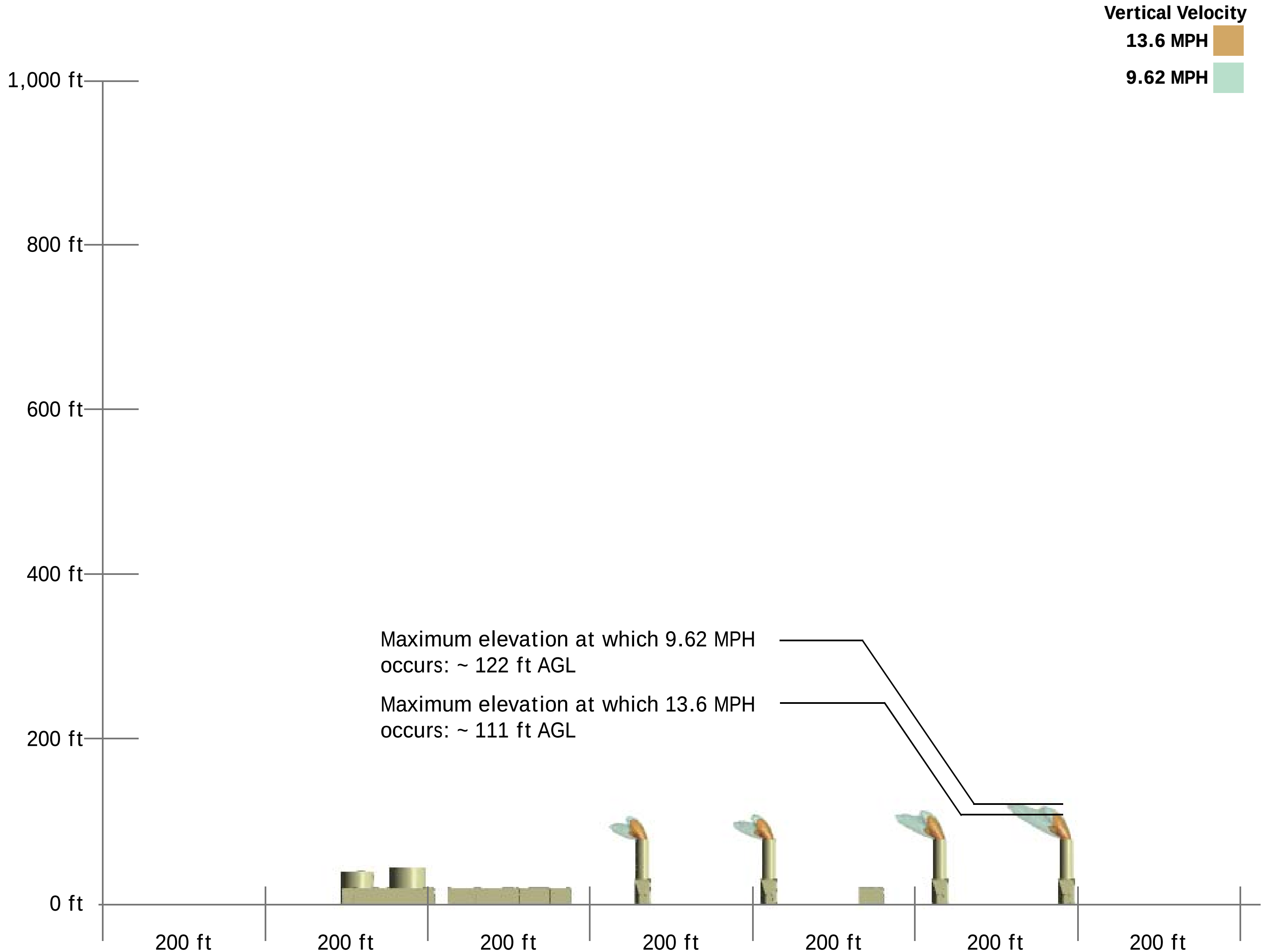
Case #2 (10 mph, 59F Ambient):

- Plan view showing Vertical Velocity Isosurfaces

CH2MHILL	Project #: 382914	*CONFIDENTIAL* Mariposa Energy Project	**Figure 2.1**
	Date: 14 May 2010	Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10	Table Of Contents	



* Blue arrow indicates the image viewpoint



Ambient Wind Speed: 10 MPH

Case #2 (10 mph, 59F Ambient):

- Elevation view showing Vertical Velocity Isosurfaces

CH2MHILL

Project #: 382914

Date: 14 May 2010

File: Diamond Exh CFD_5-14-10

CONFIDENTIAL

Mariposa Energy Project

Turbine Exhaust Velocity Characterization

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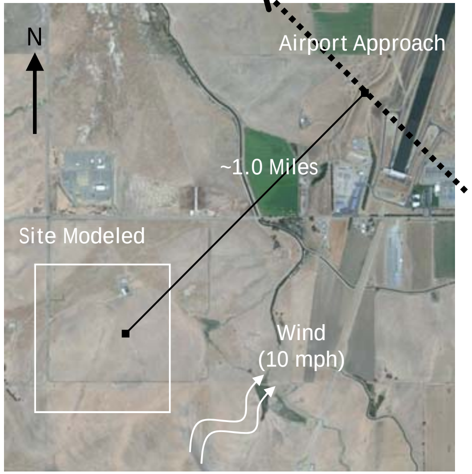
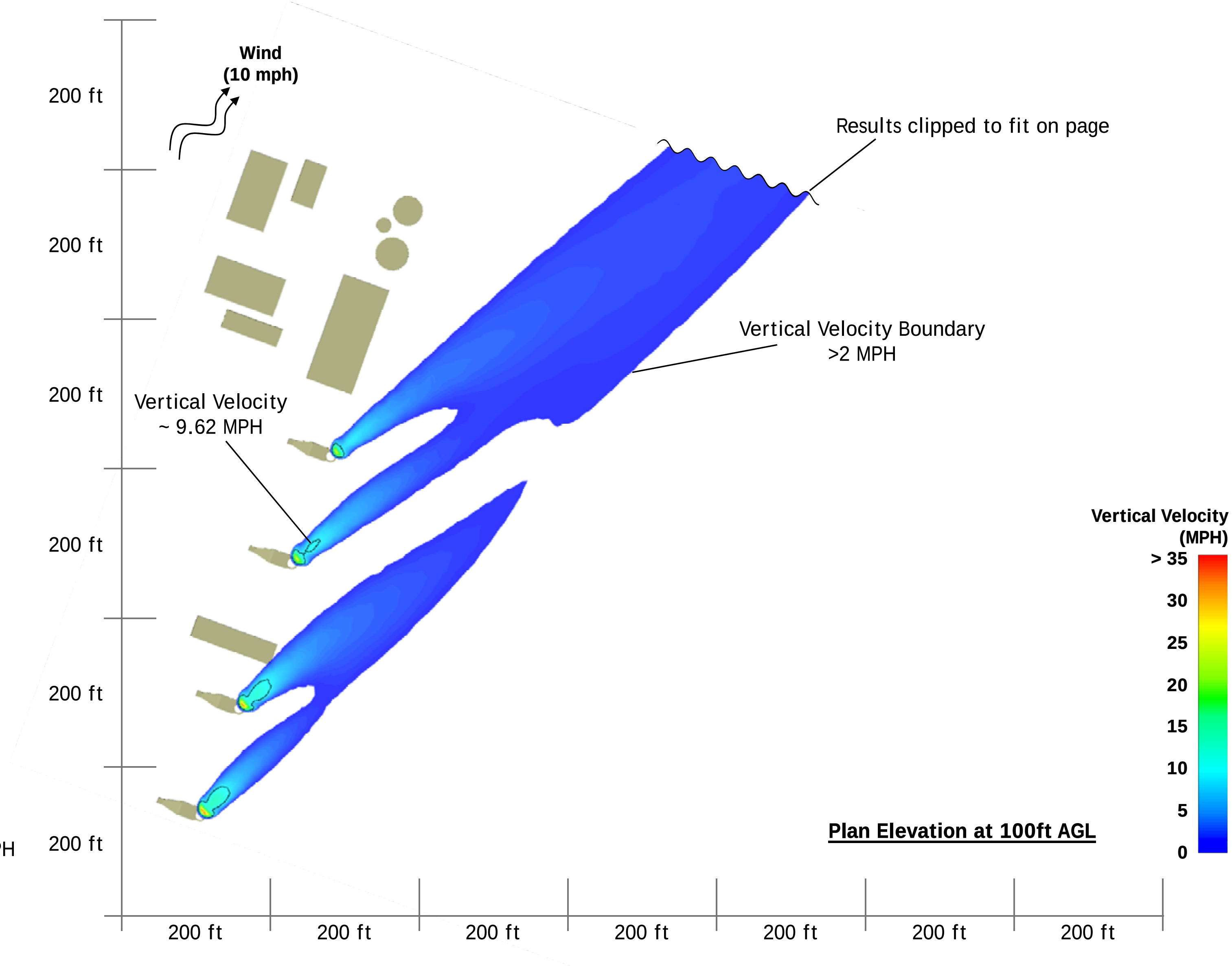
Figure 2.2



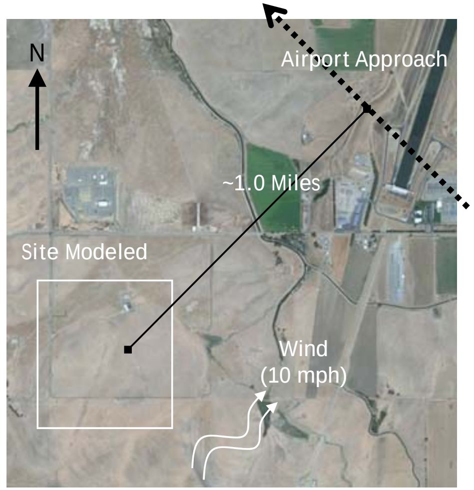


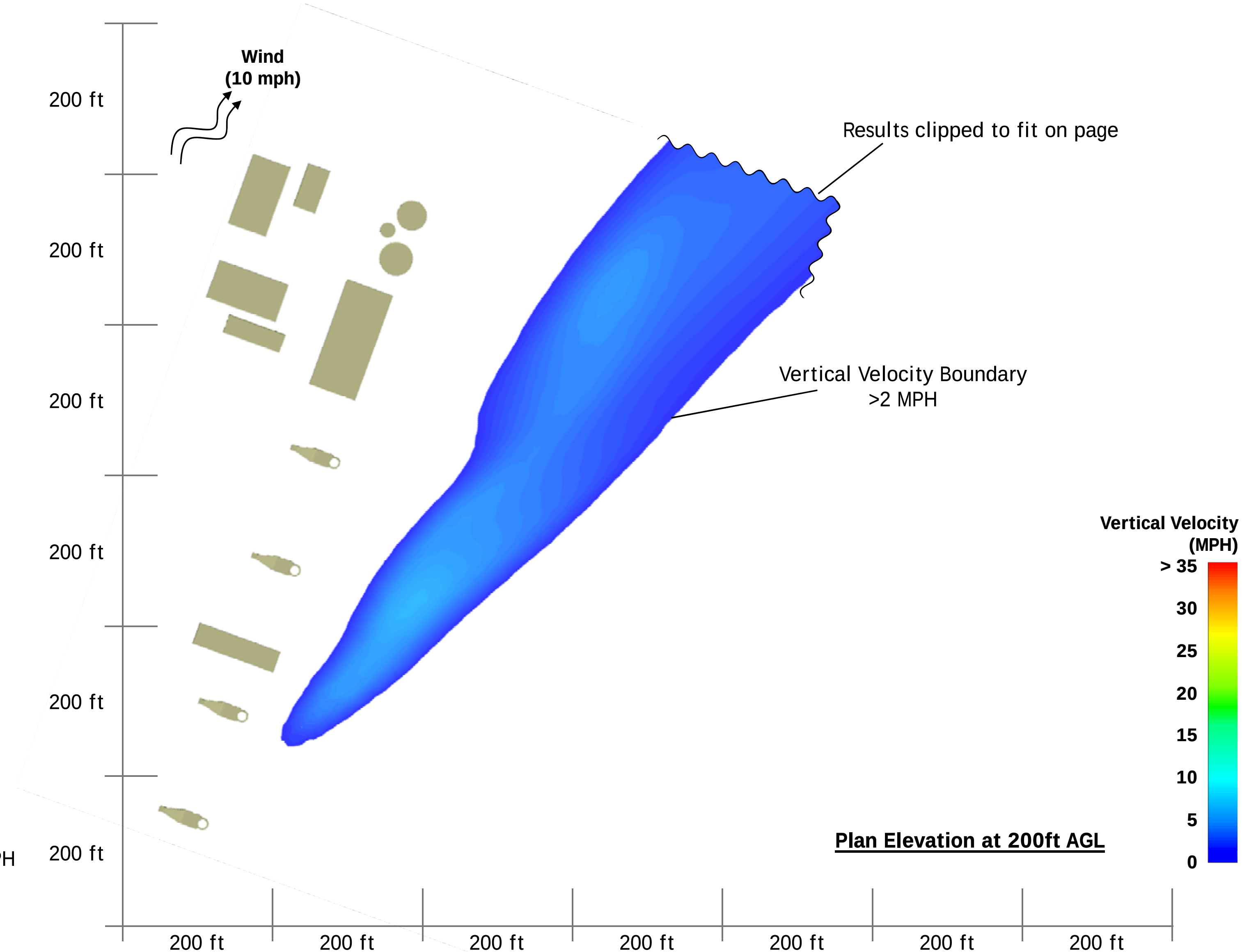
Ambient Wind Speed: 10 MPH

Case #2 (10 mph, 59F Ambient):

- Plan showing Vertical Velocity @ 100 ft AGL

CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project	Figure 2.3
	Date: 14 May 2010		Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10		Table Of Contents	





Ambient Wind Speed: 10 MPH

Case #2 (10 mph, 59F Ambient):

- Plan showing Vertical Velocity @ 200 ft AGL

CH2MHILL

Project #: 382914

Date: 14 May 2010

File: Diamond Exh CFD_5-14-10

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Turbine Exhaust Velocity Characterization

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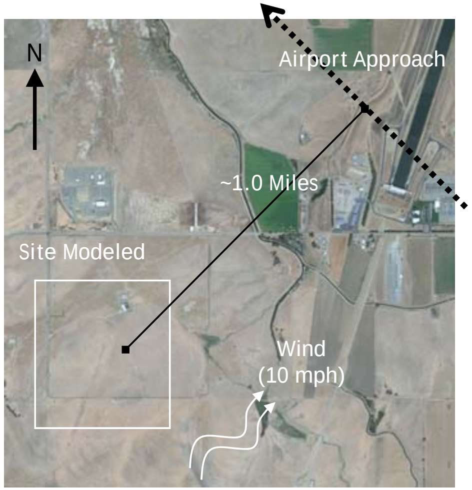
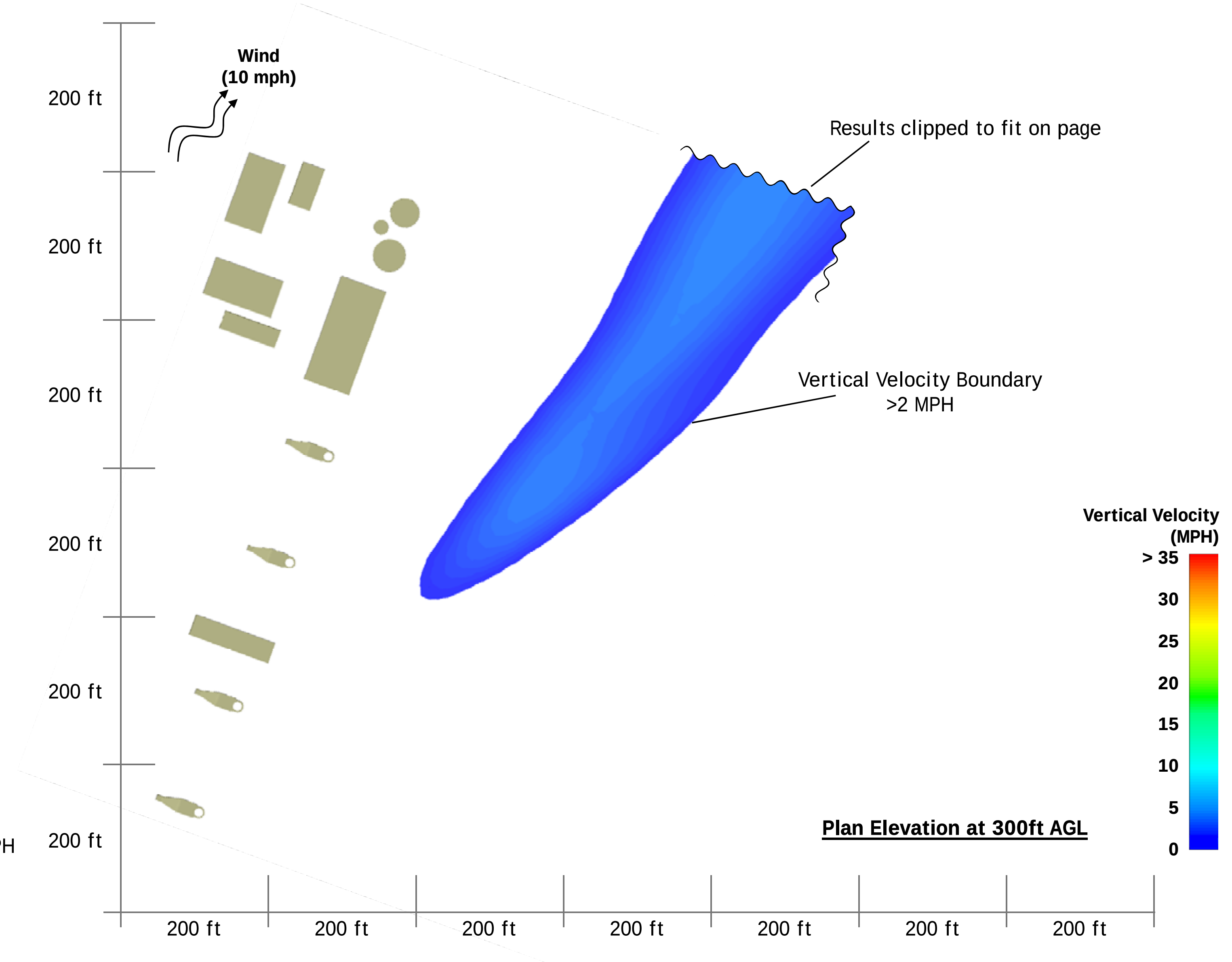
Figure 2.4





Ambient Wind Speed: 10 MPH

Case #2 (10 mph, 59F Ambient):

- Plan showing Vertical Velocity @ 300 ft AGL

CH2MHILL

Project #: 382914	
Date: 14 May 2010	
File: Diamond Exh CFD_5-14-10	

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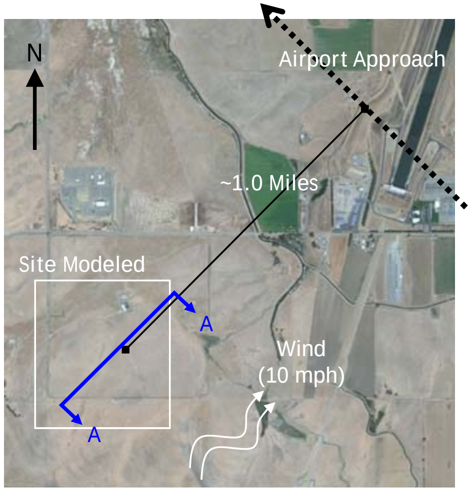
Figure 2.5



Results Summary:

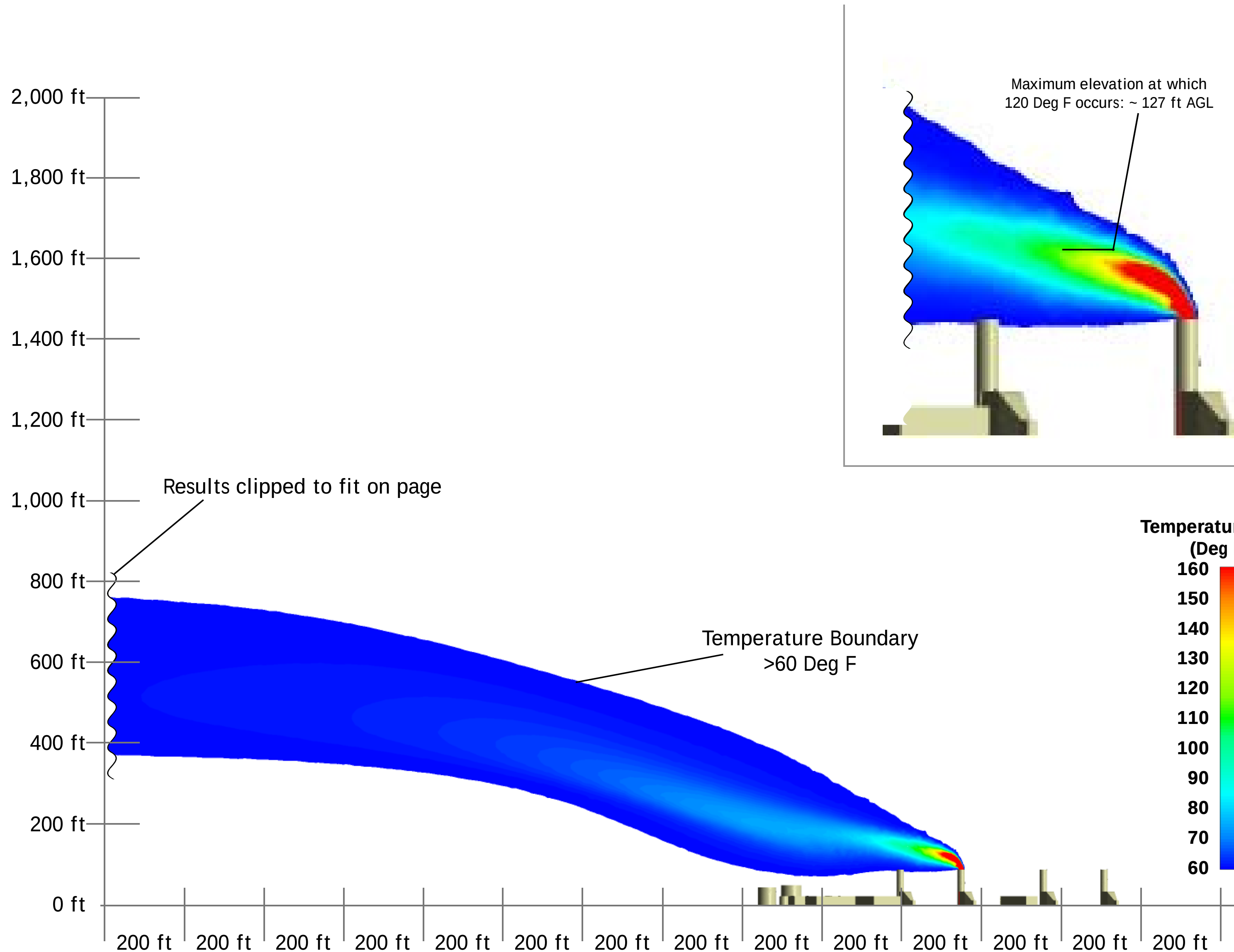
Maximum elevation at which 70 Deg F occurs:
~ 309 ft AGL

Maximum elevation at which 80 Deg F occurs:
~ 244 ft AGL

Maximum horizontal distance at which the temperature of 70 Deg F occurs: ~ 556 ft

Maximum horizontal distance at which the temperature of 80 Deg F occurs: ~ 338 ft

Ambient Temperature: 59 Deg F



Case #2 (10 mph, 59F Ambient):
- Section showing Temperature

CH2MHILL

Project #: 382914
Date: 14 May 2010
File: Diamond Exh CFD_5-14-10

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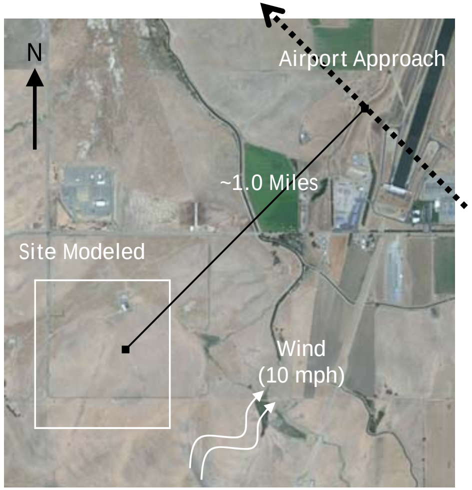
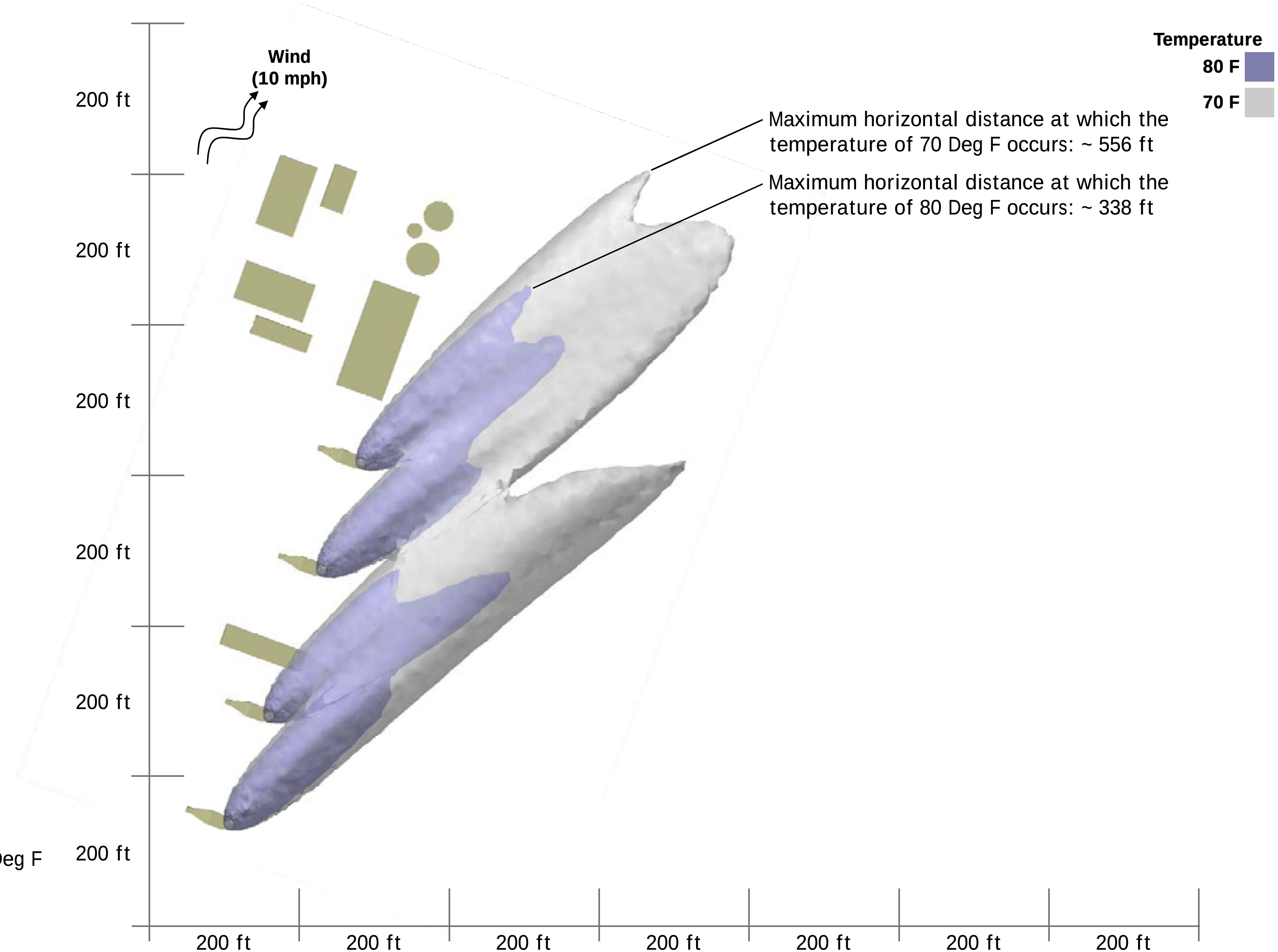
Figure 2.6



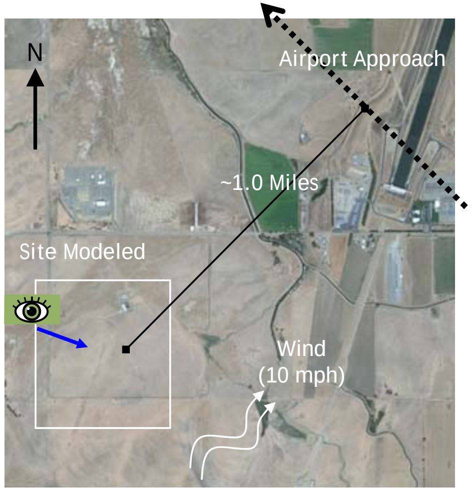


Ambient Temperature: 59 Deg F

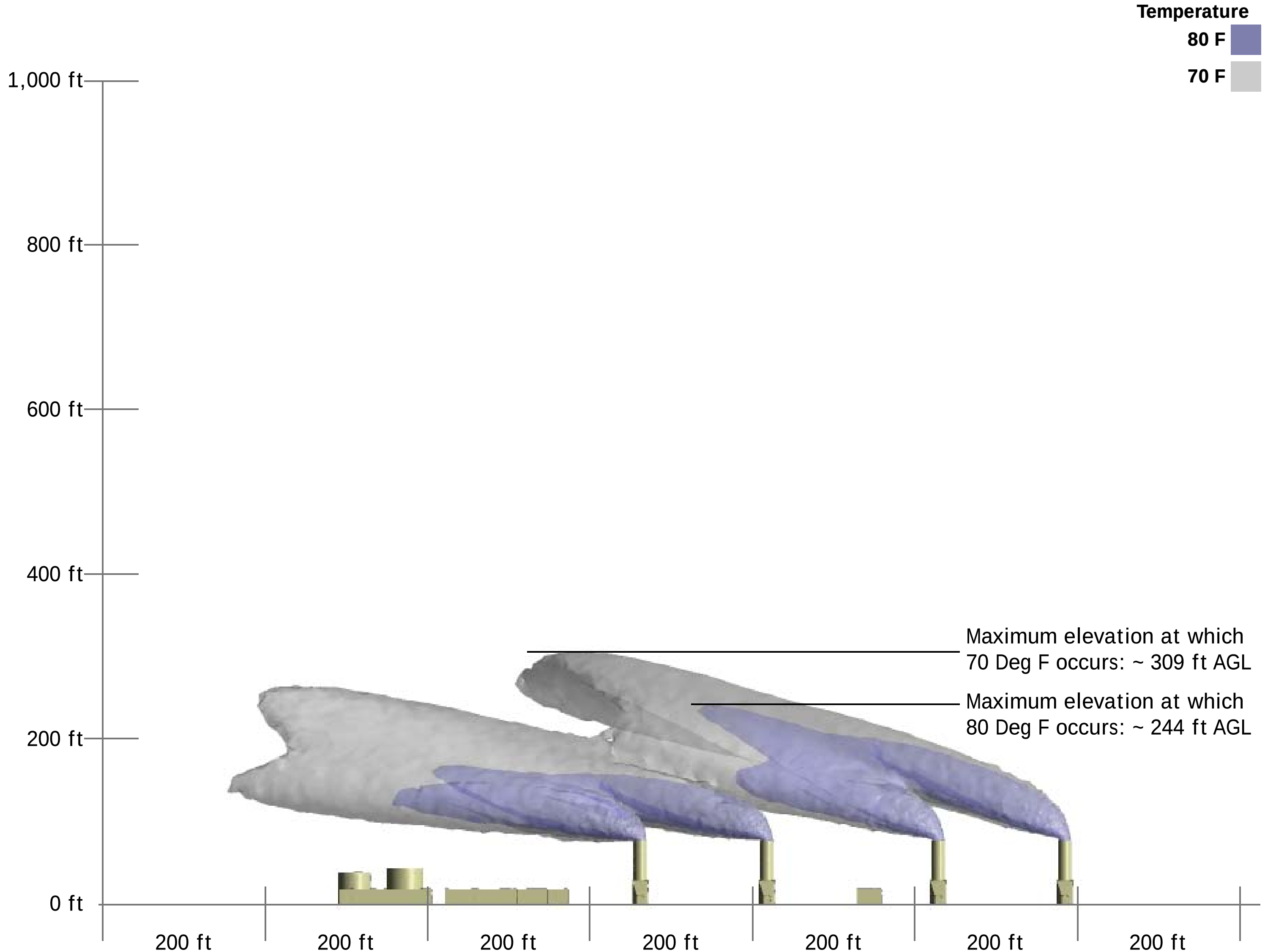
Case #2 (10 mph, 59F Ambient):

- Plan view showing Temperature Isosurfaces

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization	Table Of Contents	**Figure 2.7**



* Blue arrow indicates the image viewpoint



Ambient Temperature: 59 Deg F

Case #2 (10 mph, 59F Ambient):

- Elevation view showing Temperature Isosurfaces

CH2MHILL

Project #: 382914	
Date: 14 May 2010	
File: Diamond Exh CFD_5-14-10	

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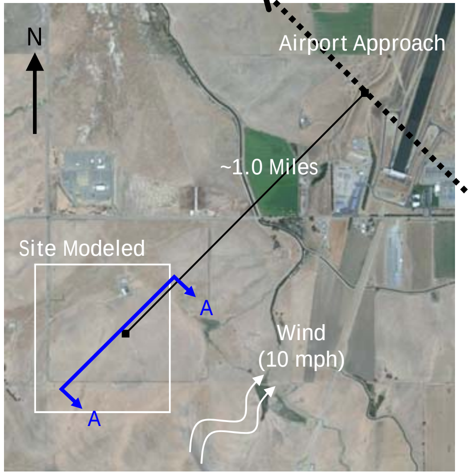
Figure 2.8



Results Summary:

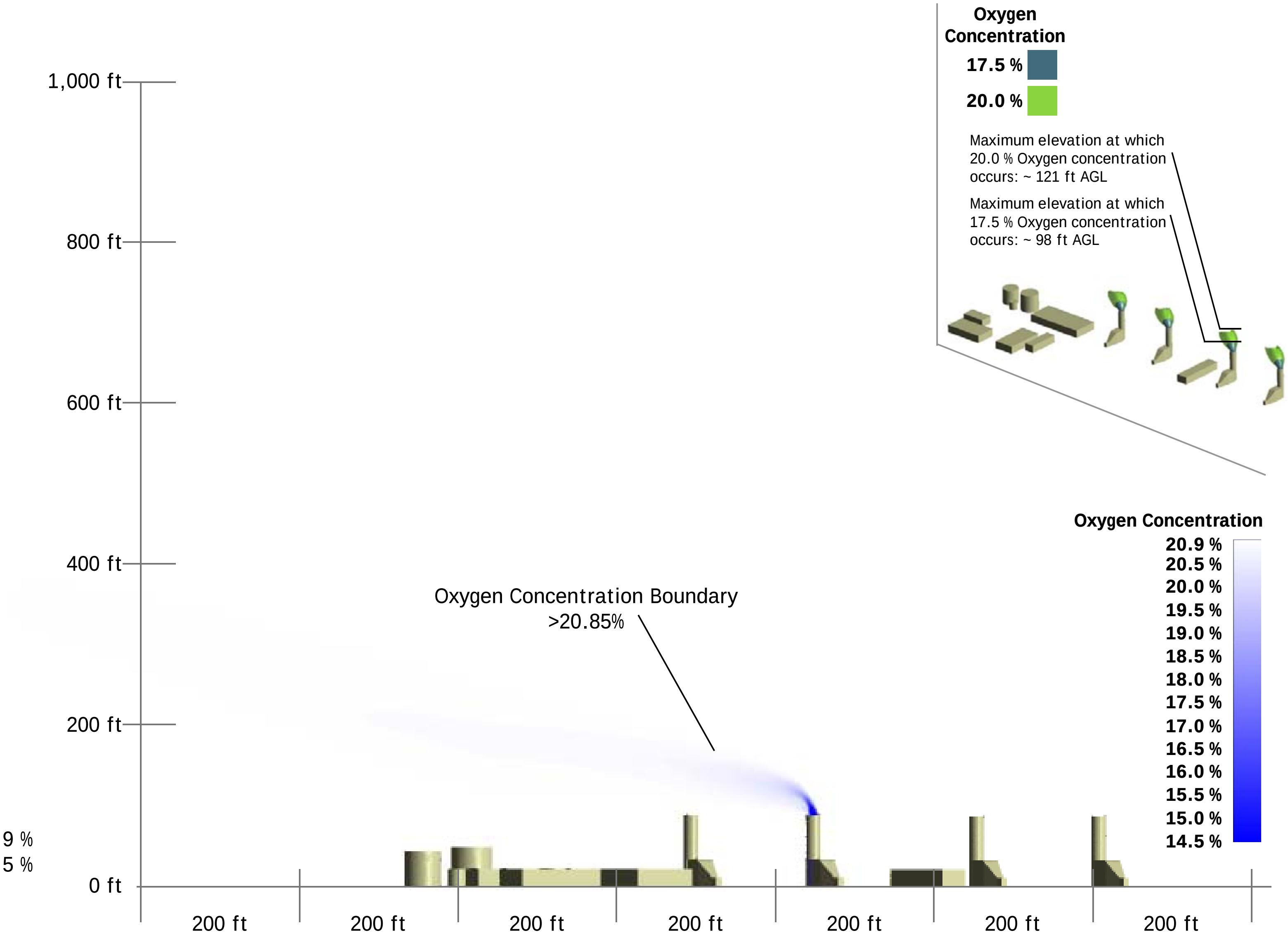
Maximum elevation at which 17.5 % Oxygen concentration occurs: ~ 98 ft AGL

Maximum elevation at which 20.0 % Oxygen concentration occurs: ~ 121 ft AGL

Maximum horizontal distance at which the concentration of 17.5 % occurs: ~ 21 ft

Maximum horizontal distance at which the concentration of 20.0 % occurs: ~ 63 ft

Ambient Oxygen: 20.9 %
Stack Exhaust Oxygen: 14.5 %



Case #2 (10 mph, 59F Ambient):
- Section showing Oxygen Concentrations

CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project Turbine Exhaust Velocity Characterization	Figure 2.9
	Date: 14 May 2010			
	File: Diamond Exh CFD_5-14-10			

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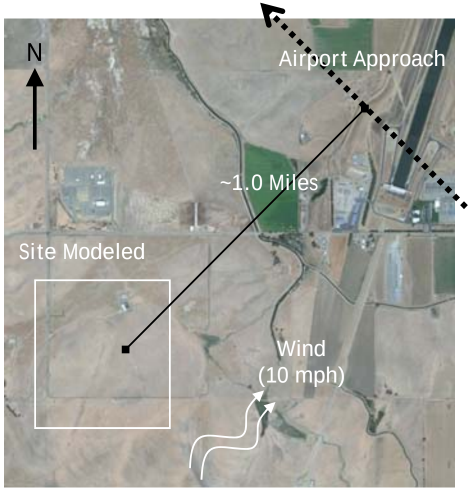
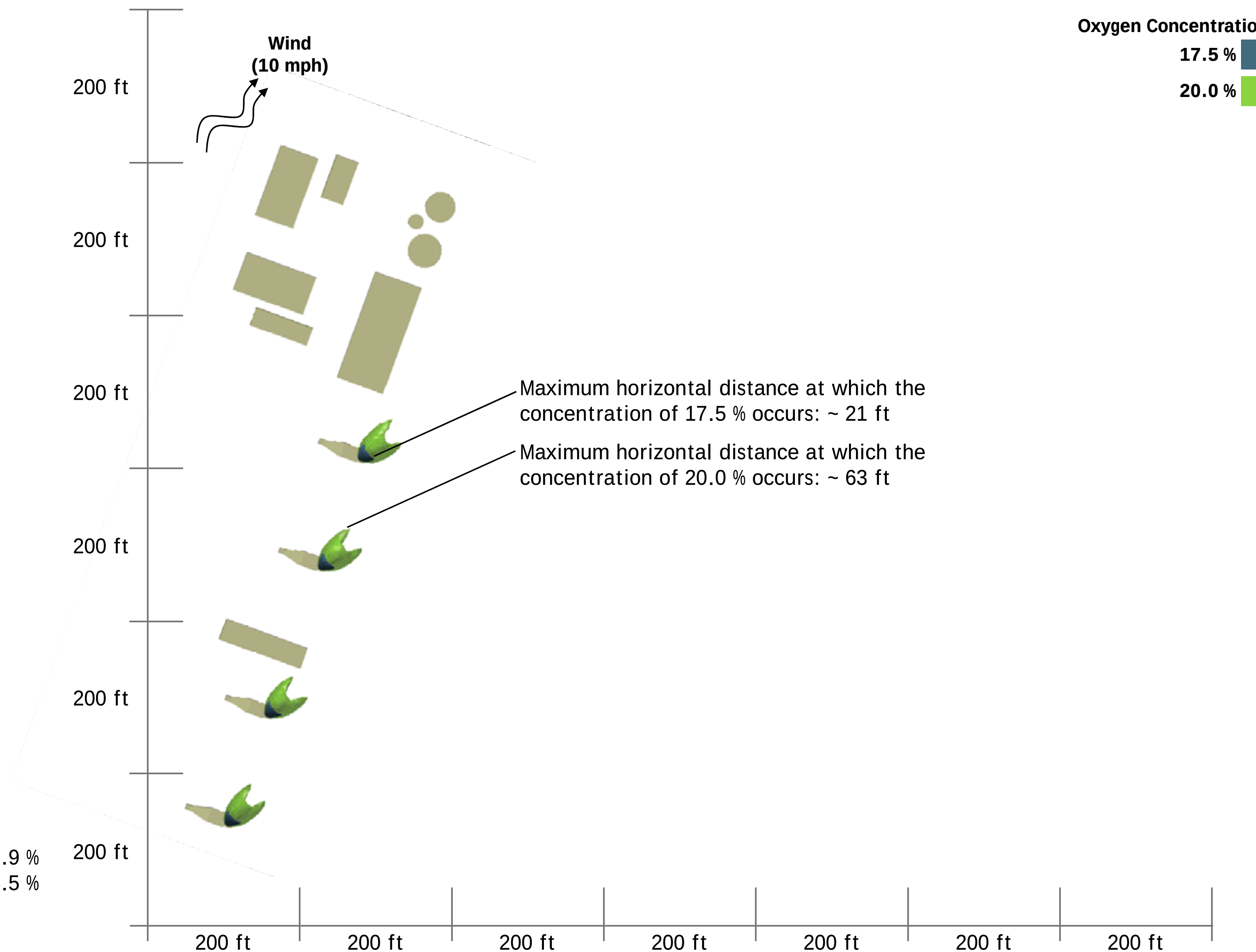
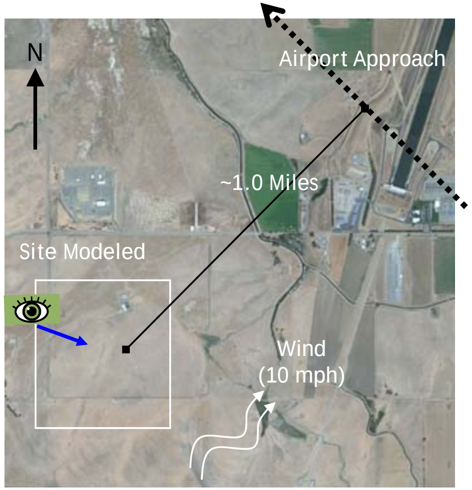




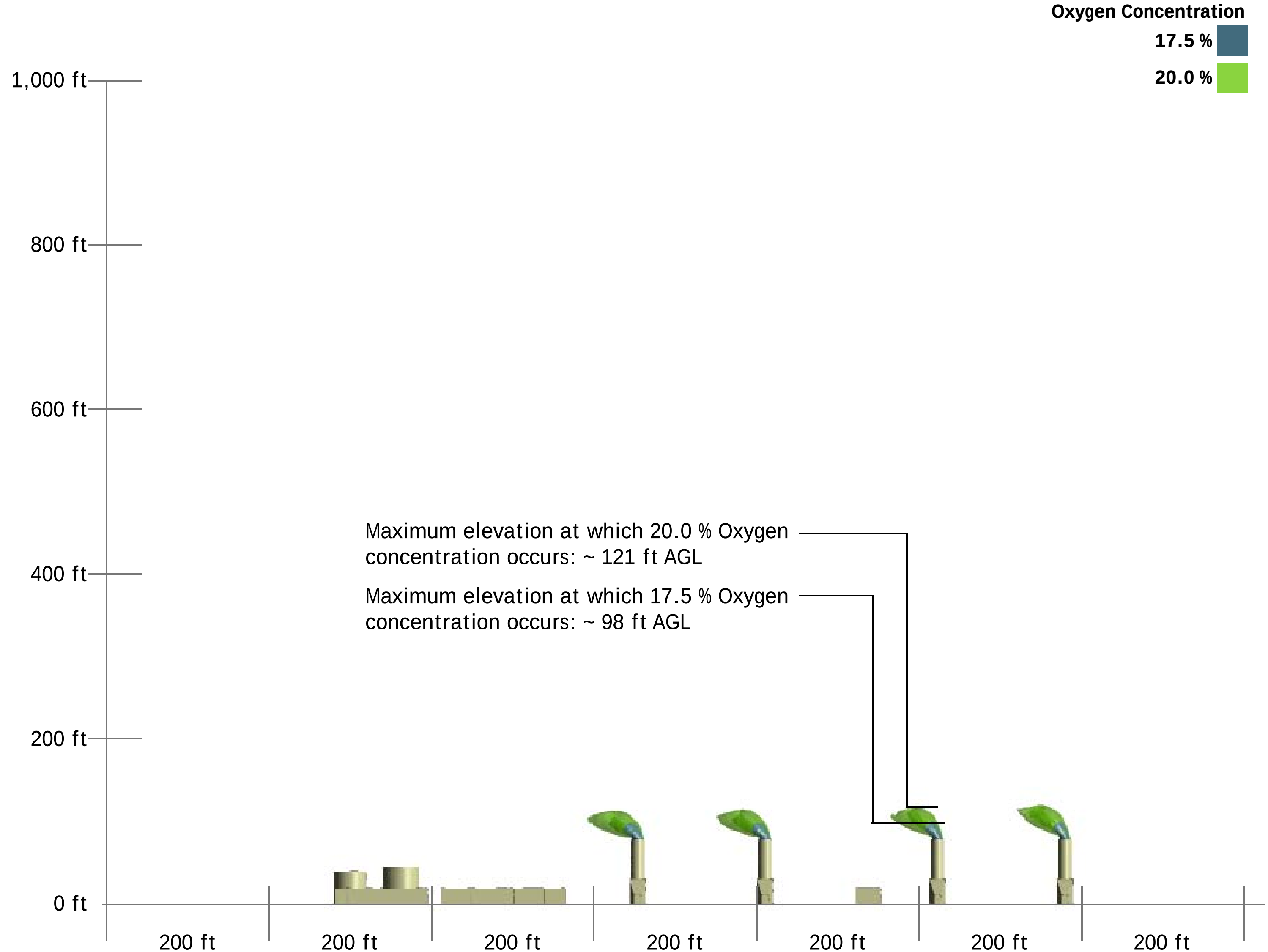
Ambient Oxygen: 20.9 %
Stack Exhaust Oxygen: 14.5 %

Case #2 (10 mph, 59F Ambient):

- Plan view showing Oxygen concentration Isosurfaces



* Blue arrow indicates the image viewpoint



Ambient Oxygen: 20.9 %
Stack Exhaust Oxygen: 14.5 %

Case #2 (10 mph, 59F Ambient):
- Elevation view showing Oxygen concentration Isosurfaces

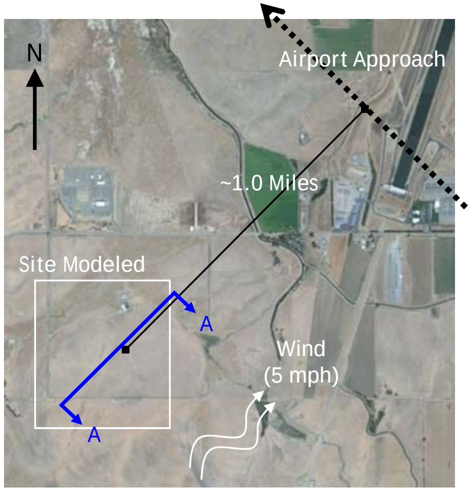
CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL* Mariposa Energy Project Turbine Exhaust Velocity Characterization	Table Of Contents	**Figure 2.11**

Case #3

5 MPH Wind Speed – 112F Ambient Conditions

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
112	15	100	863	845,007	485,749	79.5	12.0	15.3	48.8

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)



Results Summary:

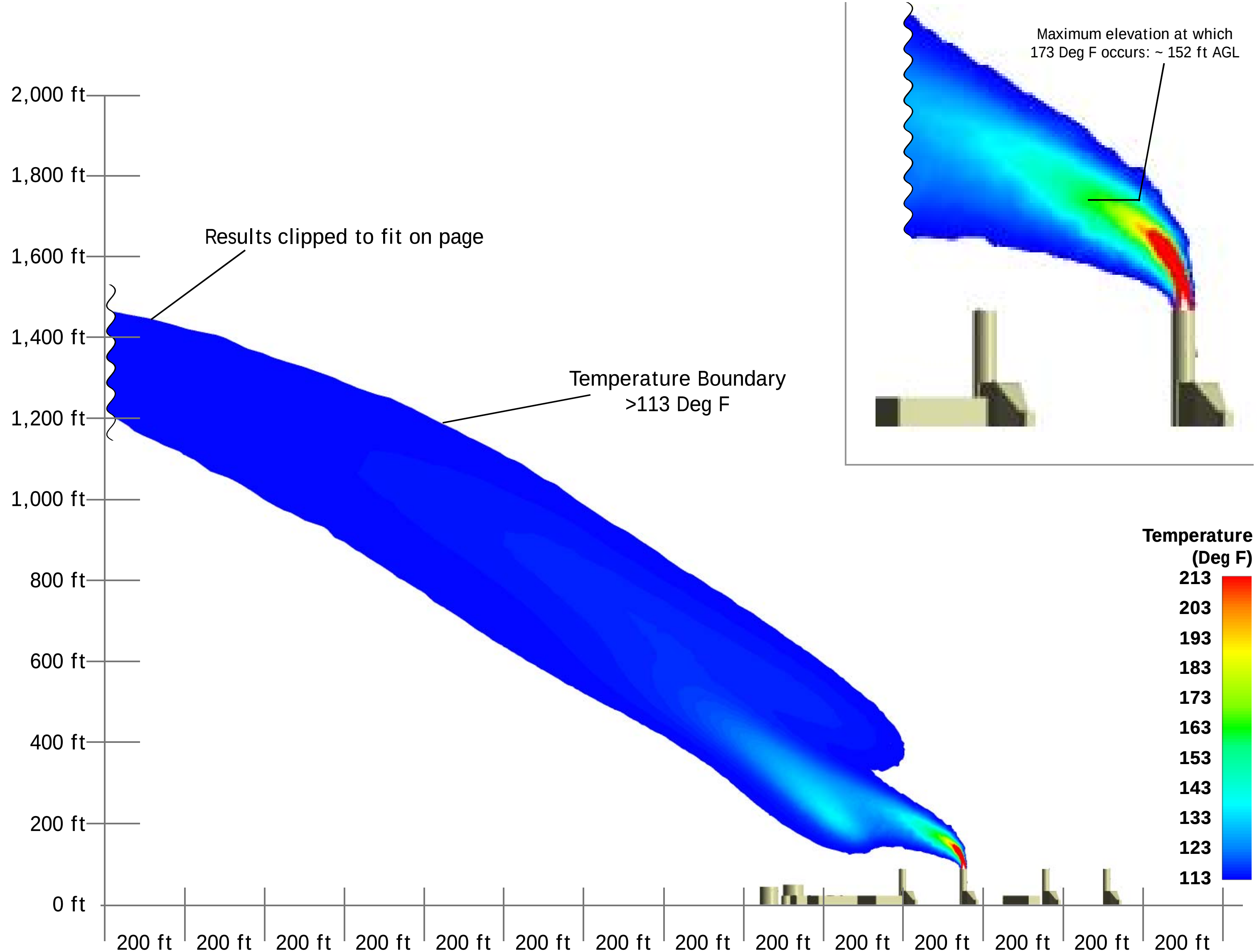
Maximum elevation at which 122 Deg F occurs:
~ 461 ft AGL

Maximum elevation at which 132 Deg F occurs:
~ 325 ft AGL

Maximum horizontal distance at which the temperature of 122 Deg F occurs: ~ 480 ft

Maximum horizontal distance at which the temperature of 132 Deg F occurs: ~ 298 ft

Ambient Temperature: 112 Deg F



Case #3 (5 mph, 112F Ambient):

- Section showing Temperature

CH2MHILL

Project #: 382914	
Date: 14 May 2010	
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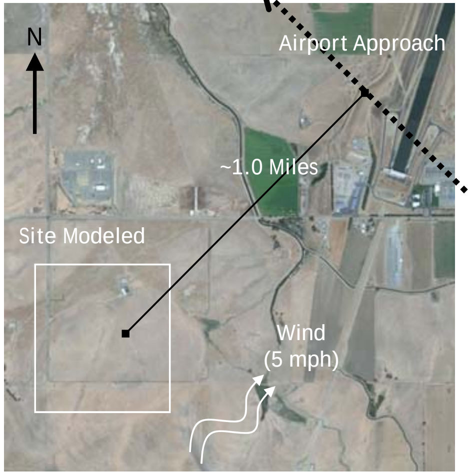
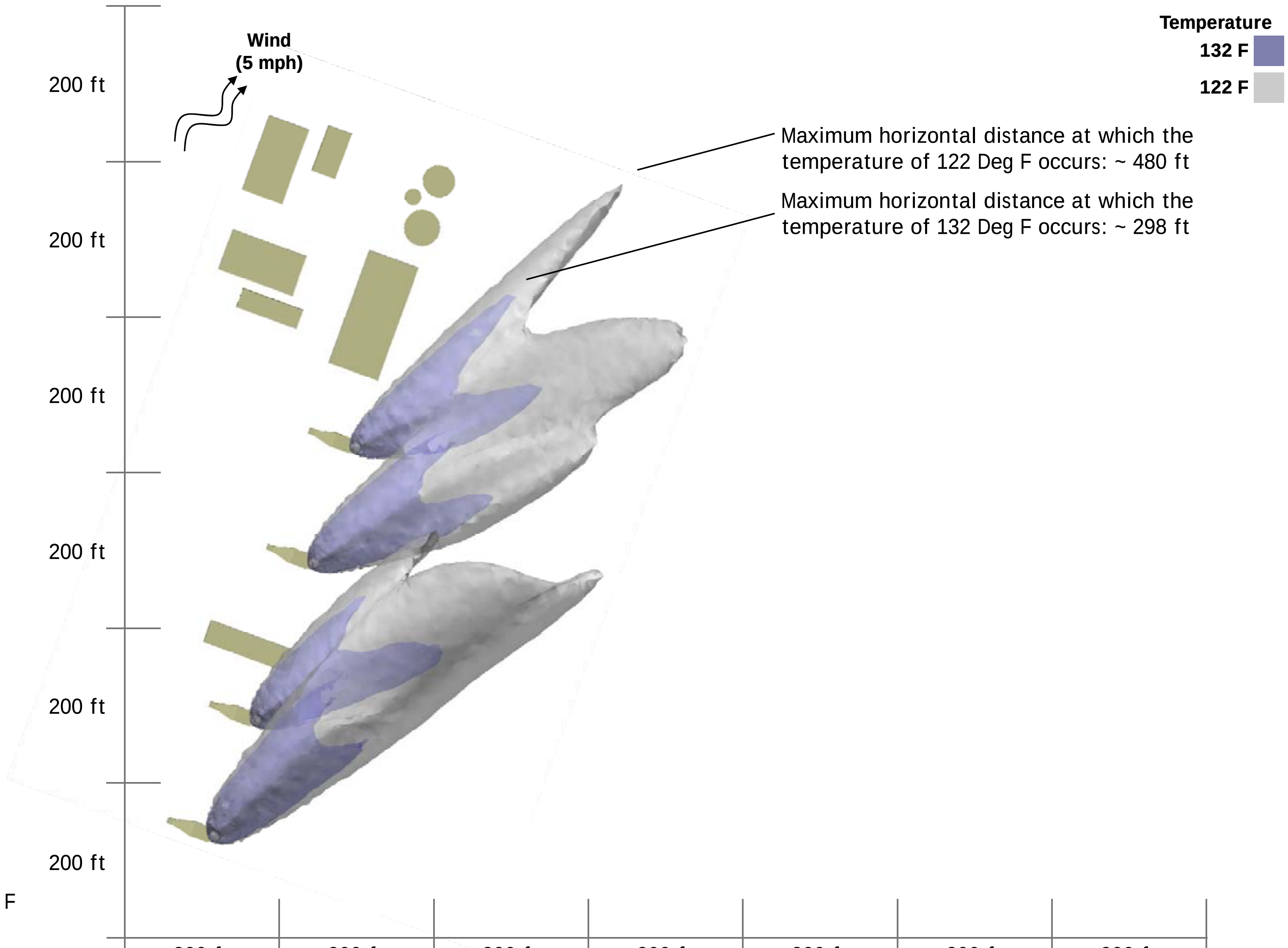
Figure 3.1





Ambient Temperature: 112 Deg F

Case #3 (5 mph, 112F Ambient):

- Plan view showing Temperature Isosurfaces

CH2MHILL

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File: Diamond Exh CFD_5-14-10

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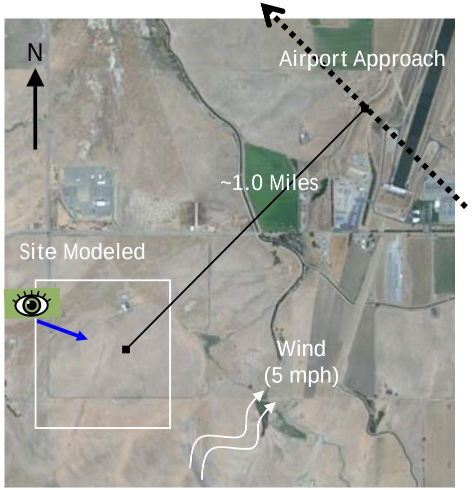
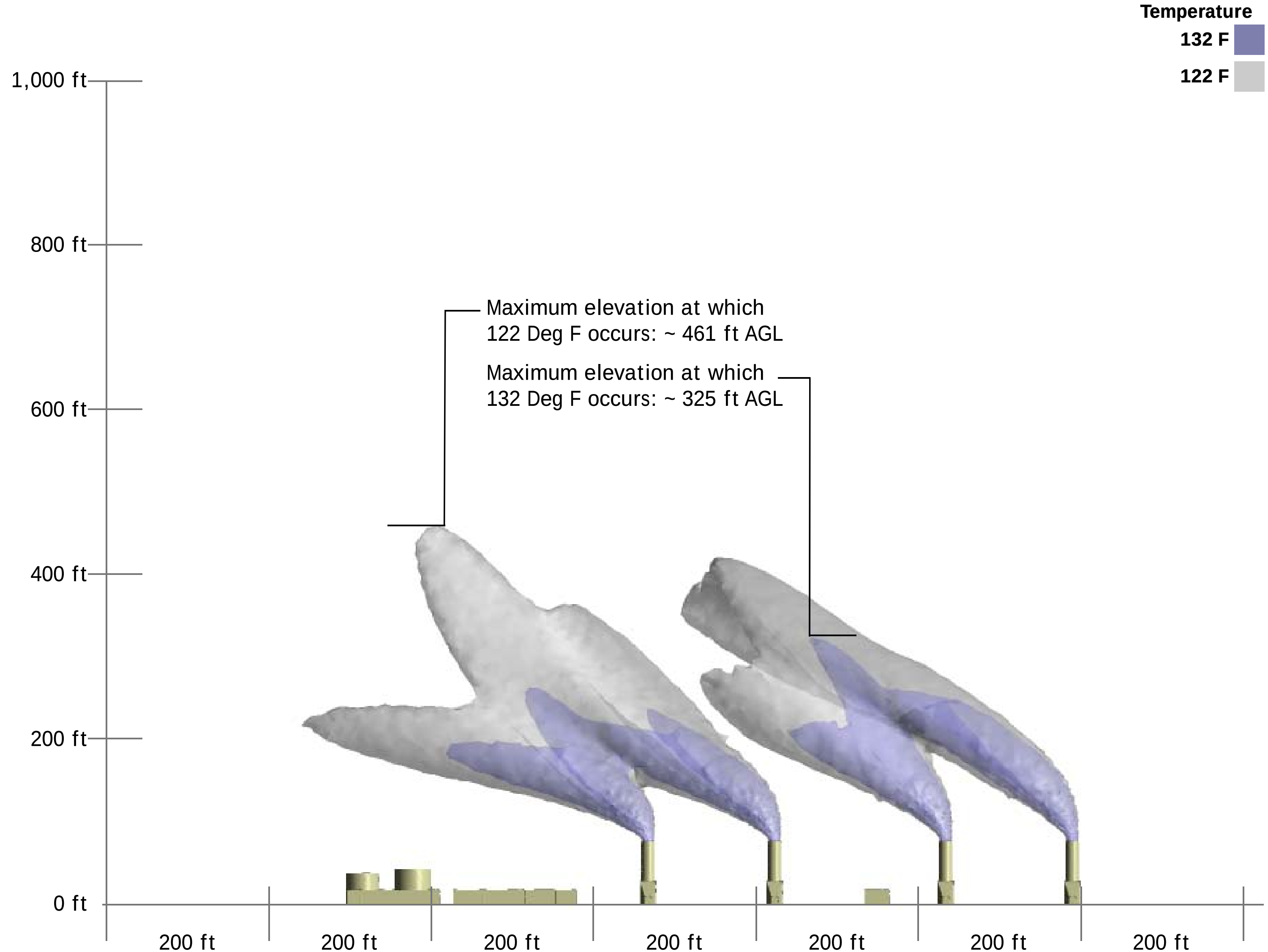
Figure 3.2



* Blue arrow indicates the image viewpoint



Ambient Temperature: 112 Deg F

Case #3 (5 mph, 112F Ambient):
- Elevation view showing Temperature Isosurfaces

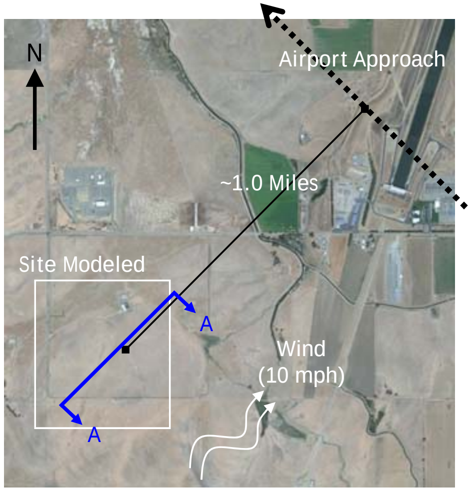
CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project	Figure 3.3
	Date: 14 May 2010		Turbine Exhaust Velocity Characterization	
	File: Diamond Exh CFD_5-14-10		Table Of Contents	

Case #4

10 MPH Wind – 112F Ambient Conditions

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
112	15	100	863	845,007	485,749	79.5	12.0	15.3	48.8

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)



Results Summary:

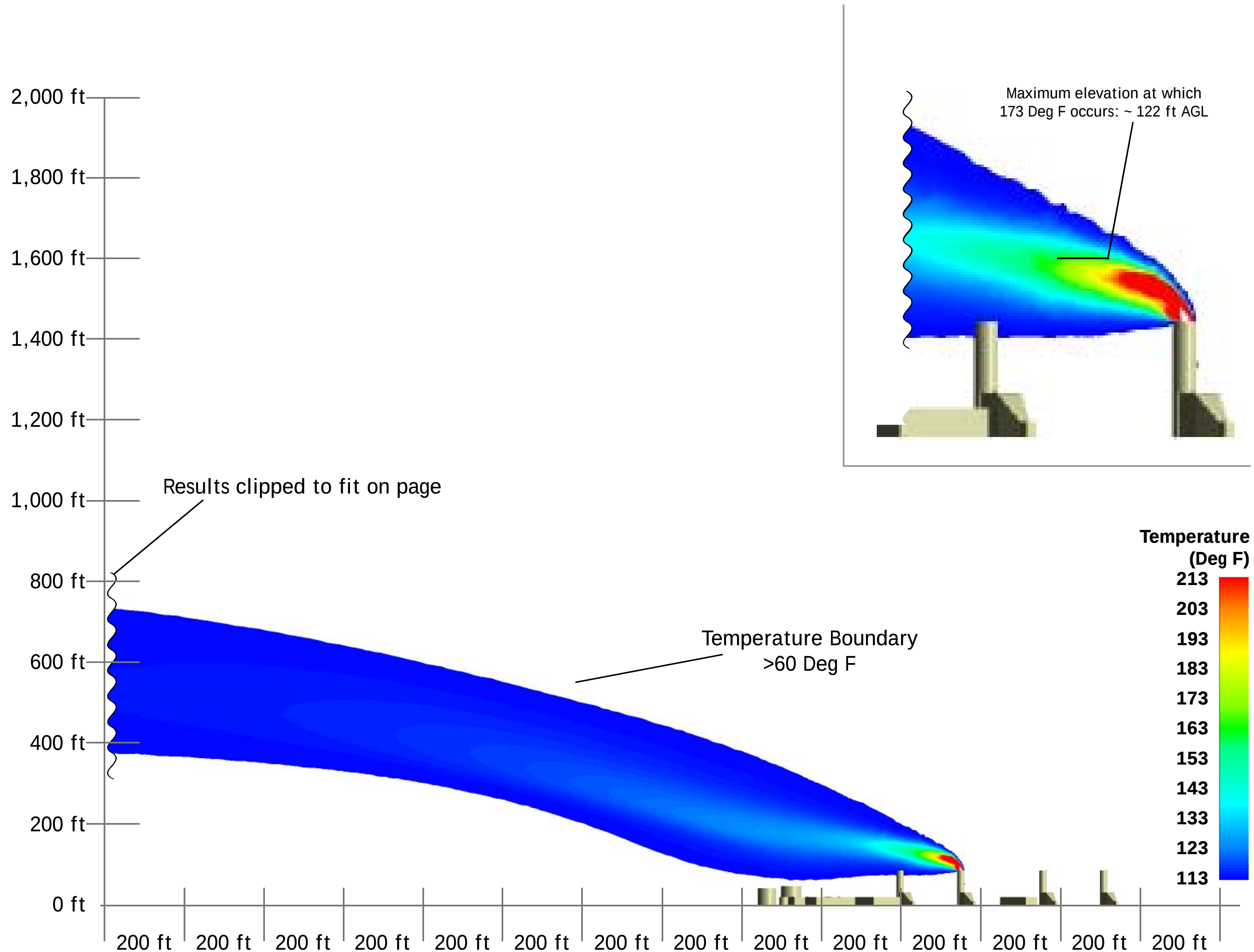
Maximum elevation at which 70 Deg F occurs:
~ 276 ft AGL

Maximum elevation at which 80 Deg F occurs:
~ 208 ft AGL

Maximum horizontal distance at which the temperature of 70 Deg F occurs: ~ 535 ft

Maximum horizontal distance at which the temperature of 80 Deg F occurs: ~ 309 ft

Ambient Temperature: 112 Deg F



Case #4 (10 mph, 112F Ambient):

- Section showing Temperature

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Date: 14 May 2010
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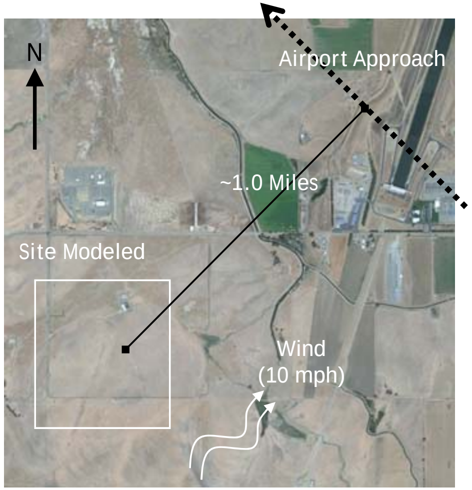
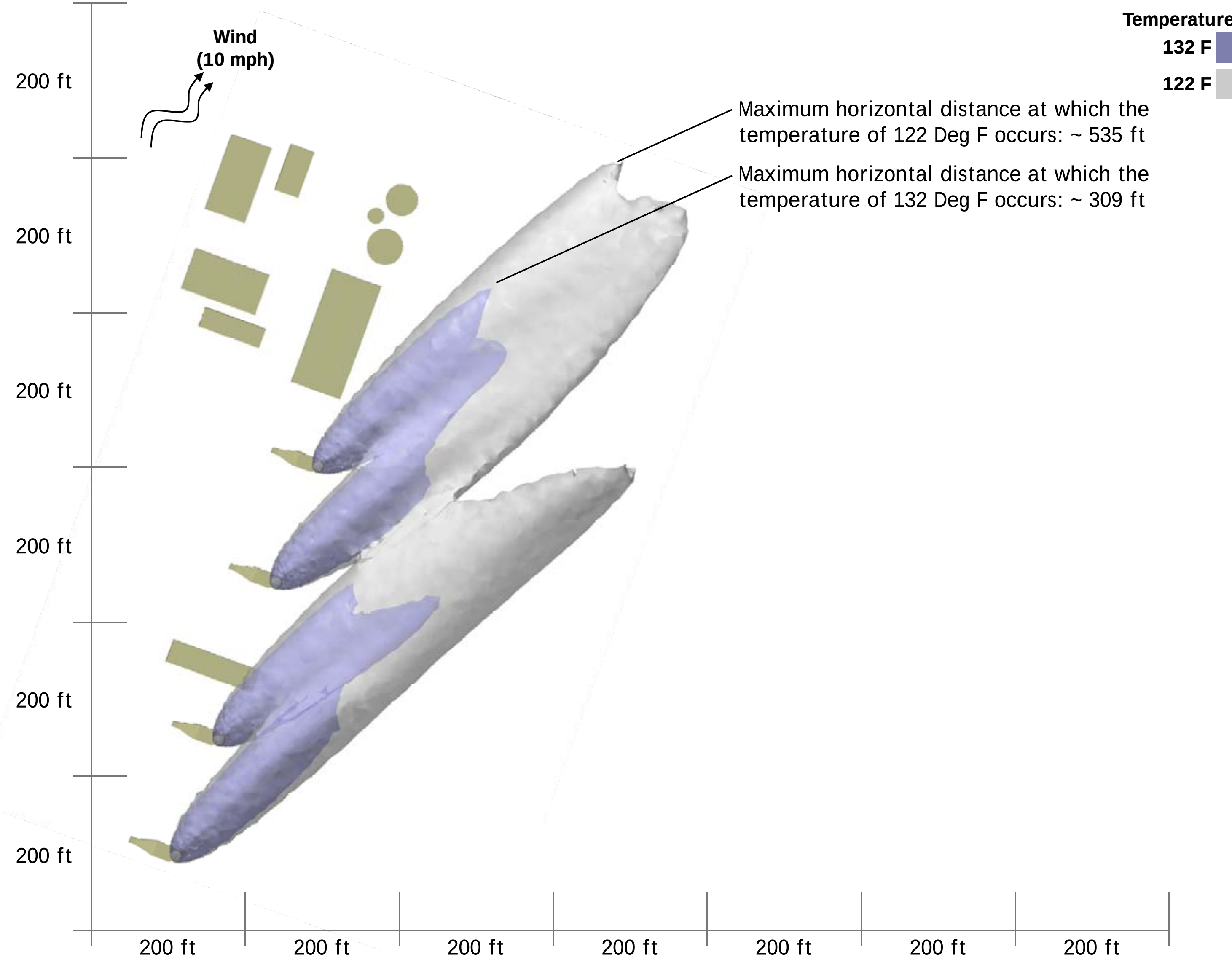
Figure 4.1



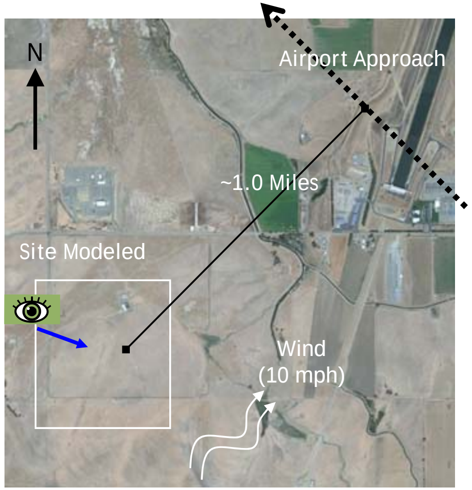


Ambient Temperature: 112 Deg F

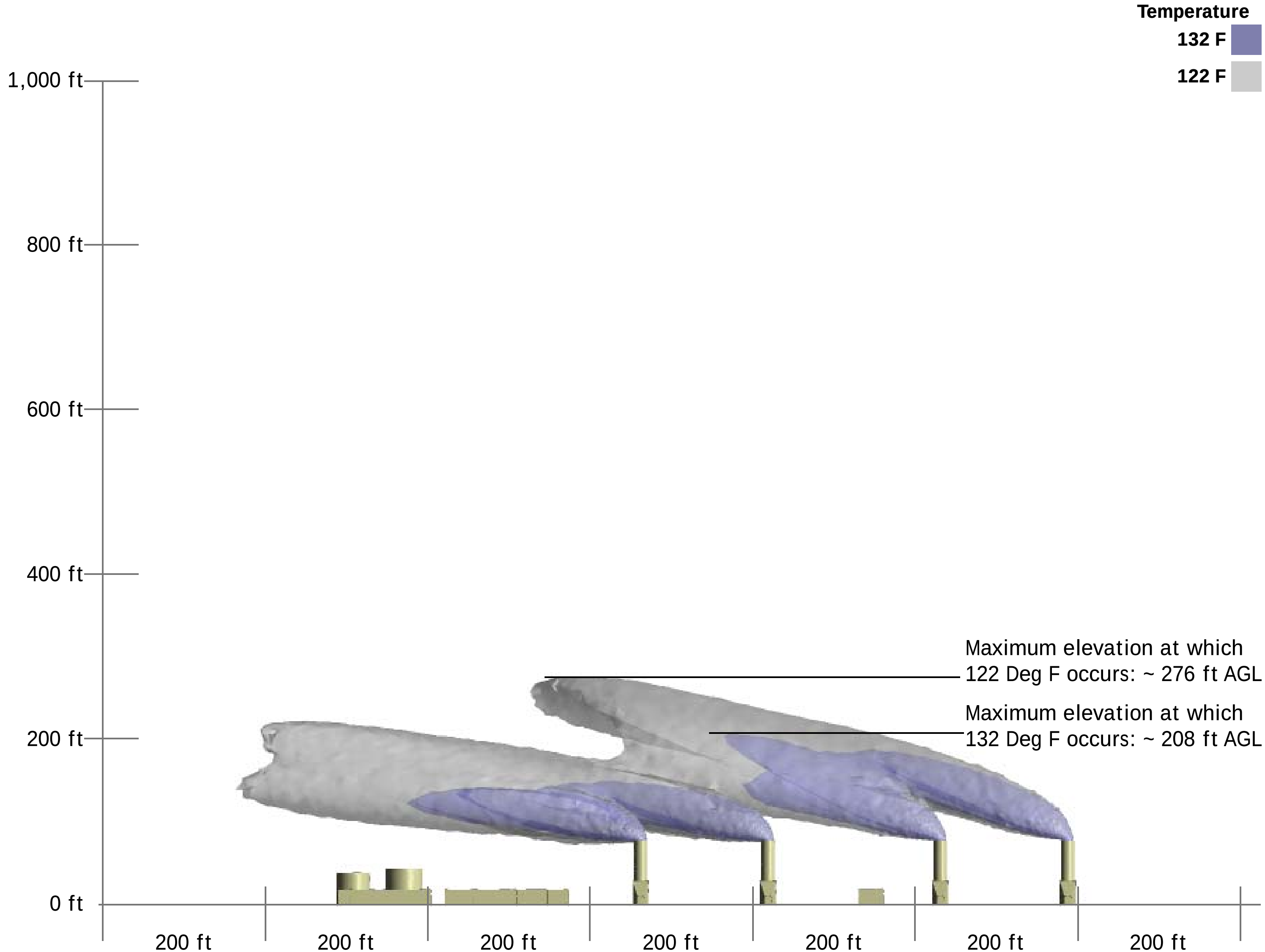
Case #4 (10 mph, 112F Ambient):

- Plan view showing Temperature Isosurfaces

CH2MHILL	Project #: 382914	*CONFIDENTIAL*	Mariposa Energy Project	
	Date: 14 May 2010		Turbine Exhaust Velocity Characterization	**Figure 4.2**
	File: Diamond Exh CFD_5-14-10		Table Of Contents	



* Blue arrow indicates the image viewpoint



Ambient Temperature: 112 Deg F

Case #4 (10 mph, 112F Ambient):

- Elevation view showing Temperature Isosurfaces

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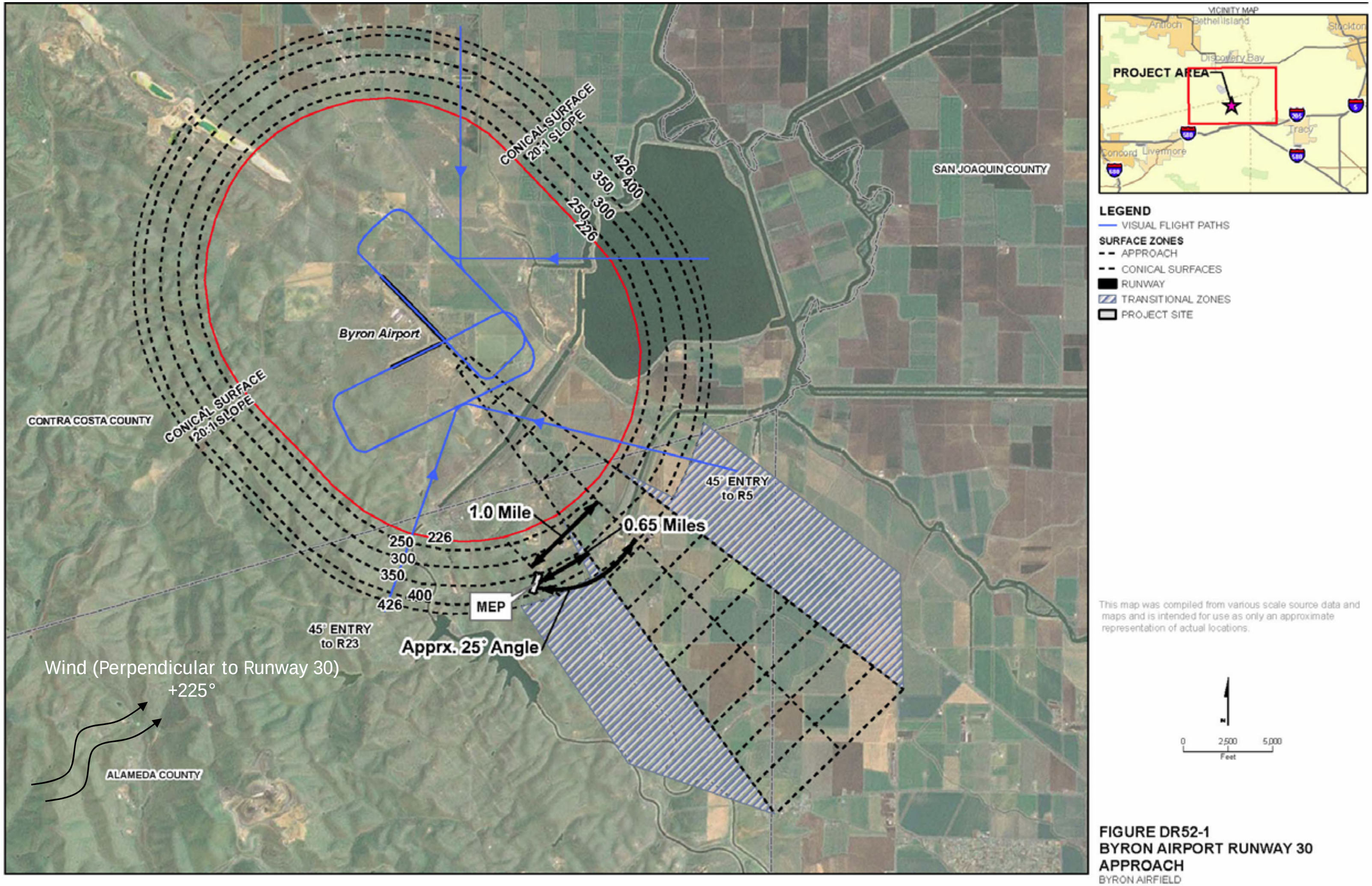
Figure 4.3

Appendix #1

Airport Approach Pattern



Byron Airport - Plan View

CH2MHILL	Project #: 382914 Date: 14 May 2010 File: Diamond Exh CFD_5-14-10	*CONFIDENTIAL*	Mariposa Energy Project Turbine Exhaust Velocity Characterization	A1.1

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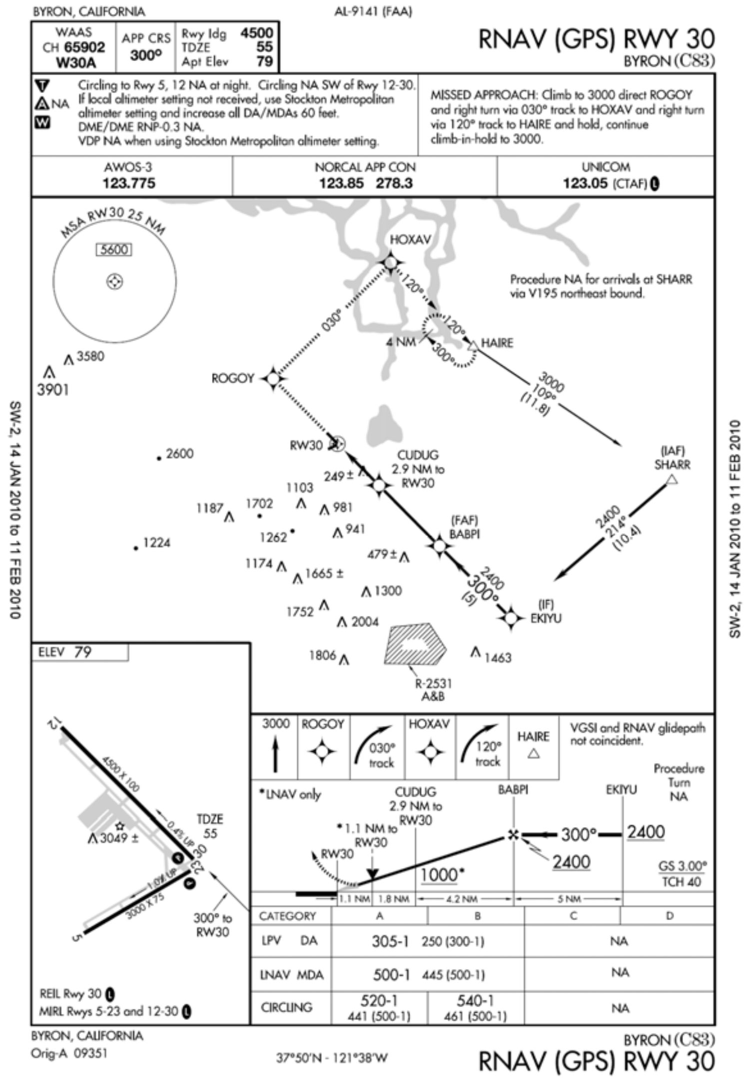


Runway 12/30
Dimensions: 4500 x 100 ft. / 1372 x 30 m
Elevation: 64.1 ft / 19.5 m. 48.4 ft / 14.8.
Traffic pattern: left right
Runway heading: 120 magnetic, 135 true,   300 magnetic, 315 true

Runway 5/23
Dimensions: 3000 x 75 ft. / 914 x 23 m
Elevation: 78.5 ft / 24 m. 48.6 ft / 14.8 m.
Traffic pattern: right left
Runway heading: 048 magnetic, 063 true,   228 magnetic, 243 true

Byron Airport IFR Approach

Appendix #2

Average plume velocity comparison between TAPM and CFD results

Objective

This appendix presents additional analyses that have been performed to compare results from two different plume modeling approaches, The Air Pollution Model (TAPM) and Computational Fluid Dynamics (CFD) model. The vertical velocity of the exhaust plume has been predicted using both approaches during "calm" wind conditions at 950 ft AGL (flight pattern altitude of the closest airport), and 1,309 ft AGL (greatest height predicted by TAPM where average vertical velocity of the plume equals or exceeds 9.62 mph). The objective of this analysis is to compare predictions between two methodologies, and to use CFD to further define the cross sectional vertical velocity of the plume. TAPM results have been provided by Katestone Environmental Ltd. (April 2010).

Assumptions

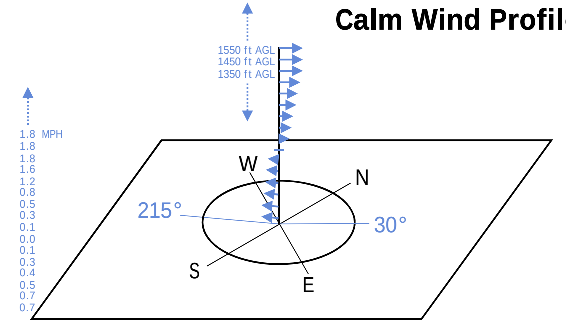
Calm Wind, 59F Ambient, Case Design Basis and Assumptions

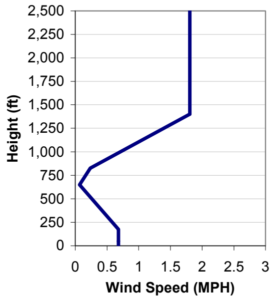
- The Calm wind profile assumed was developed by Katestone Environmental Ltd. (April 2010) and is based on weather local weather data from year 2003, and corresponds to the hour when the highest plume height is predicted to occur by TAPM (8-April-2003 10:00 AM) Profile to he right shows the wind profile used in both the TAPM and CFD models.
- Ambient and stack conditions are detailed in the table below:

Ambient Temp	RH	Load	Stack Temp	Flow		Stack Height	Stack Diameter	Stack Oxygen	Stack Velocity
F	%	%	F	lb/hr	aCFM*	Feet	Feet	%	MPH
59	60	100	848	1,051,375	597,341	79.5	12.0	14.5	60.0

* Volume flow rate and velocity were corrected to match the molecular weight of exhaust gas provided by GE.
(Exhaust gases have an average molecular weight of 28.0 lb/lbmol, pressure of 1 atm, and gas constant equal to 0.7302 atm ft3/(lbmol R).)

Calm Wind Profile





Findings

Analysis of the TAPM and CFD results show that the calculated average velocity results are similar for both methods:

Comparison of Average Velocity Across Plume

	950 ft AGL	1,309 ft AGL
TAPM	11.5 MPH	9.6 MPH
CFD	9.5 MPH	10.0 MPH

These two differing methodologies predict very similar results for average velocities across the plume at these elevations; the difference is due to the individual model assumptions. The TAPM model assumes a Gaussian plume profile; where the plume shape from each stack is symmetric about a central axis. With the symmetric shape any averaging data gathered across a section line, intersecting the plume axis, will have the same average velocity at a particular elevation. In the CFD results additional factors cause the plume shape to be non-symmetric (see A2.2 and A2.3). Therefore, when averaging data is gathered from the CFD results the section line chosen has an impact on the resultant average velocity. In obtaining the CFD average velocities on pages A2.2 and A2.3 two perpendicular section lines were drawn, through the estimated plume axis, and the average velocity of both is considered as the plume average velocity. Changing the angle or location of these section lines will result in a different calculated average velocity. The section lines presented were chosen to capture representative plume velocities for flight paths through the center of the plume from two directions (length and width) at each elevation.

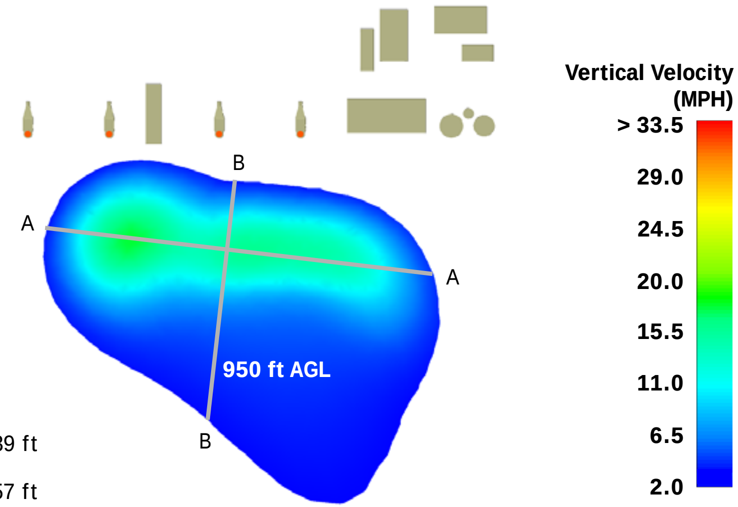
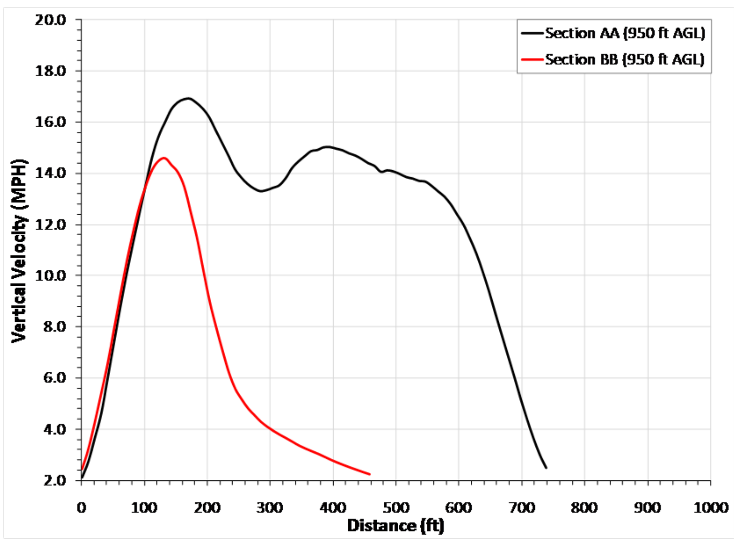


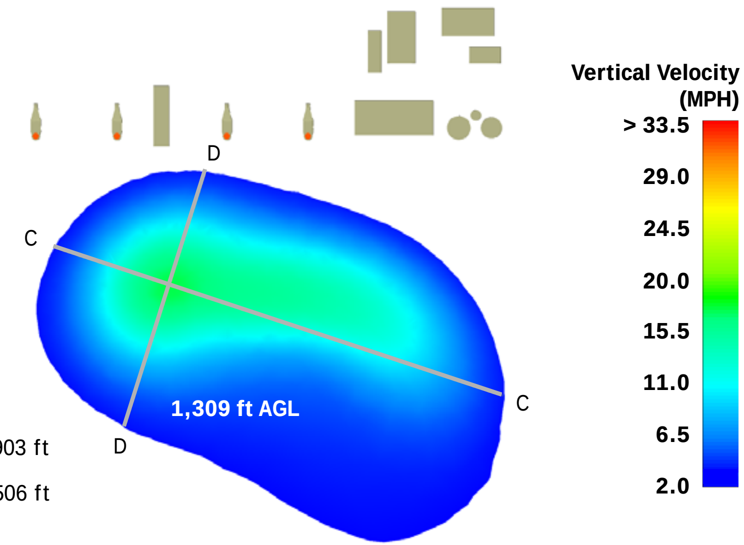
Chart A2-1 - Velocity Profiles 950 ft AGL



950 ft AGL											
Section AA						Section BB					
Distance (ft)	Vertical Velocity (fpm)	(MPH)	Distance (ft)	Vertical Velocity (fpm)	(MPH)	Distance (ft)	Vertical Velocity (fpm)	(MPH)	Distance (ft)	Vertical Velocity (fpm)	(MPH)
2	187	2.13	375	1313	14.92	1	214	2.43	234	545	6.19
12	243	2.76	385	1322	15.02	11	285	3.24	244	489	5.56
22	323	3.67	396	1323	15.03	21	376	4.28	255	453	5.15
32	407	4.62	406	1317	14.96	31	476	5.40	265	422	4.80
42	526	5.98	416	1311	14.90	41	577	6.56	275	399	4.53
52	650	7.39	426	1301	14.78	52	697	7.92	285	376	4.28
62	773	8.79	436	1293	14.70	62	815	9.27	295	359	4.08
72	887	10.08	446	1281	14.56	72	930	10.56	305	344	3.91
82	992	11.27	456	1268	14.40	82	1031	11.71	315	331	3.76
92	1094	12.43	466	1258	14.29	92	1121	12.74	326	319	3.63
103	1193	13.56	476	1238	14.06	102	1191	13.53	336	307	3.49
113	1287	14.63	486	1243	14.12	112	1245	14.15	346	294	3.34
123	1358	15.43	497	1239	14.08	123	1275	14.49	356	284	3.23
133	1406	15.98	507	1230	13.98	133	1284	14.59	366	275	3.12
143	1451	16.49	517	1219	13.86	143	1260	14.32	376	266	3.02
153	1476	16.77	527	1214	13.80	153	1235	14.03	386	255	2.90
163	1487	16.90	537	1206	13.71	163	1185	13.46	397	245	2.78
173	1489	16.92	547	1204	13.68	173	1098	12.47	407	236	2.68
183	1474	16.75	557	1189	13.51	184	1007	11.45	417	227	2.58
193	1454	16.52	567	1170	13.30	194	895	10.17	427	219	2.49
204	1425	16.19	577	1152	13.09	204	788	8.95	437	211	2.40
214	1381	15.69	587	1126	12.79	214	700	7.96	447	203	2.31
224	1337	15.20	598	1090	12.39	224	620	7.04	457	196	2.23
234	1294	14.70	608	1056	12.00						
244	1248	14.18	618	1009	11.47						
254	1219	13.85	628	958	10.88						
264	1196	13.59	638	896	10.18						
274	1181	13.42	648	827	9.40						
284	1171	13.31	658	752	8.54						
294	1175	13.35	668	678	7.70						
305	1183	13.44	678	606	6.88						
315	1191	13.54	688	533	6.05						
325	1215	13.81	699	457	5.19						
335	1250	14.20	709	387	4.40						
345	1273	14.46	719	322	3.66						
355	1291	14.67	729	265	3.01						
365	1308	14.87	739	220	2.50						
			Average	1,067.1	12.1				Average	599.1	6.81

	(fpm)	(MPH)	(m/s)
950 AGL Average	833.1	9.5	4.2

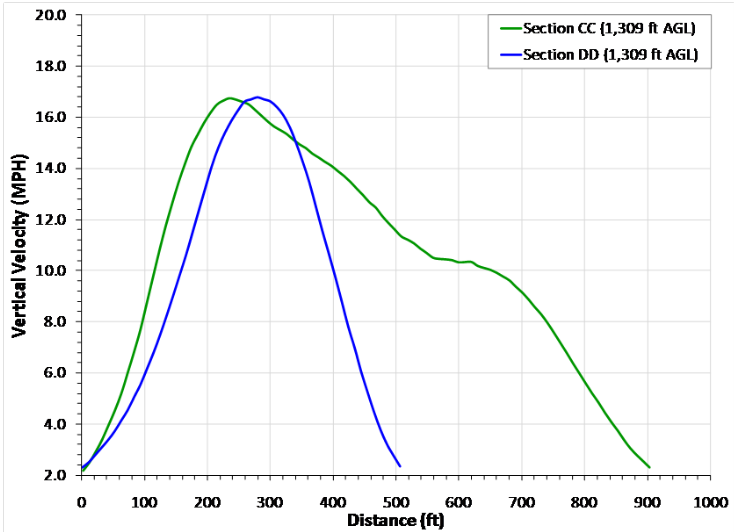
Calm Wind - Plume Velocity Profiles 950 ft AGL



CC length = 903 ft

DD length = 506 ft

Chart A2-2 - Velocity Profiles 1,309 ft AGL



1,309 ft AGL											
Section CC						Section DD					
Distance (ft)	Vertical Velocity (fpm)	(MPH)	Distance (ft)	Vertical Velocity (fpm)	(MPH)	Distance (ft)	Vertical Velocity (fpm)	(MPH)	Distance (ft)	Vertical Velocity (fpm)	(MPH)
2	193	2.19	457	1116	12.68	1	202	2.30	259	1460	16.60
12	221	2.51	467	1098	12.47	11	220	2.50	269	1468	16.69
22	259	2.94	478	1069	12.15	22	246	2.79	279	1476	16.77
32	300	3.41	488	1044	11.87	32	271	3.08	290	1469	16.69
42	350	3.97	498	1022	11.61	42	297	3.38	300	1461	16.61
52	400	4.55	508	999	11.35	53	327	3.72	310	1442	16.39
63	458	5.21	518	988	11.22	63	364	4.13	321	1414	16.07
73	529	6.01	528	975	11.08	73	400	4.54	331	1373	15.60
83	600	6.82	538	957	10.87	83	445	5.05	341	1316	14.96
93	677	7.70	548	942	10.70	94	489	5.56	352	1253	14.24
103	769	8.74	559	925	10.52	104	543	6.17	362	1184	13.45
113	861	9.78	569	922	10.47	114	598	6.80	372	1101	12.51
123	952	10.81	579	920	10.45	125	659	7.49	382	1018	11.56
133	1037	11.78	589	917	10.42	135	725	8.23	393	939	10.67
144	1113	12.64	599	910	10.34	145	793	9.01	403	859	9.76
154	1186	13.47	609	911	10.35	156	863	9.81	413	774	8.80
164	1249	14.19	619	911	10.35	166	933	10.61	424	688	7.82
174	1307	14.85	629	897	10.20	176	1011	11.48	434	614	6.98
184	1350	15.34	640	890	10.12	187	1089	12.37	444	532	6.04
194	1390	15.79	650	884	10.04	197	1166	13.25	455	460	5.23
204	1424	16.18	660	874	9.93	207	1241	14.10	465	392	4.46
214	1452	16.50	670	861	9.78	218	1304	14.81	475	331	3.76
224	1466	16.66	680	847	9.63	228	1354	15.38	486	281	3.20
235	1475	16.76	690	826	9.38	238	1395	15.86	496	243	2.76
245	1470	16.70	700	806	9.16	248	1430	16.25	506	206	2.34
255	1462	16.62	710	782	8.88						
265	1454	16.52	720	755	8.58						
275	1435	16.30	731	730	8.30						
285	1415	16.08	741	700	7.96						
295	1395	15.85	751	666	7.57						
305	1377	15.65	761	632	7.18						
316	1365	15.51	771	597	6.79						
326	1351	15.36	781	561	6.38						
336	1332	15.14	791	527	5.99						
346	1316	14.95	801	492	5.59						
356	1303	14.81	812	458	5.20						
366	1284	14.59	822	426	4.85						
376	1271	14.44	832	392	4.45						
386	1256	14.27	842	360	4.09						
397	1242	14.11	852	330	3.75						
407	1224	13.91	862	298	3.39						
417	1207	13.71	872	269	3.06						
427	1187	13.48	882	246	2.79						
437	1163	13.22	893	225	2.56						
447	1141	12.96	903	204	2.32						
			Average	909.1	10.33				Average	842.4	9.57

	(fpm)	(MPH)	(m/s)
1309 AGL Average	875.8	10.0	4.5

Calm Wind - Velocity Profiles 1,309 ft AGL

Attachment DR52-8
Analysis of Analysis of Aircraft Engine Effects of Reduced Oxygen Levels
Senta Engineering, June 2010

Mariposa Energy Project
Plume Effects on Local Aviation:
Effects of Reduced Oxygen Levels

Prepared and Submitted By:
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Submitted To:
Bo Buchynsky
Gary Normoyle
Diamond Generating Corporation

Date:
9 June 2010

1 OVERVIEW

Diamond Energy Corporation is proposing the Mariposa Energy Project (MEP), a 200 MW power plant in Alameda County. MEP would consist of four gas turbines, each with a 79.5 feet tall exhaust stack, and would be located 2.7 miles south of Byron Airport, a small general aviation (GA) airport. Given the proximity of the airport, concerns have been raised about the potential impact of MEP's emissions plumes on aircraft and aircraft handling. Specifically, three items have been identified:

1. The effects on aircraft engines from the reduced oxygen levels within the plumes.
2. The vertical loads imposed on aircraft by the vertical velocity of the plumes.
3. The potential for roll upset of aircraft if they happen to pass partially through the plumes (e.g., only the left half of the aircraft or only one wingtip).

This report studies the first item above for both reciprocating (piston) and turbine engines.

1.1 Plume Characterization and Assumptions

In the following analyses, it is assumed that the winds are relatively calm (<2 mph) and all four of the power plant's turbines are operating (exhausting from all four stacks). The calm winds represent worst-case conditions for these analyses, with minimal air mixing to reintroduce oxygen into the plume and the tightest vertical velocity gradients across the plume, imparting the largest forces and loads on transiting aircraft. Aircraft passing through the plume are assumed to be arriving to or departing from the Byron Airport at an altitude of 1079 feet above mean sea level (954 feet above ground level at the MEP) and in a landing configuration (if applicable). The characteristics of the plumes were determined in a prior study[1]. Figure 1 and 2 show the calculated oxygen level and temperature in the plume as a function of height above ground (AGL).

Two cases will be analyzed for aircraft operating in the plume:

Case 1: Aircraft at the nominal air traffic pattern altitude of 954 feet AGL. Oxygen content in the plume is approximately 20.90% and the temperature is 75°F.

Case 2: Aircraft at a very low altitude of approximately 500 feet AGL and within 500 feet of high voltage transmission lines and other ground level objects. Fixed-wing aircraft operating at such a low level would be in violation of 14 CFR Part 91 FAA Part 91.119 Minimum Safe Altitudes, General. Oxygen content in the plume is approximately 20.85% and the temperature is 100°F

For comparison, the normal atmospheric oxygen level is nominally 20.95%. Over the past two years, nearby ground temperatures[2] (including both day and night) ranged from 33°F to 109°F, averaging 62°F.

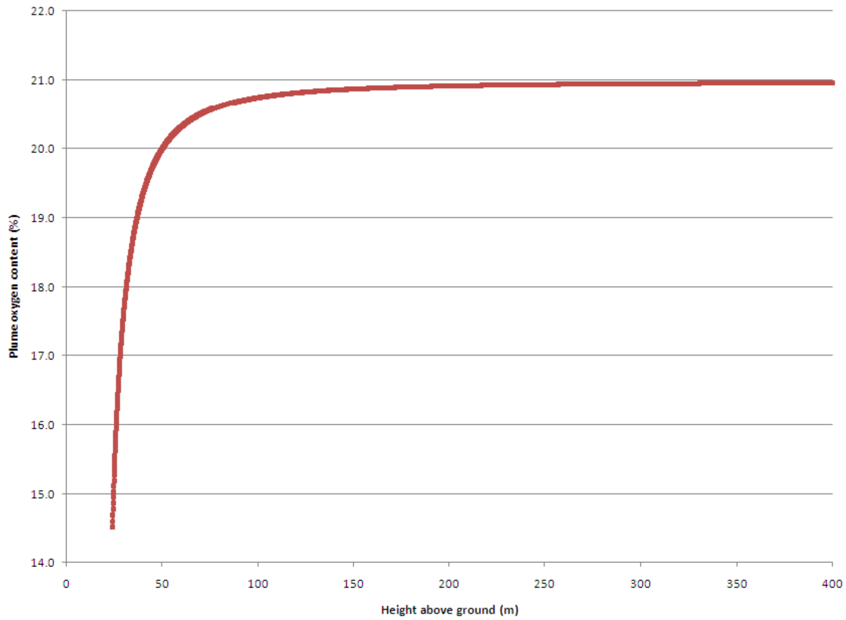

Figure 1. Oxygen content of the MEP plumes relative to altitude. Source: Katestone[1].

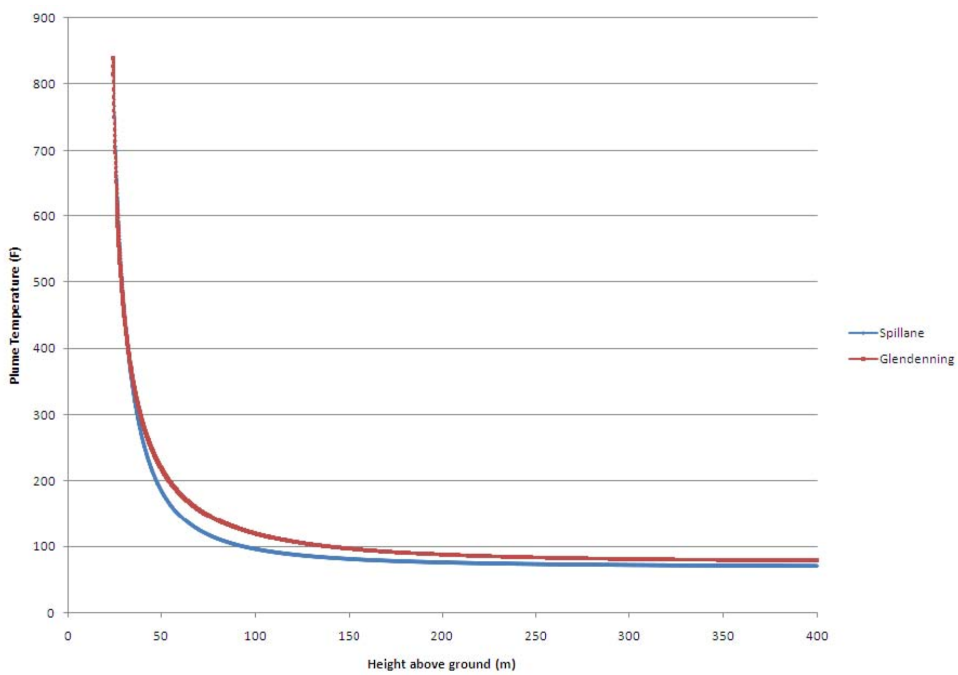

Figure 2. Temperature in the MEP plumes relative to altitude. The two curves represent different computational models. Source: Katestone[1].

2 OPERATING IN A REDUCED OXYGEN ENVIRONMENT

Aircraft engines work by combusting fuel and oxygen. The aircraft pilot and various engine subsystems manage the amounts of fuel and air in the engine to maintain smooth operation. Within the MEP exhaust plume, the oxygen levels are lower than the atmospheric norm, potentially affecting engine operation of transiting aircraft. We assess these effects by:

1. Surveying air/fuel (A/F) mixtures used in aircraft engines.

2. Comparing equivalent reductions in oxygen level at higher altitudes.

3. Reviewing past incidents involving aircraft operations in reduced oxygen environments

The other gases in the MEP exhaust plume are nitrogen, carbon dioxide, water, and other by-products of natural gas combustion in gas turbines; they are assumed to be inert with respect to the combustion process.

2.1 Reciprocating Engines

2.1.1 AIR/FUEL (A/F) MIXTURE

For a typical GA aircraft with a reciprocating engine, the A/F mixture is controlled primarily by the pilot. The ideal mixture depends on a variety of factors: the particular engine, power setting of the aircraft, engine temperature, and atmospheric conditions (which vary with altitude). For example, at takeoff and landing, the engine mixture control is typically prescribed to be set at *full rich* (minimum A/F mixture setting) in order to thermally protect the engine during high power settings. When an aircraft climbs, the pilot *leans* the mixture upon reaching the new altitude to maintain the appropriate A/F mixture as the ambient air pressure, and consequently the amount of oxygen entering the cylinders, decreases. There is no A/F mixture gauge, but other indicators such as cylinder temperatures and engine 'smoothness' are used.

A/F mixture ratios (by mass) at normal flight conditions usually range from 11:1 (i.e., 11 pounds of air for each pound of fuel) to 16:1. However, mixtures as *rich* as 8:1 and as *lean* as 20:1 typically continue to combust[3,4], as illustrated in Figure 3. As mixtures become too rich or too lean, engine operation roughens and power output degrades. At extreme mixtures, the engine can stop.

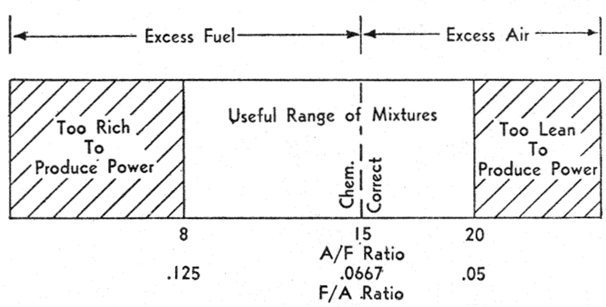

Figure 3. Typical range of A/F mixture ratios for an aircraft reciprocating engine. Source: Gill et al[4], based on a diagram from Pratt & Whitney.

Most studies of aircraft A/F mixture are directed toward maximizing power output and/or maximizing fuel efficiency (thereby focusing on leaner mixtures).[5] More recently, studies have measured emissions. Although they do not directly quantify a lower limit of oxygen for engine combustion, they do inform acceptable ranges.

Table 1 lists experimentally measured A/F mixtures for the O-200-A and the O-470-R engines found on the Cessna 150 and 182, respectively, at a pattern power condition (40% power) with full rich A/F mixture setting. Several runs with several engines of each type were tested, indicated by the serial numbers.

Table 1. Experimentally measured A/F ratios (by mass) for the O-200-A and O-470-R at full rich, pattern power (40% power). Source: Teledyne Continental Motors[6].

O-200-A		O-470-R	
Engine S/N	**A/F at Pattern Power (40%), Full Rich**	**Engine S/N**	**A/F At Pattern Power (40%), Full Rich**
213457	9.39	211280	11.48
213457	9	211280	11.37
213474	9.42	211302	10.79
213483	9.63	211302	10.83
213500	9.63	211302	10.91
213500	9.6	211305	10.98
213500	9.4	211317	11.88
213504	9.41	211317	11.25
213504	9.2	211317	11.11
		211333	11.61
Average	9.41	**Average**	11.22
Minimum	9.0	**Minimum**	10.8
Maximum	9.63	**Maximum**	11.88

In Table 1, the A/F ratio for the same engine (as indicated by the serial number) can vary as much as much 6.5% between runs, as with O-470-R #211317. Across all engines of the same type, the A/F mixtures varied as much as 6.5% for the O-200-A and 9.2% for the O-470-R. These variations indicate a tolerance band for normal operation at the prescribed conditions of 6.5% to 9.2% for this dataset.

Aircraft flying near MEP are presumed to be entering, departing, or in the pattern for Byron Airport and would therefore have a mixture setting of full rich. When passing through the plume, the reduced oxygen levels would effectively richen the A/F mixture further.

At 954 feet AGL, the oxygen fraction in the plume would be 20.90%, a 0.2% drop from the nominal oxygen fraction of 20.95%. An aircraft transiting the plume at this altitude would experience an equivalent drop (0.2%) in A/F mixture. At 500 feet AGL, the oxygen fraction would be 20.85%, a 0.5% drop from nominal. Again, this would result in a 0.5% drop in A/F mixture. As shown from the data from the repeated runs in Table 1, 0.2% and 0.5% changes in A/F mixture are well within the normal range of variation of A/F mixture during normal operation of 6.5% to 9.2%. At 954 feet AGL and 500 feet AGL, the slightly lower oxygen in the plume should therefore not significantly affect engine operation.

We can further apply the data from Table 1 to make a preliminary estimate of the lowest oxygen level that a reciprocating engine can tolerate. The richest (lowest) A/F mixture recorded during the tests was 9:1. As stated above, 8:1 is generally the richest useful mixture ratio. This ratio is 11.1% less than 9:1. This can be equated to an equivalent drop in oxygen level, from 20.95% to 18.6%, which is the oxygen level expected in the plume at 105 feet AGL. Therefore, an aircraft could be in the plume only 25 feet above the stacks, 105 AGL, and still have enough oxygen to operate the reciprocating engine. Again, these oxygen and altitude limits are rough estimates and will vary with different engines, atmospheric conditions, aircraft engine control settings, etc. Furthermore, while an 8:1 mixture may combust, engine power output may be degraded.

2.1.2 EQUIVALENT ALTITUDE COMPARISON

The effects of the plume can also be assessed by comparing them to equivalent atmospheric conditions at higher altitudes. The lower oxygen levels and the higher temperatures in the plume can be equated to the thinner, lower density air at increased altitudes.

For the nominal pattern altitude case at 954 feet AGL, the drop in oxygen level from 20.95% to 20.90% is equivalent to an altitude increase of about 82 feet. Given the plume temperature of 75°F, the corresponding density altitude is approximately 2,360 feet. Adding the effective 82 feet altitude increase due to the reduced oxygen level results in an equivalent air density altitude of approximately 2,442 feet.

For the low approach case at 500 feet AGL, the drop in oxygen level from 20.95% to 20.85% is equivalent to an altitude increase of about 161 feet. Given the plume temperature of 100°F, the corresponding density altitude is approximately 3,340 feet. Adding the effective 161 feet altitude increase due to the reduced oxygen level results in an equivalent air density altitude of approximately 3,501 feet.

Both the 2,442 foot and 3,501 foot air density altitude are well within the service envelope of GA aircraft, which can operate up to and above 5,000 foot density altitude. Therefore, the effects of the plume's reduced oxygen levels and elevated temperatures on transiting aircraft would be minimal.

2.2 Turbine Engines

Turbines, like reciprocating engines, fundamentally depend on combustion. We can take the same approach as we did with reciprocating engines to assess the affect of the plumes on turbine engine operation.

Aircraft with turbine engines are conservatively assumed to operate with the same pattern altitude and approach parameters as used above for reciprocating engines. Typically turbine engine aircraft operate at a higher pattern altitude, 1,500 feet AGL, than reciprocating engine aircraft; however for simplicity of comparison they are assumed to utilize the lower altitude. At a higher altitude the oxygen content of the plume will be even closer to ambient air and have even less effect.

2.2.1 AIR/FUEL (A/F) RATIOS

Aircraft turbines are designed to operate over a wide range of A/F ratios from full power to idling conditions.[7] A/F ratios fall typically in the range from 40 to 100 for aircraft turbines. During takeoff, an engine may operate at an A/F ratio of 60; at cruise conditions the mixture is likely to be much leaner with an A/F ratio of 100.[8] As discussed above for reciprocating engines, an aircraft transiting the plume can expect a drop in A/F mixture ratio of 0.2% at pattern altitude (954 feet AGL) and 0.5% at 500 feet AGL. Experimental data[9] for a typical turbine engine show that A/F mixture can vary under normal operating conditions by 2% - 3% due to changes in ambient temperature and pressure, and small engine control variables. The effect of the reduced oxygen level in the plume should therefore be insignificant.

Using the range of A/F ratios presented above, we can make a preliminary estimate of the lower oxygen limit that a turbine engine could tolerate. Using a minimum A/F ratio of 40 and starting with an already relatively rich A/F ratio of 60, an engine should continue to operate if it experiences a 30% drop in A/F ratio. From the nominal normal oxygen fraction of 20.95%, a corresponding decrease in oxygen would result in an oxygen fraction of 14%. Such low oxygen levels are expected only immediately above the mouth of the exhaust stacks. Therefore, a turbine engine could operate at or near the top of the stacks, even though it is unlikely that an aircraft would be only a few feet from a physical object such as a stack. Note that this oxygen limit is a rough estimate and will vary with different engines, atmospheric conditions, aircraft engine control settings, etc.

2.2.2 EQUIVALENT ALTITUDE COMPARISON

As discussed above for reciprocating engines, an aircraft transiting the plume at altitude of 954 feet AGL would encounter an equivalent air density altitude of 2,442 feet. At 500 feet AGL, the equivalent air density altitude is 3,501 feet. These altitudes are well within the service envelope of aircraft with turbine engines. The effects of the plume's reduced oxygen levels and elevated temperatures on such aircraft would therefore be minimal.

2.2.3 PAST INCIDENTS

Turbine powered helicopters have lost power while flying through a natural gas fired steam boiler power plant and a coal fired steam boiler power plant plumes in two recorded incidents.[10,11] In both cases, the helicopters lost engine power, forcing them to autorotate to a landing. In these cases, the plume from the natural gas fired steam boiler power plant contained oxygen levels of 4-5%[10] and that from the coal fired steam boiler power plant contained oxygen levels of approximately 4%[11]. Both had elevated temperatures. By comparison, MEP's plumes contain significantly more oxygen (Figure 1) and moderate temperatures (Figure 2) at the lowest altitudes expected for aviation activity.

Upon reviewing one of these incidents,[10] the Irish Air Accident Investigation Unit (AAIU) concluded that "oxygen levels of at least 12% are considered essential for the safe running of aircraft turbine engines." Previous studies[1] indicate that MEP's plumes will not have such low oxygen levels.

3 CONCLUSION

At normal pattern altitude (954 feet AGL) and at very low flight altitude (500 feet AGL), the oxygen content of MEP's exhaust plumes are very close to normal ambient atmospheric levels and temperatures in the plume are commensurate with warm to hot days regularly occurring in the region. Based on normal variation of experimentally measured A/F mixture ratios under normal operating conditions, the oxygen deficit in the plume should not have significant effect on either reciprocating or turbine engine operations.

For the normal pattern altitude and very low approach cases, the reduced oxygen content and elevated temperatures of the plume are equivalent to air density altitudes of 2,442 feet and 3,501 feet, respectively. These altitudes are well within the service altitudes of GA aircraft, which indicates that the plume should have a not significant effect on engine operation. The effects due to solely the oxygen reduction would be minimal, but the effects of the higher density altitude (due to the plume temperature) will result in a measurable, but momentary, reduction in available power commensurate to an aircraft operating at that density altitude.

Preliminary estimates suggest that aircraft reciprocating engines should be able to operate as low as 25 feet above the exhaust stacks, an extremely improbable occurrence, since FAA regulations recommend at least a 500 feet separation between fixed-wing aircraft and fixed ground objects. Aircraft turbine engines should be able to operate at any altitude within the plume. This is consistent with the findings of a review of a past incident involving aircraft and power plant exhaust.

In summary, the plumes will not have significant effect on the operation of aircraft reciprocating and turbine engines, even at low altitudes.

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[4] Gill, P., Smith, J., and Ziurys, E., *Fundamentals of Internal Combustion Engines as applied to Reciprocating, Gas Turbine, and Jet Propulsion Power Plants*, The United States Naval Institute, Annapolis, MD, 1959.

[5] Sparrow, S. "Relation of Fuel-Air Ratio to Engine Performance", NACA 189, 1924.

[6] "Collection and Assessment of Aircraft Emissions." Prepared for the Environmental Protection Agency by Teledyne Continental Motors, October 1971, Contract 68-04-0035.

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[9] Rubins, Philip M. et al, "T53 and T55 Gas Turbine Combustor and Engine Exhaust Emission Measurements," AD-778 769, Avco Lycoming Division, December 1973.

[10] "Accident: Agusta B206 Jetranger, EI-BKT, Dublin Port, 11 Sep 2002: Report No 2004-001", Air Accident Investigation Unit, January 2004, AAIU Synoptic Report No 2004-001.

[11] Report, Accident Number LAX89LA270, Sept 9 1992.

Attachment DR52-9
Analysis of Aircraft Loads and Handling
Senta Engineering, June 2010

Mariposa Energy Project
Plume Effects on Local Aviation: Aircraft Loads and Handling

Prepared and Submitted By:
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Submitted To:
Bo Buchynsky
Gary Normoyle
Diamond Generating Corporation

Date:
15 June 2010

1 OVERVIEW

Diamond Generating Corporation is proposing the Mariposa Energy Project (MEP), a 200 MW power plant in Alameda County. MEP would consist of four gas turbines, each with a 79.5 ft tall exhaust stack, and would be located 2.7 miles south of Byron Airport, a small general aviation (GA) airport. Given the proximity of the airport, concerns have been raised about the potential impact of MEP's emissions plumes on aircraft and aircraft handling. Specifically, three items have been identified:

1. The effects on aircraft engines from the reduced oxygen levels within the plumes.
2. The vertical loads imposed on the aircraft by the vertical velocity of the plumes.
3. The potential for roll upset of the aircraft if they happen to pass partially through the plumes (e.g., only the left half of the aircraft or only one wingtip).

The second and third items are discussed in this report. The first item is covered in a separate report.

1.1 Plume Characterization and Assumptions

In the following analyses, it is assumed that the winds are relatively calm (< 2 mph) and the power plant is running (exhausting from all four stacks). The calm winds represent worst-case conditions for these analyses, resulting in the tightest vertical velocity gradients across the plume, thereby imparting the largest forces and loads on transiting aircraft. The characteristics of the plumes were determined in prior studies[1,2]. Aircraft passing through the plume are assumed to be in an approach for Byron Airport at an altitude of 1079 ft above mean sea level (954 ft above ground level at the MEP site) and in a landing configuration (if applicable). At this altitude, the temperature in the plume[1] is approximately 75 °F, which corresponds to a density altitude of 2360 ft. The vertical velocity profile[2] of the plume at this altitude are shown in Figure 1 and 2.

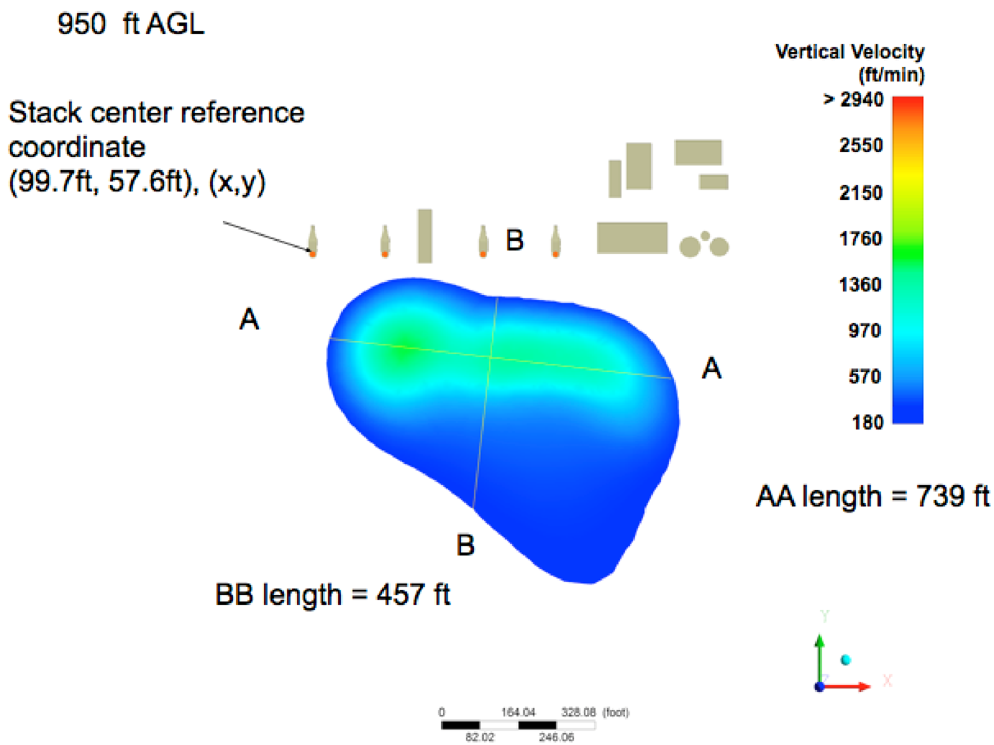

Figure 1. Vertical velocity of MEP plume at 950 ft above ground level (AGL), calm winds. Source: CH2M Hill[2].

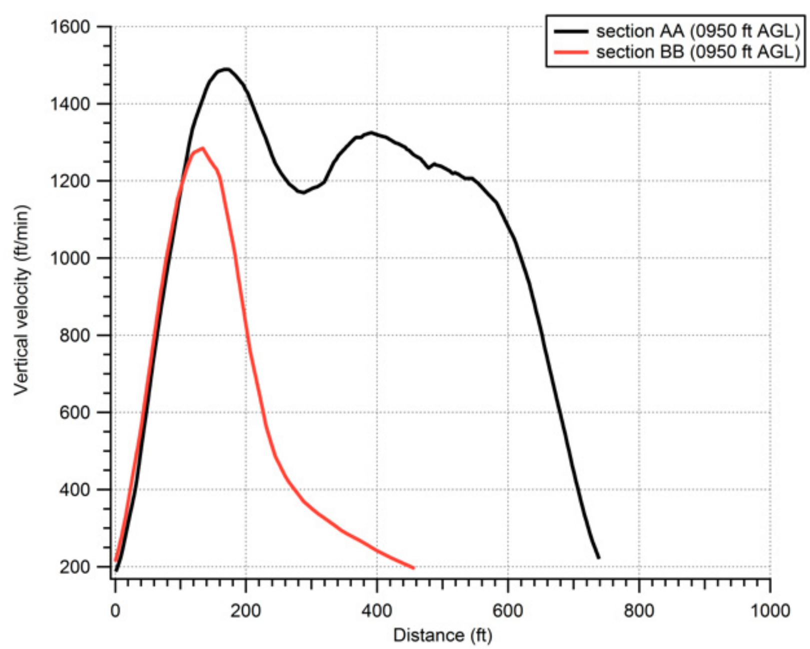

Figure 2. Vertical velocity profiles of sections of the MEP plume at 950 ft above ground level (AGL), calm winds. The cuts (AA and BB) are shown in Figure 1. Source: CH2M Hill[2].

1.2 Turbulence Characterization and Classification

In order to qualitatively convey the intensity of a turbulence encounter, descriptions of the expected aircraft reaction and turbulence intensity rating are listed in Table 1. However, for the purposes of this study, a more quantitative way of categorizing the turbulence is also needed, and is listed in Table 2. While both the qualitative and quantitative descriptions of turbulence are to some extent subjective, they provide a reference frame that can be used when examining aircraft gust responses.

Table 1. Turbulence reporting criteria. Source: FAA[3].

Intensity	Aircraft Reaction	Reaction Inside Aircraft
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as Light Turbulence; or Turbulence that causes slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as Light Chop.	Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking.
Moderate	Turbulence that is similar to Light Turbulence but of greater intensity. Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as Moderate Turbulence; or Turbulence that is similar to Light Chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude. Report as Moderate Chop.	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as Severe Turbulence.	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food Service and walking are impossible.
Extreme	Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as Extreme Turbulence.	

Table 2. Turbulence levels corresponding to various load factors.[4]

Turbulence Level	Load Factor
Light	$0.2 < \lvert \Delta n \rvert \leq 0.5$
Moderate	$0.5 < \lvert \Delta n \rvert \leq 1.0$
Severe	$1.0 < \lvert \Delta n \rvert \leq 2.0$
Extreme	$2.0 < \lvert \Delta n \rvert$

2 STRUCTURAL LOADS IMPARTED BY VERTICAL VELOCITY OF THE PLUME

2.1 Methodology

A single degree-of-freedom model for an aircraft encountering a vertical gust (in this case, caused by the plume) is used to assess the loads on an aircraft transiting the plume. The load imparted by a gust can be modeled[5] as follows:

$$\Delta n(t) = \frac{w_g}{2g}\left[\omega \sin \omega t + \frac{1}{1+(\omega t)^{-2}}\left(\frac{1}{\lambda} e^{\frac{-t}{\lambda}} - \frac{1}{\lambda}\cos \omega t - \omega \sin \omega t\right)\right]$$

where:

$$\lambda = \frac{\left(\frac{W}{S}\right)}{C_{L\alpha}} \frac{2}{\varrho V g}$$

$$\omega = \frac{\pi V}{d}$$

Δn = incremental vertical load factor at the center of gravity due to the gust

W = aircraft weight (lb)

S = wing reference area (ft^2)

$C_{L\alpha}$ = lift curve slope (rad^{-1})

ρ = air density at altitude ($slugs/ft^3$)

g = acceleration due to gravity (ft/s^2)

d = gradient distance for a one-minus-cosine gust (ft)

U_0 = magnitude of vertical gust velocity (ft/s)

V = airplane airspeed (ft/s)

Schmidt shows an over-prediction of about 5% when compared to a more complex model[5], so a 5% reduction in the loads determined from this model will be applied in this analysis.

The model assumes a vertical gust profile that has a one-minus-cosine shape. A one-minus-cosine gust profile is defined as follows:

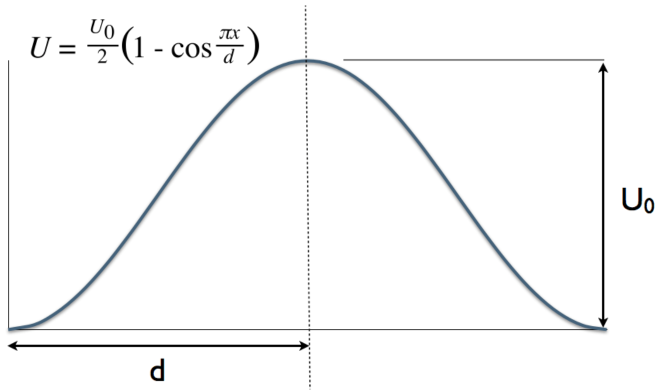

Figure 3. A one-minus-cosine vertical gust profile. Note that d is the gradient distance, not the diameter.

2.2 Analysis, Results, and Discussion

The one-minus-cosine vertical gust profile was fit to the most critical areas of the plume as shown in Figure 4 and Figure 5.

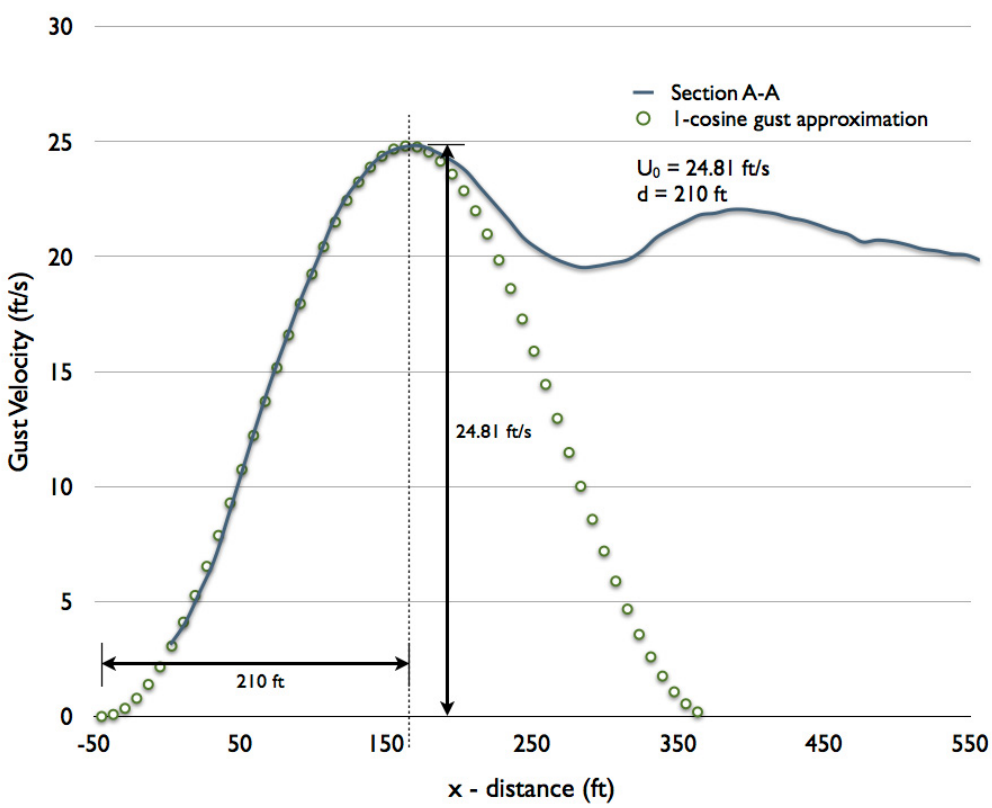

Figure 4. Vertical velocity profile of the MEP plume at 954 ft AGL, cross-section A-A (see Figure 2). A one-minus-cosine profile is fit to the most critical section of the plume.

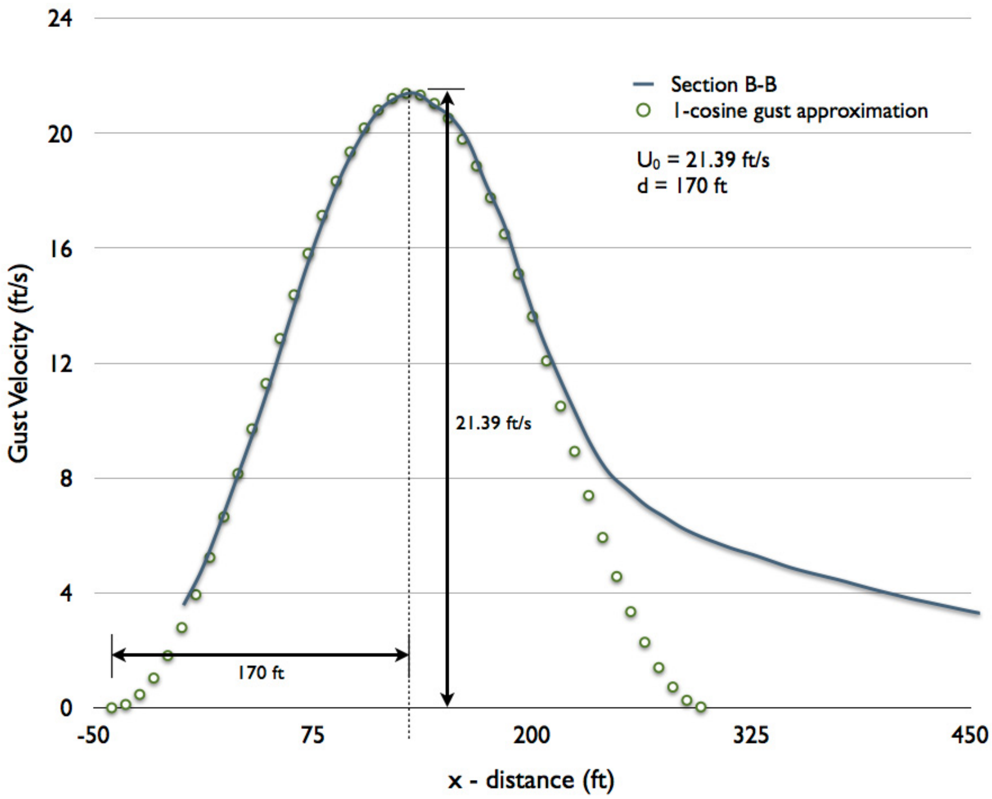

Figure 5. Vertical velocity profile of the MEP plume at 954 ft AGL, cross-section B-B (see Figure 2). A one-minus-cosine profile is fit to the most critical section of the plume.

The loads evaluated from the critical gust case from cross-section A-A are slightly higher than that from section B-B. The subsequent discussion therefore focuses on the case from A-A. Note that cross-section A-A is not necessarily aligned with an approach from MEP to Byron Airport; the critical gust case from cross-section A-A can be considered a worst case scenario.

A range of aircraft that could typically be found at Byron Airport were evaluated. Aircraft weights and dimensions, shown in Table 3, were estimated from available literature. Aircraft lift curve slopes were calculated from published data or with empirical methods[5,6].

Table 3. Aircraft characteristics applied for the vertical load evaluation.

	Cessna Citation II	Cessna 172	Vans RV-6	Powered Parachute
Span (ft)	52.2	36	23	32 - 39.5
Wing Area (ft^2)	342.6	174	110	400 - 500
Weight (lb)	11000 – 15000	1600 - 2500	1100 - 1500	254 - 860
Average Wing Chord (ft)	6.5	4.9	4.8	11.6 - 12.0
Approach Speed (knots)	90 – 120	60 - 90	50 - 80	26
Lift Curve Slope, $C_{L\alpha}$	4.9	4.6	4.19	3.06 - 3.42
Classification (Certification Basis)	Transport (FAR 25)	Normal (FAR 23)	Experimental	Ultralight, Light Sport Aircraft

The vertical gust load model was applied to each of the aircraft, using a range of weights and speeds to bracket typical operating conditions of each aircraft. A powered parachute typically cruises or glides at nearly constant speed except for flaring on touchdown, so only one speed was evaluated. The results are shown in Figure 6.

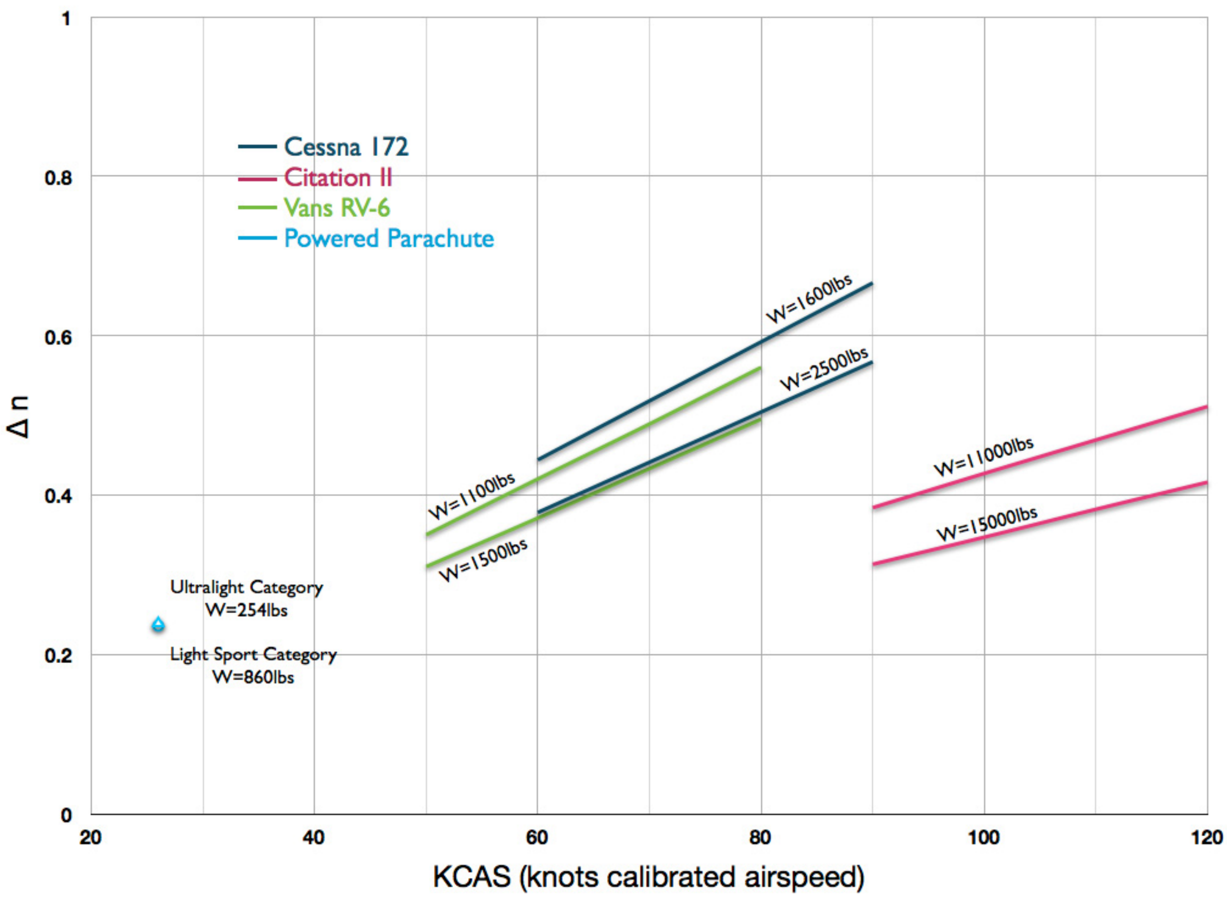

Figure 6. Incremental load imparted by the MEP plumes at 950 ft AGL.

The gust loads in Figure 6 correspond to light to moderate turbulence, as defined in Table 2 (using the gust intensity categorization from Table 2). Powered parachutes, due to their relatively slow speeds, would experience a light level of turbulence.

To assess the airframe structural impact of the vertical load imparted by the gust, we look at the required design maneuvering envelope of the aircraft. Table 4 lists the design loading envelope for the aircraft being evaluated.

Table 4. Comparison of loads imparted by the plume and the load limits for various aircraft.

	Cessna Citation II	Cessna 172	Vans RV-6	Powered Parachute
Load Limit	+2.5g, -1.0g	Flaps Up: +3.8g, -1.52g Flaps Down: +3.0g	+6.0g, -3.0g; +4.4g, -1.75g *	+6.0g
Required per FARs	+2.5g, -1.0g See Appendix A	See Appendix A	n/a	n/a
Load Imparted by Plume	1.31 - 1.51	1.38 - 1.67	1.31 - 1.56	1.24

* +6.0g, -3.0g at or below aerobatic gross weights; +4.4g, -1.75g between aerobatic gross weight to maximum design gross weights (www.vansaircraft.com)

The loads imparted by the MEP plume are well within the prescribed operating load limits. It follows that aircraft transiting the plume would experience no detrimental structural effects since they are operating within certified structural limits. While there is no structural requirement for ultralight vehicles in terms of maneuver or gust load limits, adherence to the FAR regulations (Part 23) is highly encouraged and is often found in literature available for the homebuilder[7].

3 ROLL UPSET

An aircraft flying through the plume may encounter an asymmetric vertical velocity gradient across its wingspan which imparts a rolling moment on the aircraft. The following analysis assesses this rolling moment and its effect on aircraft handling.

3.1 Methodology

The rolling moment encountered by the aircraft was calculated with a piecewise integration of the lift imparted by the vertical velocities of the plume across the span of the aircraft. This is illustrated in Figure 6. The rolling moment was evaluated at several lateral distances into the plume to determine the highest rolling moment that would occur. As discussed in Section 2, the one-minus-cosine gust profile was used to model the plume, taking the critical case on cross-section A-A. In addition, the aileron deflection required to neutralize the rolling moment was calculated.

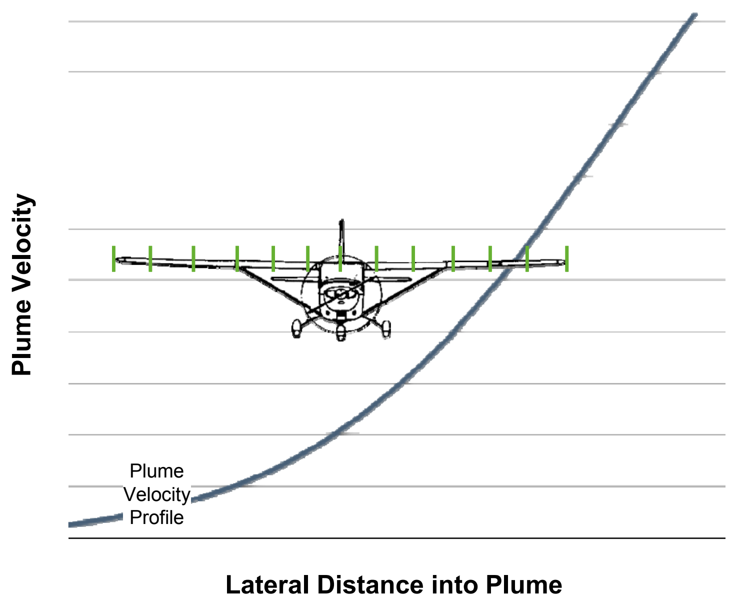

Figure 7. The rolling moment was calculated by integrating the lift on spanwise sections (indicated by the green lines) of the wing. The moment was evaluated over a range of lateral distances into the plume. In this illustration, the left portions of the airplane (this refers to the left from the perspective of the pilot, which is to the right in the figure) are experiencing higher vertical velocities from the plume than the right; this would impose a rolling moment to the right.

3.2 Analysis, Results, and Discussion

The rolling moment was evaluated on several aircraft for which the required geometric parameters and stability derivatives were available[8]. The aircraft were: Cessna 172, Beech 99, and Learjet 24. Figure 8 shows the rolling moment imparted on a Cessna 172 by the plume for a range of lateral distances into the plume. The right axis shows the corresponding aileron deflection to neutralize the rolling moment. Note that as the aircraft is evaluated at lateral distances nearing the centerline of the plume, the vertical velocities across the span of the aircraft become symmetric and the rolling moment goes to zero.

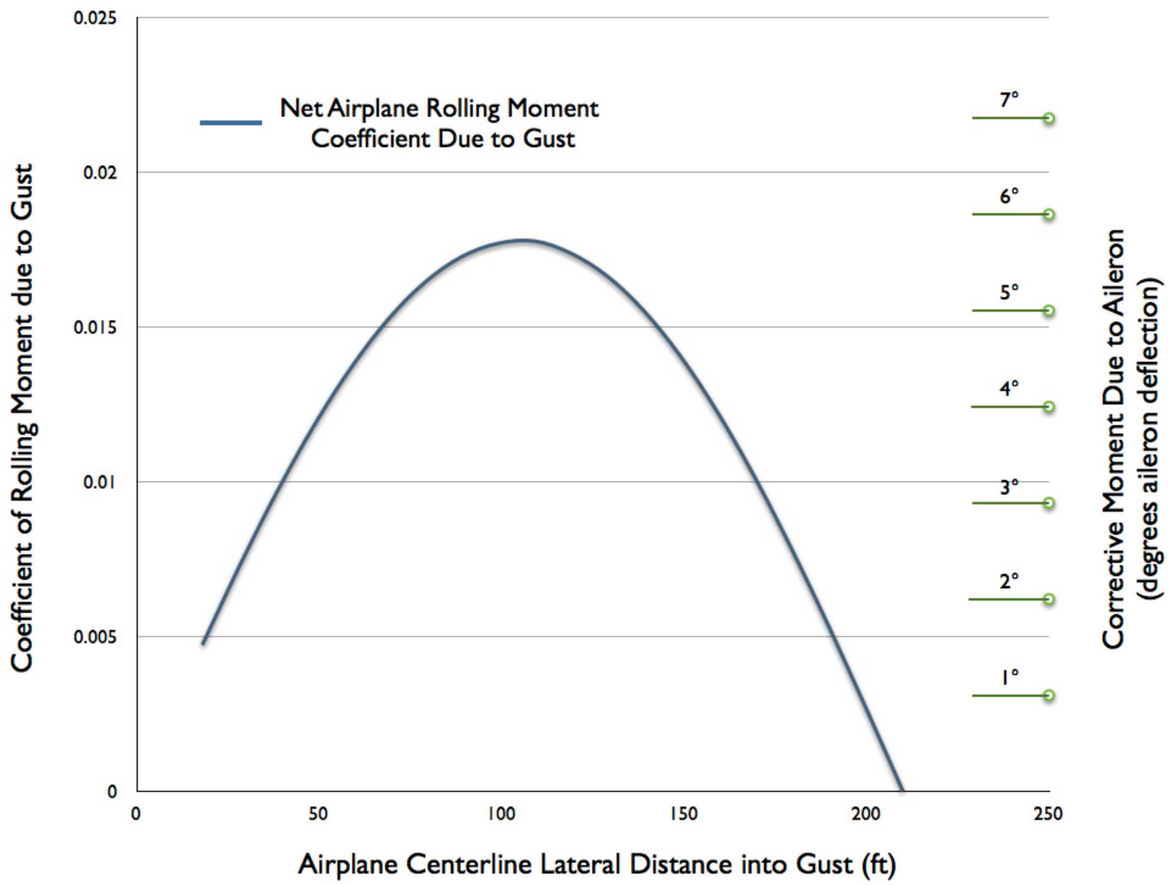

Figure 8. Rolling moment on a Cessna 172 and the corresponding corrective aileron deflection required.

The following table summarizes the maximum rolling moment coefficient encountered, the estimated amount of aileron deflection required to counteract the roll, and the maximum aileron deflection available for each aircraft under consideration.

Table 5. Maximum encountered rolling coefficient and corresponding neutralizing aileron deflection.

Aircraft	Maximum Rolling Moment Coefficient	Neutralizing Aileron Deflection (Degrees)	Maximum Aileron Deflection Available[9] (Degrees Up / Down)
Cessna 172	0.0178	5.7	20 / 14
Beech 99	0.0182	6.7	18 / 20
Learjet 24	0.0131	5.0	18 / 18

As indicated above in Table 5, the aileron input required to counter the roll upset imparted by the MEP plume was well within the aileron operating range of all evaluated aircraft.

4 CONCLUSIONS

The effect of the MEP plume on aircraft loads and handling were evaluated. Aircraft were assumed to be in an approach for Byron Airport at an altitude of 1079 ft above mean sea level (954 ft above ground level at the MEP site) and in a landing configuration (if applicable). Winds were assumed to be calm

The loads imposed on aircraft by the vertical velocity of the plumes were evaluated for a Cessna Citation II, Cessna 172, Vans RV-6, and a powered parachute. The loads were equivalent to light to moderate turbulence. Powered parachutes, due to their relatively slow speeds, would experience a light level of turbulence. These loads are well within the prescribed operating load limits of the aircraft. It follows that aircraft transiting the plume would experience no detrimental structural effects since they are operating within certified structural limits.

An aircraft flying through the plume may encounter an asymmetric vertical velocity gradient across its wingspan which imparts a rolling moment on the aircraft. This potential for roll upset was evaluated on a Cessna 172, Beech 99, and Learjet 24. For these aircraft, the aileron input required to counter the roll upset imparted by the MEP plume was between 5.0° and 6.7°, well within aileron operating limits.

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[1] "Assessment of Vertical Plume Velocities for the Mariposa Energy Project", prepared for Ellison, Schneider & Harris, LLP by Katestone Environmental, 13 April 2010.

[2] "Mariposa Energy Project Turbine Exhaust Velocity Characterization Case 1 - 59F 'Calm' Wind, Data plots and reference file descriptions," prepared for Diamond Generating Corporation by CH2M Hill, April 2010.

[3] Anon., "Aeronautical Information Manual", FAA.

[4] Turner, E. W., et al., "Categorization of Atmospheric Turbulence in Terms of Aircraft Response for Use in Turbulence Reports and Forecasts," Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories, November 1981. AFWAL-TR-81-3058.

[5] Schmidt, Louis V., "Introduction to Aircraft Flight Dynamics," AIAA Education Series, 1998.

[6] Schemensky, Roy T., "Development of an Empirically Based Computer Program to Predict the Aerodynamic Characteristics of Aircraft. Volume 1 Empirical Methods," Air Force Flight Dynamics Laboratory, November 1973 AD-780-100.

[7] Strojnik, Alex, "Low Power Laminar Structures," 1995.

[8] Roskam, J., *Airplane Flight Dynamics and Automatic Flight Controls, Part VI*, Roskam Aviation and Engineering Corporation, 1989.

[9] Federal Aviation Administration Type Certificate Data Sheets, http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/MainFrame?OpenFrameSet, accessed June 2010.

APPENDIX A: FAR 23 AND 25 LIMIT MANEUVERING LOAD FACTORS

FAR §23.337 Limit Maneuvering Load Factors[1]

(a) The positive limit maneuvering load factor *n* may not be less than—

(1) 2.1+(24,000÷(W+10,000)) for normal and commuter category airplanes, where W=design maximum takeoff weight, except that n need not be more than 3.8;

(2) 4.4 for utility category airplanes; or

(3) 6.0 for acrobatic category airplanes.

(b) The negative limit maneuvering load factor may not be less than—

(1) 0.4 times the positive load factor for the normal utility and commuter categories; or

(2) 0.5 times the positive load factor for the acrobatic category.

(c) Maneuvering load factors lower than those specified in this section may be used if the airplane has design features that make it impossible to exceed these values in flight.

FAR §25.337 Limit Maneuvering Load Factors[2]

(a) Except where limited by maximum (static) lift coefficients, the airplane is assumed to be subjected to symmetrical maneuvers resulting in the limit maneuvering load factors prescribed in this section. Pitching velocities appropriate to the corresponding pull-up and steady turn maneuvers must be taken into account.

(b) The positive limit maneuvering load factor *n* for any speed up to Vn may not be less than 2.1+24,000/ (W +10,000) except that *n* may not be less than 2.5 and need not be greater than 3.8— where W is the design maximum takeoff weight.

(c) The negative limit maneuvering load factor—

(1) May not be less than −1.0 at speeds up to V C; and

(2) Must vary linearly with speed from the value at V C to zero at V D.

(d) Maneuvering load factors lower than those specified in this section may be used if the airplane has design features that make it impossible to exceed these values in flight.

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[1] "Federal Aviation Regulations", Federal Aviation Administration, Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23–7, 34 FR 13088, Aug. 13, 1969; Amdt. 23–34, 52 FR 1829, Jan. 15, 1987; Amdt. 23–48, 61 FR 5144, Feb. 9, 1996, accessed at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl, June 2010.

[2] "Federal Aviation Regulations", Federal Aviation Administration, Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25–23, 35 FR 5672, Apr. 8, 1970, accessed at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl, June 2010.

Keith Freitas E-mail (Staff Queries 1–3)

Background

Contra Costa County Airports Division has some concerns regarding the proposed Mariposa Energy Power Plant being proposed near the Byron Airport. In our [Contra Costa County Airports Division] research there are several unanswered questions regarding possible hazards to aviation from exhaust plumes. Contra Costa County Airports Division would like the opportunity to provide input into to the CEC regarding the traffic and transportation analysis.

Byron Airport has more than 100 based aircraft ranging from gliders to corporate jet aircraft. The Airport operations total approximately 50,000 annually, which is approximately 140 per day. These operations include significant glider, flight training, and skydiving activities.

Staff Query

SQ1. The proposed power plant is approximately 2.65 miles south east of the Byron Airport, just a few hundred feet from the main precision instrument runway corridor (Runway 30). (Would the proposed location be hazardous to aircraft on an instrument landing, including if they slightly deviated from the prescribed corridor?)

Response:

For informational purposes, a brief general description of various instrument-aided flight procedures and instrument flight rules are provided below. The specific effects of these procedures at Byron Airport are described in detail for each applicable procedure or requirement.

General Description of Instrument Approach Procedures

An instrument approach procedure (IAP) is a type of air navigation that allows pilots to land an aircraft during periods of reduced visibility. IAPs are classified as either precision or non-precision, depending on the accuracy and capabilities of the navigation aids used. The navigation aids used may be either ground-based or satellite-based.

Precision approaches utilize both lateral and vertical course guidance information. Non-precision approaches provide lateral course guidance only. Aircraft executing a non-precision instrument approach must descend incrementally along the instrument approach path rather than follow a fixed glide slope. This distinguishes a "non-precision" approach from a precision approach in which there is electronic vertical (slope) guidance down to a decision altitude (usually 200 feet AGL or lower) and within 0.25 mile of the runway end.

The publications depicting IAPs are called Terminal Procedures, but are commonly referred to by pilots as "approach plates." These documents graphically depict the specific procedure to be followed by a pilot for a particular type of approach to a given runway. They depict prescribed altitudes and courses to be flown, as well as obstacles, terrain, and potentially conflicting airspace. In addition, they also list missed approach procedures and commonly used radio frequencies.

Byron Airport RNAV (GPS) RWY 30 Instrument Approach Procedure

Byron Airport is equipped with one satellite-based IAP, the RNAV (GPS) RWY 30. The RNAV (GPS) RWY 30 is a precision-type IAP wherein all course guidance, both vertical and lateral, is provided by Global Positioning Satellites (GPS). This IAP may also be flown as a non-precision approach, if required. Figure SQ1-1 (figures are provided at the end of this section) is the terminal procedures depiction of the RNAV (GPS) RWY 30 IAP.[4]

Instrument Flight Rules

Instrument Flight Rules (IFR) are regulations and procedures for flying aircraft using only the aircraft instrument panel for navigation. Even if nothing can be seen outside the cockpit windows, an IFR-rated pilot can fly safely while looking only at the instrument panel using Air Traffic Control (ATC) procedures designed to maintain separation from terrain, obstacles, and other aircraft.

Separation

The distance from which an aircraft avoids obstacles or other aircraft is termed separation. The most important concept in IFR flying is that separation is maintained by ATC regardless of weather conditions. Air traffic controllers separate IFR aircraft from obstacles and other aircraft by means of issuing an ATC clearance based on route, time, distance, speed, and altitude. In the case of the airspace surrounding the Byron Airport area, air traffic controllers utilize RADAR in the performance of their separation services.

ATC Clearance Required

Pilots operating under IFR require an ATC clearance for each segment of their flight, from takeoff to climb, throughout the enroute segment, then descent and landing. An ATC clearance typically provides a heading or route to follow, an altitude to maintain and communication instructions. Pilots must immediately and strictly comply with all ATC clearances and instructions. Pilots may not deviate from an assigned ATC clearance except for emergencies or unless a revised ATC clearance is received.

Federal Air Regulations – IFR

Federal Air Regulations (FAR) are specific in regard to the requirements and procedures for operating under IFR. FAR Part 91 prescribes that:

- No person may operate under IFR unless that person has received an ATC Clearance.[5]
- No pilot may deviate from an ATC clearance except under certain circumstances such as an emergency.[6]

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[4] U.S. Terminal Procedures, RNAV (GPS) RWY 30 Byron (C83)

[5] 14 CFR Part 91 (FAR) Part 91.173 ATC clearance and flight plan required

[6] 14 CFR Part 91 (FAR) Part 91.123 Compliance with ATC clearances and instructions

- Pilots must navigate along the centerline of an airway or along the direct course between the navigational aids or fixes defining that route.[7]
- Pilots shall maintain the altitude assigned that aircraft by ATC.[8]
- After the aircraft is established on the IAP, published altitudes apply to descent within each succeeding route or approach segment.[9]

Northern California TRACON (NCT)

Northern California Terminal RADAR Approach Control (TRACON) or NORCAL is responsible for the control of all air traffic in the Byron, California area. NORCAL exercises this control 24 hours per day, 7 days per week and separates IFR aircraft from obstacles and other aircraft within the confines of their delegated airspace.

No pilot may operate under IFR within the confines of NORCAL airspace unless they have received an ATC clearance and are in direct communications with NORCAL.

Byron Airport ATC Instrument Approach Clearance and Pilot Procedure

IFR aircraft inbound to Byron Airport and requesting the RNAV (GPS) RWY 30 IAP are initially cleared by NORCAL direct to the Initial Approach Fix (IAF) SHARR (see Figure SQ1-1), at a minimum altitude of 2,400 feet. This initial clearance to SHARR is followed by the actual approach clearance wherein the pilot receives an ATC clearance to execute the IAP and wherein the pilot will also be instructed to maintain an altitude of 2,400 feet until established on the approach centerline.

Once established on the approach centerline (beginning at SHARR), aircraft must navigate along the centerline or the direct course between the navigation fixes defining that approach procedure.

Additionally, published altitudes apply to descent within each succeeding route segment of the instrument approach. As specified in the RNAV (GPS) RWY 30 Approach Plate, aircraft may descend no lower than 1,000 feet until within 2.9 miles of the runway (CUDUG) if executing the LNAV (Lateral navigation only – no vertical reference available) non-precision procedure (see Figure SQ1-1). If executing the LPV (Localizer Performance with Vertical Guidance) precision approach procedure, the published 3-degree glide slope descent path (300 feet per nautical mile) will position an aircraft to cross at the same Fix CUDUG at the same distance (2.9 miles) from the runway, but at a slightly higher altitude of 1,140 feet.

This 2.9-mile location is approximately abeam, or directly abreast of the middle of, MEP, which will be located 2.7 miles south of Runway 5/23. Therefore, aircraft will be crossing abeam the MEP while established on the RNAV (GPS) RWY 30 final approach course at or above 1,000 feet AMSL.

[7] 14 CFR Part 91 (FAR) Part 91.181 Course to be flown

[8] 14 CFR Part 91 (FAR) Part 91.179 IFR cruising altitude or flight level

[9] 14 CFR Part 91 (FAR) Part 91.175 Takeoff and landing under IFR

Missed Approach Procedure

While executing the RNAV (GPS) RWY 30 approach, if a pilot determines that a safe landing cannot be accomplished for any reason, the landing approach must be discontinued and the missed approach procedure (MAP) must be initiated immediately. A pilot initiates the MAP by immediately adding power to initiate a climb, and by so doing arrests the descent of the aircraft. The pilot climbs on the assigned heading to the altitude specified in the MAP (3,000 feet) and navigates via the published MAP route to the holding fix, HAIRE.

Protected Airspace

Protected airspace associated with IAP provides the pilot with separation from terrain and obstructions. Pilots executing an IAP are required to fly the IAP under specific tolerances and remain within protected airspace. The regulations governing the tolerances for operation under IFR are established in 14 CFR Part 91.

For a pilot, remaining within protected IAP airspace is a matter of staying as close as possible to the centerline of the final approach course. The final approach course on the RNAV (GPS) RWY 30 begins at the Final Approach FIX (BABPI) and terminates just prior to the runway (see Figure SQ1-1).

For approaches, it is not enough for a pilot to simply remain within protected airspace. A pilot must maintain a track that will ensure arrival at the runway with the aircraft continuously in a position from which a descent to landing can be made at a normal rate of descent using normal maneuvering.

While executing an IAP, pilots utilize a cockpit instrument called a Course Deviation Indicator (CDI) for course guidance. Following and responding to the on/off course indications of the CDI, pilots ensure they remain on the centerline and within protected airspace as they complete the approach to a safe landing.

Beginning Descent on an Instrument Approach

Pilots must be established on course before they may begin descent on the approach. An aircraft is considered established when it is within a ½ full needle deflection of the CDI.[10]

Off-course Deviations – Required Pilot Action

Because of the safety critical nature of a properly executed IAP, it is imperative that a pilot maintains a stabilized final approach at all times. Safety also demands that a missed approach be initiated whenever the position of the aircraft within protected airspace can no longer be assured or when the corrective maneuvering required may lead to positioning the aircraft such that it cannot safely complete the required landing procedure using normal maneuvers.[11]

The farther off course an aircraft drifts, the larger a heading correction is required to remain in the safety buffer and to re-stabilize the approach.

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[10] ICAO Procedures for Air Navigation Services-Aircraft Operations (PANS-OPS) Volume 1 Flight Procedures

[11] 14 CFR Part 91 (FAR) Part 91.175

The FAA requires that a pilot who is executing an instrument approach:[12]

- Establish a rate of descent and track that will ensure that the aircraft is continuously in a position from which descent to a landing on the intended runway can be made at a normal rate using normal maneuvers.
- While on the final approach segment, allow no more than a three-quarter-scale deflection of either the vertical or lateral indications of the CDI.

A full-scale deflection of the CDI (full-scale lateral course deviation indication) equates to a linear 0.3 nautical mile off of centerline (about 1,800 feet to the left and right) when inside the final approach fix and extending to the missed approach point.[13]

Figure SQ1-2 contains a depiction of the RNAV (GPS) RWY 30 Final Approach Course and its position relative to the MEP stacks. It also contains a depiction of the 0.3 nautical mile full-scale deflection of the CDI.

Staff Query 1 states "The proposed power plant is approximately 2.65 miles south east of the Byron Airport, just a few hundred feet from the main precision instrument runway corridor (Runway 30)." Rather than being situated "just a few hundred feet from the main precision instrument runway corridor," the MEP stacks will actually be located approximately 1 mile laterally from the centerline of the main precision instrument runway corridor (Runway 30), or over 4 times the deviation that is allowed before the pilot must execute a MAP

Pilots deviating from the final approach course centerline must immediately initiate a missed approach when the degree of the deviation places the aircraft in a potentially unsafe position. The FAA standard as to the maximum allowed course deviation before a missed approach must be initiated is a ¾-scale needle deflection of the CDI. Since a ¾-scale deflection of the CDI equates to 1,350 feet off course, a pilot must initiate a missed approach at a point no further than a displacement of 0.22 mile (1,350 feet) from the final approach course centerline.

When and if an aircraft deviates from the final approach course centerline by 0.22 or more miles, the pilot is required to immediately apply full power, pull up, begin a climb and execute a missed approach. Because the MEP stacks will be located approximately 1 mile lateral distance from the centerline of the final approach course, FAA missed approach requirements ensure that the deviating aircraft will pass no closer than 0.78 mile from the MEP stacks.

Off-course Pilot Deviations – Required Air Traffic Controller Action

The air traffic controller who clears an aircraft for the RNAV (GPS) RWY 30 approach is required to RADAR monitor the flight path of the aircraft as it executes the approach. FAA Order 7110.65, *Air Traffic Control* requires that the air traffic controller instruct the pilot to execute a missed approach whenever the completion of a safe approach is questionable because safety limits are exceeded or radical target deviations are observed.[14]

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[12] FAA PTS FAA-S-8081-4D, April 2004

[13] FAA Safety Team (FAAST) Stabilized Instrument Approach & Landing (RNAV (GPS) Approaches, February, 2009

[14] FAA Order 7110.65, Air Traffic Control, Paragraph 5-10-4, Final Approach Abnormalities

An air traffic controller observing a pilot making a radical deviation from the final approach course is required by FAA order to instruct the pilot to execute a missed approach. This is a second level of defense and a safety measure to preclude against a pilot inadvertently deviating dangerously off course during this critical phase of flight.

Summary

The FAA requires pilots executing IAPs to initiate a missed approach whenever the position of the aircraft within protected airspace can no longer be assured or when the corrective maneuvering required may lead to positioning the aircraft such that it cannot safely complete the required landing procedure.

The maximum off-course divergence allowed by the FAA before a missed approach must be initiated is approximately 0.22 mile from the final approach course centerline. Since the MEP stacks will be located approximately 1 mile abeam the centerline of the RNAV (GPS) RWY 30 final approach course, aircraft drifting off course must execute a missed approach at a point that is no closer than approximately 0.78 miles to MEP.

A second level of defense and a safety measure to preclude against a pilot inadvertently deviating dangerously off course during this critical phase of flight is the FAA requirement that air traffic controller RADAR monitor the flight path of the aircraft as it executes the instrument approach. A controller observing a pilot making a radical deviation from the final approach course is required by FAA order to instruct the pilot to execute a missed approach.

Conclusion

The MEP facility will be located 1.0 mile from the centerline of the RNAV (GPS) RWY 30 Final Approach Course. Pilots diverging from the centerline of the RNAV (GPS) RWY 30 Final Approach Course by 0.22 miles are required by the FAA to immediately initiate a missed approach, and air traffic controllers are required to instruct the pilot to initiate a missed approach whenever the completion of a safe approach is questionable because safety limits are exceeded or radical target deviations are observed. These required actions of both the pilot and the air traffic controller ensures against aircraft inadvertently overflying the MEP facility due to slight deviations from the final approach corridor. Therefore the MEP location is not hazardous to aircraft executing a precision or non-precision instrument approach and landing at Byron Airport.

Staff Query

SQ2. The power plant site is also near the downwind leg of both Runway's 5 and 23. It appears the site would also be adjacent to the standard "45" entry into the Runway's 5 and 23 traffic pattern. (Would flying at 1000' near or over the proposed location pose a hazard to aircraft in flight?)

Response:

Two points are expressed in this concern: (1) that standard "45" entry into Runways 5 and 23 would overfly MEP, and (2) an overflight at 1,000 feet could pose a hazard to aircraft. Each of these points is addressed in this response.

"45" Entry to the Runway 5/23 Traffic Pattern

FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*

Byron Airport is not equipped with an operating control tower. At non-towered airports such as Byron, the FAA, by means of Advisory Circular AC 90-66A, prescribes and recommends traffic patterns and operational procedures for aircraft, lighter than air, glider, parachute, helicopters, and ultralight operations at airports without operating control towers.

All student pilots, as an element of their flight training, receive instruction with regard to the provisions contained in AC 90-66A. In order to obtain a Private Pilot license, student pilots must demonstrate knowledge of and proficiency in the performance of the practices recommended in this AC before an FAA examiner.

Byron Airport Runway 5/23 Traffic Pattern Location

The Airport Facility Directory (AF/D) indicates a right traffic pattern for Runway 5, and a left traffic pattern for Runway 23.[15] Therefore, the position of the Runway 5/23 traffic patterns is to the south of Runway 5/23.

Byron Airport Runway 5/23 Traffic Pattern Altitude and Width

AC 90-66A recommends that aircraft observe a 1,000-foot-AGL traffic pattern altitude and that large and turbine-powered aircraft should maintain a 1,500-foot-AGL traffic pattern altitude. Pilots may vary the size of the traffic pattern depending on the aircraft's performance characteristics.[16]

Since the Byron Airport field elevation is 79 feet above mean sea level (AMSL), the recommended Runway 5/23 traffic pattern altitude is 1,079 AMSL (1,000 feet AGL).

Although traffic pattern widths vary with aircraft performance characteristics, aircraft normally remain within 0.75 to 1 mile of the runway. Therefore, aircraft operating in the Runway 5/23 fixed wing traffic pattern will remain at least 1.5 miles from MEP.

AC 90-66A Prescribed Traffic Pattern Entry Procedure

The FAA recommends that arriving aircraft should be at the appropriate traffic pattern altitude before entering the traffic pattern, and that entry to the downwind leg of the traffic pattern should be at a 45 degree angle abeam the midpoint of the runway.[17]

MEP Location in Regard to the "45" Entry to Runway 5/23

MEP is located approximately 2.7 miles southeast of the Byron Airport, approximately midway between the 45 degree entries to both Runway 5 and Runway 23 (see Figure SQ2-1).

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[15] FAA AF/D C83, Byron Airport

[16] FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*, Recommended Standard Traffic Pattern

[17] FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*, Recommended Standard Traffic Pattern

Pilots operating in compliance with the FAA-recommended practice for traffic pattern entry will enter the downwind leg of the Runway 5/23 traffic pattern at a 45 degree angle abeam the midpoint of Runway 5/23. The ground track of these aircraft is approximately 1 mile from the MEP location. It will not be necessary for pilots to overfly MEP as they enter the Runway 5/23 traffic pattern.

Regulatory Minimum Safe Altitude

FAR Part 91 specifies that except when necessary for takeoff or landing, no person may operate an aircraft below an altitude at which an emergency landing cannot be made without undue hazard to persons or property on the surface.[18] For the purpose of takeoff or landing, operating an aircraft below an altitude of 1,000 feet AGL is not necessary outside of the confines of the airport traffic pattern. Prudent pilots comply with this regulation by operating their aircraft at safe altitudes, normally at least 1,500 to 2,000 feet AGL, unless a lower altitude is necessary while in the traffic pattern for the purpose of takeoff or landing.

Prior to entering the traffic pattern at non-towered airports such as Byron Airport, AC 90-66A prudently recommends approaching the airport at an altitude above traffic pattern altitude, noting wind direction and active runway, then proceeding to a point well clear of the pattern before descending to the pattern altitude.[19]

While on the recommended 45 degree traffic pattern entry ground track, prudent pilots adhering to the regulatory requirements specified in FAR Part 91 and the recommended practices of AC 90-66A will be descending from altitudes well above the limits of the effects of an exhaust plume and will not pass through the plume.

Notice to Airman (NOTAM)

A Notice to Airmen (NOTAM) is a notice, essential to safety of flight, which contains information pertaining to the National Airspace System, the timely knowledge of which is essential to personnel concerned with flight operations.

One specific type of NOTAM pertaining to MEP is the Flight Data Center (FDC) NOTAM. An FDC NOTAM is regulatory in nature and issued to establish restrictions to flight and changes to charts or IAPs. Pilots in violation of regulatory NOTAMs are subject to FAA enforcement action which could result in either suspension or revocation of their pilot certificate.

A national FDC NOTAM, which restricts pilots from overflying power plants and other structures, is currently active. Aircraft directly overflying power plants, when avoidable, are not in compliance with FDC NOTAM 4/0811. Although primarily intended for national security purposes, an unintended consequence is that this NOTAM also advises pilots against flying over or through exhaust plumes from a power plant. It reads as follows:

FDC 4/0811 FDC…SPECIAL NOTICE…THIS IS A RESTATEMENT OF A PREVIOUSLY ISSUED ADVISORY NOTICE. IN THE INTEREST OF NATIONAL SECURITY AND TO THE EXTENT PRACTICABLE, PILOTS ARE STRONGLY ADVISED TO AVOID

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[18] 14 CFR Part 91 (FAR Part 91.119, Minimum Safe Altitudes: General

[19] FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*, Recommended Standard Traffic Pattern

THE AIRSPACE ABOVE, OR IN PROXIMITY TO SUCH SITES AS POWER PLANTS (NUCLEAR, HYDRO-ELECTRIC, OR COAL), DAMS, REFINERIES, INDUSTRIAL COMPLEXES, MILITARY FACILITIES, AND OTHER SIMILAR FACILITIES. PILOTS SHOULD NOT CIRCLE AS TO LOITER IN THE VICINITY OVER THESE TYPES OF FACILITIES.

Effects of Flying through the MEP Plume

Should an aircraft stray from the designated "45" entry for Runways 5 and 23, disregard the aforementioned FDC NOTAM and overfly MEP at flight pattern altitude of 1,079 feet AMSL or greater, it may fly through the exhaust plume of the facility. An overflight at 1,079 feet AMSL would not cause any concern related to physical structures at MEP because all structures are less than 100 feet AGL, as recommended by the Contra Costa County Airport Land Use Plan.

Turbulence Associated with Overflight of Exhaust Plumes

Figure SQ2-2 depicts the average level of turbulence a pilot would experience during overflight of the proposed MEP exhaust plume at 1,076 feet AMSL, which is equivalent to 954 feet AGL, the MEP site elevation being 125 feet AMSL. The average vertical gust rates were computed based on the work of Peter F. Lester, Emeritus Professor of Meteorology, San Jose State University, who has assigned velocity rates to light, moderate and severe turbulence levels.[20]

The data presented in Figure SQ2-2 are based on the conclusions of the Katestone Environmental analysis (Attachment DR52-6), which are summarized below:

- Exhaust plume elevation has been calculated for instances when average plume velocity exceeds 9.6 mph (847 fpm, 4.3 m/s), which is the mid-range of light turbulence. Based on the thermal plume and meteorological analysis conducted by Katestone Environmental (Attachment DR52-6), this level of average velocity, 847 fpm, is exceeded only 26 hours per year at the MEP location at the Flight Pattern Altitude (1,079 feet AMSL).

- Based on average plume velocities the light turbulence upper limit of 13.6 mph (1,200 fpm, 6.09 m/s) is never exceeded at the Flight Pattern Altitude. A pilot overflying MEP and flying through the plume at pattern altitude will therefore typically encounter no more than light turbulence.

- The meteorological modeling predicts that at the MEP location (Altamont Pass area), wind conditions are calm enough to allow a vertical plume velocity of 9.6 mph to occur at the Flight Pattern Altitude (1,079 AMSL) or greater only 26 hours per year. Relatively calm wind conditions exist at elevations from 33 feet to 5,740 feet AGL; the predicted average wind velocity over this range of elevations during these 26 hours ranges from 1.3 to 6.05 mph. In general terms, at higher wind velocities it is less likely that a plume velocity of 9.6 mph could occur at 1,079 feet AMSL, because higher wind velocities will break up the plume.

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20 Lester, Peter F.1995. Aviation Weather. Jeppesen Sanderson Training Products

- During the 26 annual hours that a vertical plume velocity of 9.6 mph (4.3 m/s) would be exceeded at the Flight Pattern Altitude or higher, the pilot of a general aviation aircraft (considering a groundspeed of 75 mph) overflying an exhaust plume at an altitude above 954 feet AGL may experience turbulence for 6.8 seconds. The level of turbulence experienced will amount to no more than a "bump" and will not present a safety hazard to the aircraft.
- At wind velocities over 6 mph at the MEP site, the plume will begin dissipating the moment it clears the confines of the exhaust stack and will never reach the Flight Pattern Altitude with an average vertical velocity of 9.6 mph.
- Orographic winds (mechanical turbulence) and solar heating (convective turbulence) in the Altamont Pass area have historically created sustained light to moderate turbulence in the hills and valleys surrounding the Byron Airport. Pilots inadvertently overflying a MEP exhaust plume will not experience turbulence greater than that which they are accustomed to experiencing in the Byron Airport area.

CH2M HILL developed further information on plume conditions through a CFD modeling of the plume under various conditions. Senta Engineering further evaluated plume impacts on various types of aircraft. The reports are attached as Attachment DR52-7 and Attachment DR52-9, respectively. The findings of these two reports are summarized below:

- At a Flight Pattern Altitude of approximately 950 feet AGL, the plume from all four gas turbines operating at maximum load has a length of approximately 739 feet and a width of 457 feet.
- Based on two perpendicular section lines, the instantaneous velocities across the plume at 950 feet AGL vary from 187 fpm to 1,489 fpm (2.13 mph to 16.92 mph).
- An average of the instantaneous velocities along the two perpendicular section lines is 833.1 fpm (9.5 mph), slightly less than but generally consistent with the 11.5 mph velocity in the Katestone Environmental analysis.
- Based on the aforementioned plume analysis, the load imparted by the plume to an airframe ranges from +1.24g to +1.67g, while the load limits for aircraft range from +6.0g to -1.75g.
- Light aircraft—for example, Cessna 172 at 1,600 lb or Vans RV-6 at 1,100 lb—traveling at 70 knots (80 mph) at a point through the plume where the maximum instantaneous velocity occurs would experience moderate turbulence. This condition is only expected to occur during worst-case plume rise, which occurs only 1 hour per year as predicted in the Katestone Environmental analysis. The same aircraft traveling at less than 70 knots would experience only light turbulence.
- Aircraft flying through the plume may encounter asymmetrical vertical velocity loading across its wingspan imparting a rolling moment. Aileron deflections required to neutralize the rolling moment range from 5.0 to 6.7 degrees, with the respective aircraft having an available aileron deflection of 14 to 20 degrees.

Summary and Conclusion

The standard 45 degree entry into the Runway 5 or 23 traffic patterns does not require aircraft to overfly MEP, and standard/typical traffic pattern entries would be approximately 1 mile from MEP. Once the facility is built, aircraft will be able to clearly see the facility and practice standard "see and avoid" procedures. Even if an aircraft overflew MEP at an elevation of 950 feet AGL, the average vertical velocity would only create light turbulence. A more detailed instantaneous velocity evaluation of the plume's impact shows that airframe loadings would be below load limits and any asymmetrical wing loadings can be controlled by typical aileron movement. MEP has received a "Determination of No Hazard to Air Navigation" from the FAA for all four exhaust stacks, which included an evaluation by Flight Standards Division. Therefore, based on the aforementioned results, MEP would not pose a hazard to aircraft in flight during traffic pattern entry, whether or not they inadvertently overflew MEP.

Staff Query

SQ3. Lastly, the power plant site would be under the "right 45" for aircraft departing Runway 12. This is specifically significant because it is the preferred departure runway for the skydiving company jump planes based on the airfield. (Would flying near or over the proposed location pose a hazard to aircraft in flight?)

Response:

FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*

FAA Advisory Circular AC 96-66A addresses appropriate practices for airports that do not have an operating control tower.

Byron Airport is not equipped with an operating control tower. At non-towered airports such as Byron, the FAA, by means of Advisory Circular AC 90-66A prescribes and recommends traffic patterns and operational procedures for aircraft, lighter-than-air, glider, parachute, helicopter, and ultralight operations at airports without operating control towers.

All student pilots, as an element of their flight training receive instruction with regard to the provisions contained in AC 90-66A. In order to obtain a Private Pilot license, student pilots must demonstrate knowledge of and proficiency in the performance of the practices recommended in this AC before an FAA examiner.

Byron Airport Runway 12/30 Traffic Pattern Location

The Airport Facility Directory (AF/D) indicates a right traffic pattern for Runway 30, and a left traffic pattern for Runway 12.[21] Therefore, the position of the Runway 12/30 traffic pattern is to the east-northeast of Runway 12/30, while MEP is located to the south-southeast of Runway 12/30.

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[21] FAA AF/D C83, Byron Airport

Byron Airport Runway 12/30 Traffic Pattern Altitude and Width

AC 90-66A recommends that aircraft observe a 1,000-foot-AGL traffic pattern altitude, and large and turbine-powered aircraft maintain a 1,500 foot AGL traffic pattern altitude. Pilots may vary the size of the traffic pattern depending on the aircraft's performance characteristics.[22]

Since the Byron Airport field elevation is 79 feet AMSL, the recommended Runway 12/30 traffic pattern altitude is 1,079 AMSL (1,000 feet AGL). Although traffic pattern widths vary with aircraft performance characteristics, aircraft normally remain within 0.75 to 1 mile of the runway. MEP is 2.7 miles from the end of Runway 30.

FAA AC 90-66A Prescribed Traffic Pattern Departure Procedure

The FAA recommends that when departing the traffic pattern, aircraft should continue straight out or exit with a 45 degree left turn (right turn for right traffic patterns) beyond the departure end of the runway and after reaching pattern altitude.[23]

Since Byron Airport Runway 12 has a published left traffic pattern, the FAA recommended departure procedure is as follows: Depart straight out, or exit the traffic pattern straight out, then commence a 45 degree left turn after reaching pattern altitude (1000 feet AGL).

Byron Airport Runway 12 Departure Procedure and MEP Location

Pilots operating in compliance with the FAA recommended practice for departing the Byron Airport traffic pattern may depart straight out, in which case the aircraft ground track will pass 1 mile northeast of MEP. Other aircraft may elect to depart straight out, and then execute a left turn after reaching 1,000 feet AGL. In this case, departing aircraft will turn away from MEP. In either case, a pilot would not overfly the MEP exhaust plumes (Figure SQ3-1).

Byron Airport Skydiving Company Jump Plane Non-Standard Departure Procedure

The comment and question indicates that the skydiving company jump planes based at the Byron Airport are departing Runway 12 and executing a non-standard departure procedure by turning right rather than either proceeding straight out or performing a left turn after reaching pattern altitude. This non-standard departure procedure has not been published by the Byron Airport operator and is contrary to the FAA recommendations contained in AC 90-66A.

Prevailing winds at the Byron Airport are from the west/northwest. On days when winds are not calm and the wind is from the west/northwest, aircraft will operate on either Runway 30 or Runway 23. On calm wind days, the Byron Airport/Facility Directory specifies Runway 30 as the calm wind runway.[24]

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[22] FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*, Recommended Standard Traffic Pattern

[23] FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*, Recommended Standard Traffic Pattern

[24] Airport/Facility Directory, C83, Byron Airport, Airport Remarks

If the skydiving company planes are departing Runway 12 on days with westerly winds or when winds are calm, they are conducting operations against the normal flow of traffic and are operating head-on with other arriving and departing aircraft, which are appropriately using Runway 30. An opposite direction takeoff at a non-towered airport is contrary to FAA-recommended practice and may, at times, become a safety issue. In addition, executing a right turn after departing Runway 12 places that departing aircraft in conflict with aircraft that may be on the published left downwind leg of the Runway 23 traffic pattern.

The FAA believes that observance of a standard traffic pattern will improve the safety and efficiency of aeronautical operations at airports without operating control towers.[25] Pilots who depart on Runway 12 when the winds are from the west/northwest or during calm wind conditions do not contribute to the safety and efficiency of Byron Airport operations. If the skydiving company planes departing Runway 12 choose to depart straight out (as per AC 90-66A), they will pass approximately 1 mile laterally away from MEP. If they do not commence their right turn until after reaching 1,000 feet AGL (as per AC 90-66A), they will also bypass MEP by nearly 1 mile (Figure SQ3-2), assuming a speed of 100 knots and a climb rate of 600 feet per minute.

Notice to Airmen (NOTAM)

A Notice to Airmen (NOTAM) is a notice, essential to safety of flight, which contains information pertaining to the National Airspace System, the timely knowledge of which is essential to personnel concerned with flight operations.

One specific type of NOTAM pertaining to MEP is the Flight Data Center (FDC) NOTAM. An FDC NOTAM is regulatory in nature and issued to establish restrictions to flight and changes to charts or Instrument Approach Procedures. Pilots in violation of regulatory NOTAMs are subject to FAA enforcement action which could result in either suspension or revocation of their pilot certificate.

A national FDC NOTAM, which restricts pilots from overflying power plants and other structures, is currently active. Aircraft directly overflying power plants, when avoidable, are not in compliance with FDC NOTAM 4/0811. Although primarily intended for national security purposes, an unintended consequence is that this NOTAM also advises pilots against flying over or through exhaust plumes from a power plant. It reads as follows:

FDC 4/0811 FDC…SPECIAL NOTICE…THIS IS A RESTATEMENT OF A PREVIOUSLY ISSUED ADVISORY NOTICE. IN THE INTEREST OF NATIONAL SECURITY AND TO THE EXTENT PRACTICABLE, PILOTS ARE STRONGLY ADVISED TO AVOID THE AIRSPACE ABOVE, OR IN PROXIMITY TO SUCH SITES AS POWER PLANTS (NUCLEAR, HYDRO-ELECTRIC, OR COAL) DAMS, REFINERIES, INDUSTRIAL COMPLEXES, MILITARY FACILITIES, AND OTHER SIMILAR FACILITIES. PILOTS SHOULD NOT CIRCLE AS TO LOITER IN THE VICINITY OVER THESE TYPES OF FACILITIES.

As indicated in the response to Staff Query #2, if an aircraft loaded with parachutists were to inadvertently overfly MEP, the aircraft may typically experience light turbulence during

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[25] FAA Advisory Circular AC 90-66A, *Recommended Standard Traffic Patterns and Practices for Aeronautical Operations at Airports without Operating Control Towers*, Background and Scope

worst-case plume rise conditions. Even if an aircraft makes a non-standard departure on Runway 12 and once it reaches pattern altitude of 1,079 feet AMSL, makes a right "45" departure, it will not have to overfly the MEP. If it did overfly MEP, it would typically experience only light turbulence during worst-case plume rise. Therefore, flying near or over MEP does not pose a hazard to aircraft in flight.

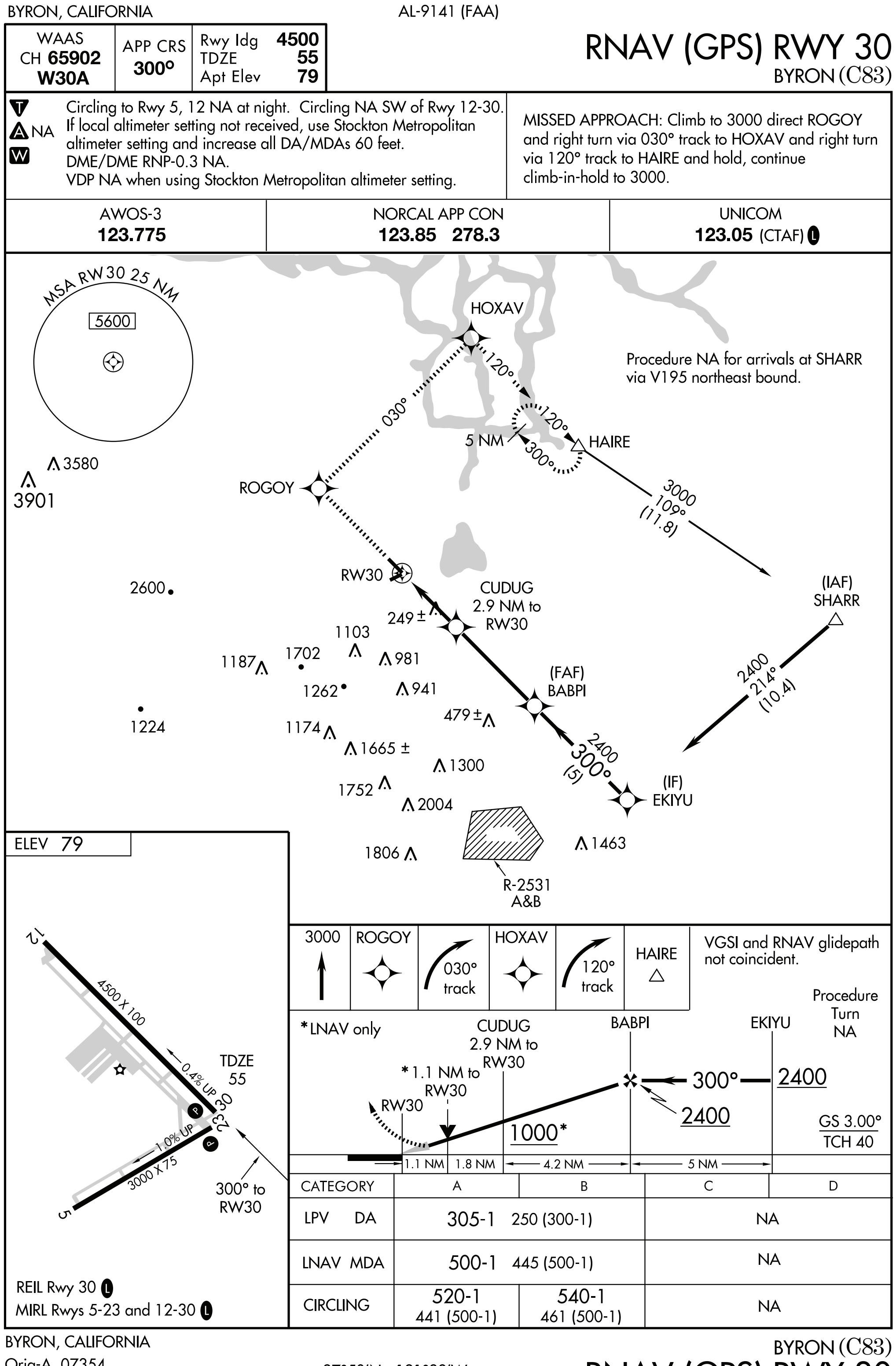

FIGURE SQ1-1
AREA NAVIGATION,
BYRON AIRPORT
Mariposa Energy Project
Alameda County, California

Source: Jeppesen Airway Manual

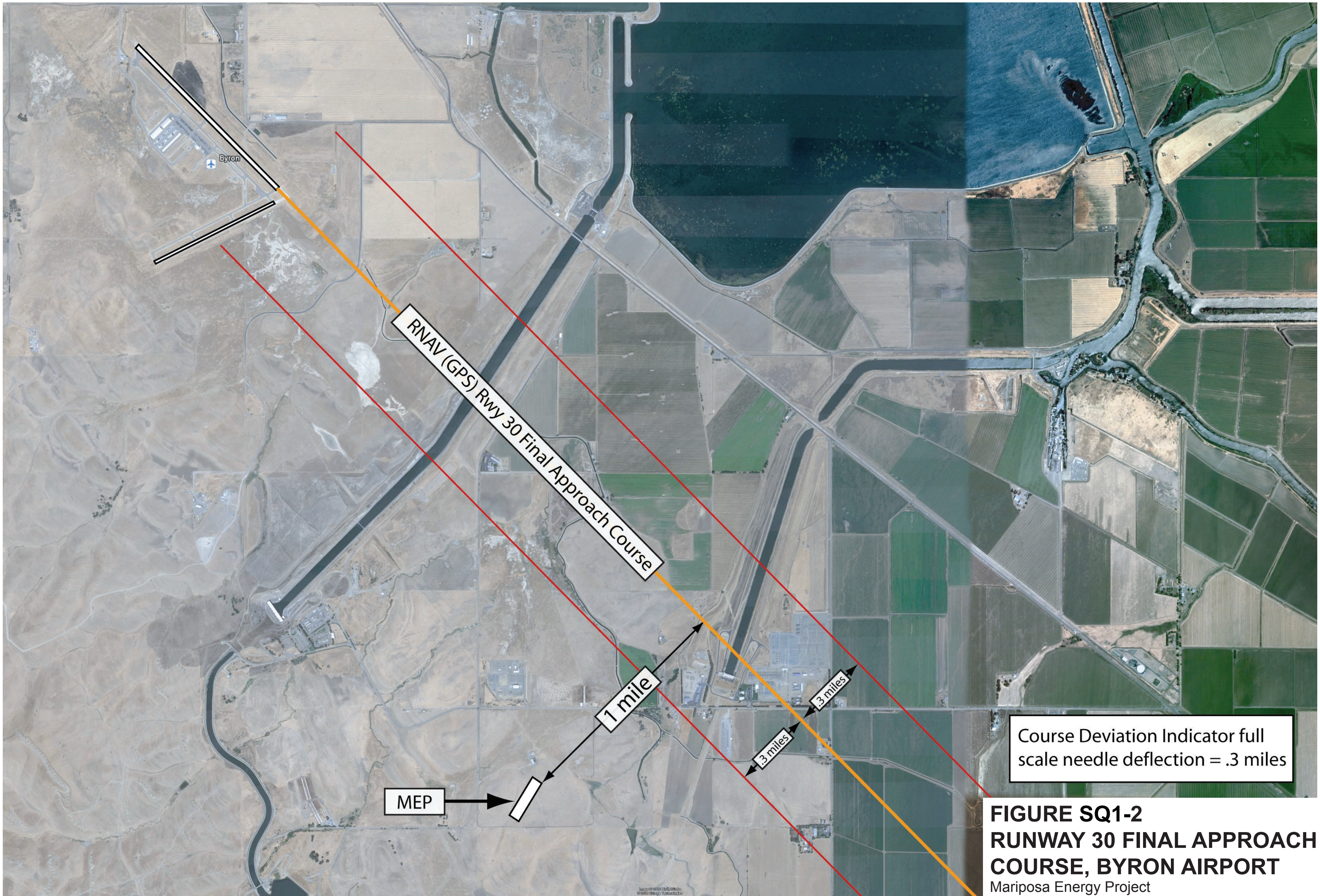

FIGURE SQ1-2
RUNWAY 30 FINAL APPROACH COURSE, BYRON AIRPORT
Mariposa Energy Project
Alameda County, California

Aerial courtesy of Google™ Earth, 2010.

EY012009005SAC Figure_SQ1-2.ai 06.10.2010 tdaus

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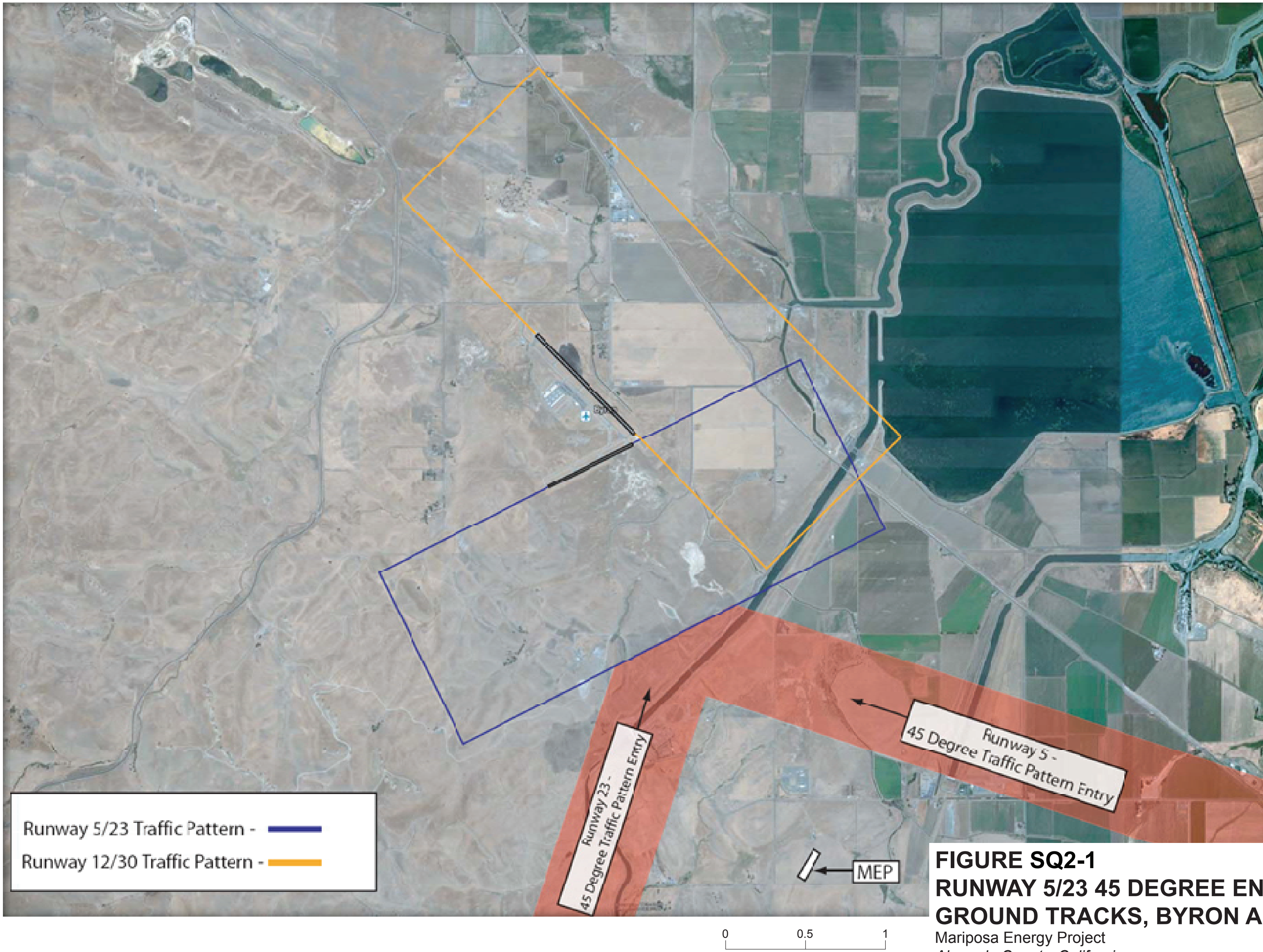

FIGURE SQ2-1
RUNWAY 5/23 45 DEGREE ENTRY GROUND TRACKS, BYRON AIRPORT
Mariposa Energy Project
Alameda County, California

Aerial courtesy of Google™ Earth, 2010.

Aviation Weather Turbulence Classifications[1]

Category	Maximum Plume Length (feet)[4]	Time Spent in Plume[5] (sec)	Plume Vertical Gust	Light Turbulence	Moderate Turbulence	Severe Turbulence
				300 FPM[2] to 1200 FPM	1200 FPM to 2100 FPM	2100 FPM to 3000 FPM
				3.4 MPH[3] to 13.6 MPH	13.6 MPH to 23.9 MPH	23.9 MPH to 34.1 MPH
Threshold Level of 4.3 m/sec (9.6 mph) is exceeded only 26 hours per year at an elevation of 1076 AMSL with all four gas turbines operational	313	3.04	846 FPM 9.6 MPH	------------------------↑		
Light Turbulance Level of 6.09 m/sec (13.6 mph) is never exceeded at an elevation of 1076 AMSL with all four gas turbines operational	103 @ 696 feet[6]	1.003	1200 FPM 13.6 mph	------------------------------------↑		
				Light Turbulence	Moderate Turbulence	Severe Turbulence

[1] **Source : Aviation Weather, Peter F. Lester, Jeppesen Sanderson Training Products © 1995**

[2] **FPM : Feet Per Minute**

[3] **MPH : Miles Per Hour**

[4] **Source: Katestone 2010, Tables 7 and 8.**

[5] **Assuming speed of 70 MPH**

[6] **Maximum elevation that a velocity of 6.09 m/s occurs is 696 feet does not reach 1076 feet**

FAA Descriptions of Turbulence:

Light:
Causes slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude.
Occupants may feel a slight strain against seat belts or shoulder straps.
Unsecured objects may be displaced slightly.
No difficulty is encountered in walking.

Moderate:
Changes in altitude and / or attitude occur but the aircraft remains in positive control at all times.
Occupants feel definite strains against the seat belts or shoulder straps.
Unsecured objects are dislodged.
Food service and walking are difficult.

Severe:
Causes large abrupt changes in altitude and / or attitude
Occupants are forced violently against seat belts or shoulder straps
Unsecured objects are tossed about
Food service and walking are impossible.

Prevailing aviation weather forecast (turbulence) on a typical summer afternoon:

Orographic winds and solar heating create sustained light to moderate turbulence in the hills and valley surrounding the airport.

FIGURE SQ2-2
AVIATION WEATHER TURBULENCE ESTIMATES
Mariposa Energy Project
Alameda County, California

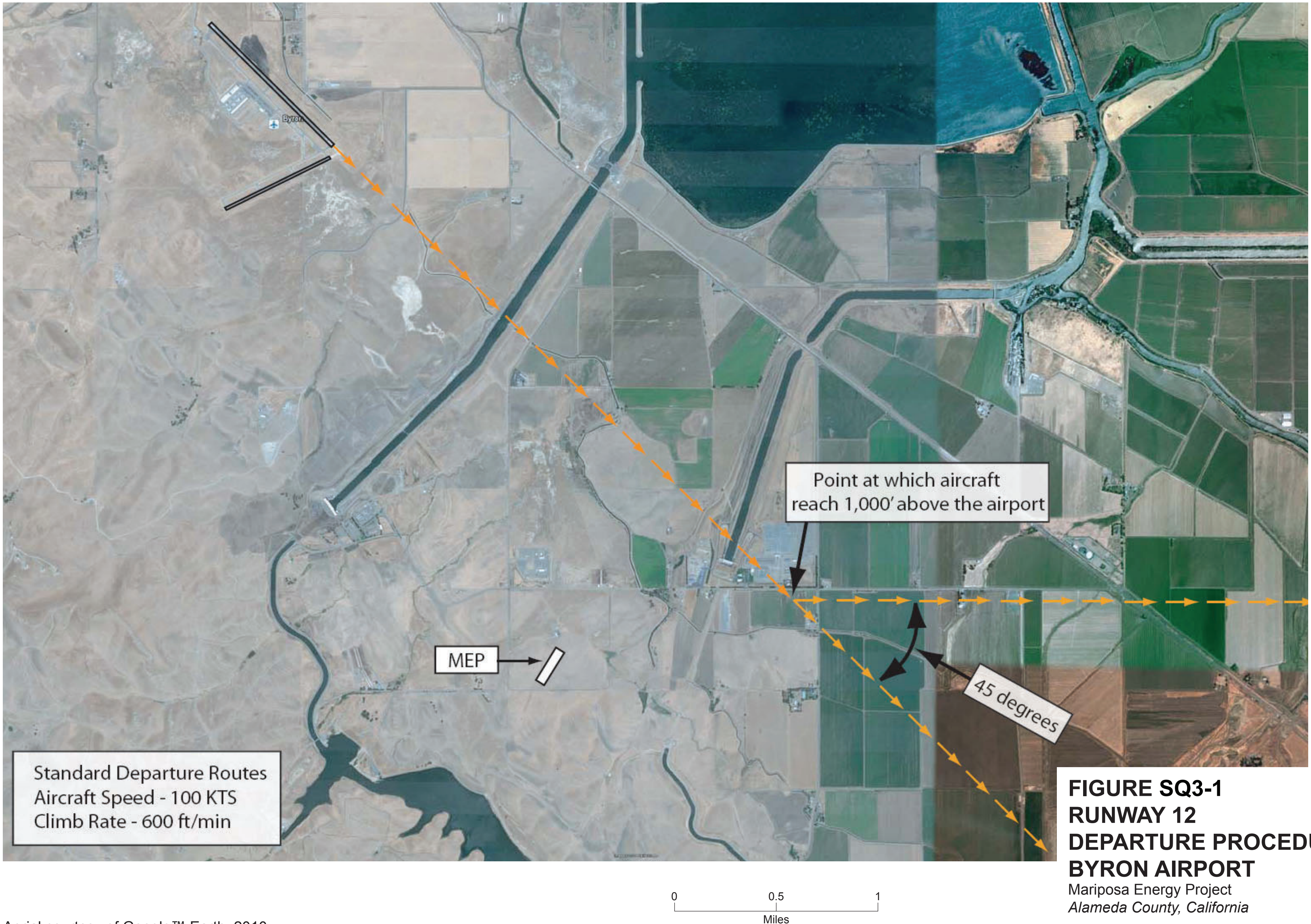

FIGURE SQ3-1
RUNWAY 12
DEPARTURE PROCEDURE,
BYRON AIRPORT
Mariposa Energy Project
Alameda County, California

Aerial courtesy of Google™ Earth, 2010.

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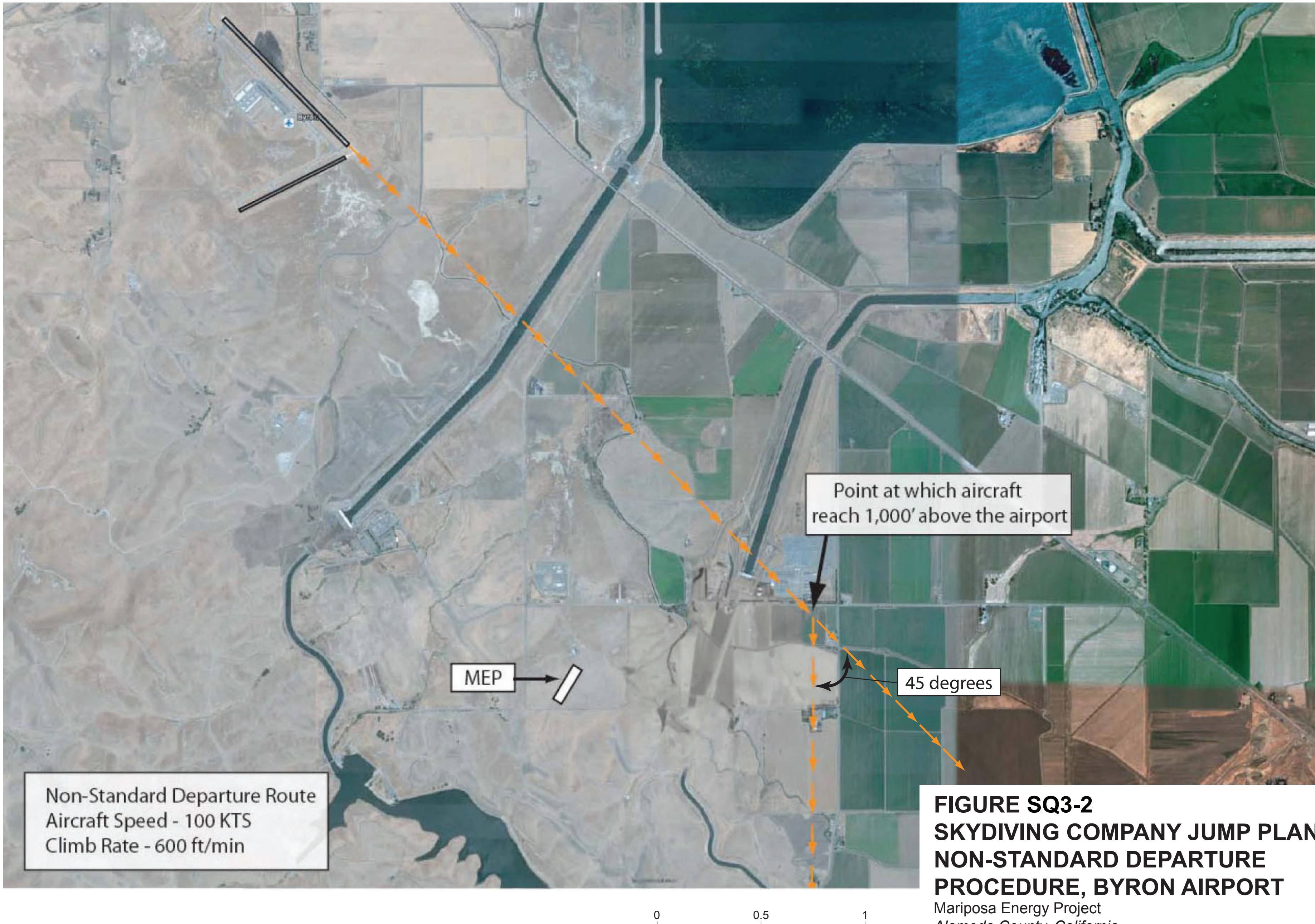

FIGURE SQ3-2
SKYDIVING COMPANY JUMP PLANE NON-STANDARD DEPARTURE PROCEDURE, BYRON AIRPORT
Mariposa Energy Project
Alameda County, California

Aerial courtesy of Google™ Earth, 2010.

EY012009005SAC Figure_SQ3-2.ai 06.11.2010 tdaus

CH2MHILL

Contra Costa County Airport Land Use Commission Letter (Staff Queries 4–11)

Background

The Contra Costa County Airport Land Use Commission (CCC ALUC) met on October 14, 2009 and November 5, 2009 to review the Mariposa project (09-AFC-03). The CCC ALUC's review of projects is guided by their 2000 *Contra Costa County Airport Land Use Compatibility Plan* (CLUP), which was drafted with guidance from the last two editions of the *Airport Land Use Planning* Handbook issued by CalTrans Division of Aeronautics. There is relatively little guidance in the current and past editions of the CalTrans Handbook pertaining specifically to power plants, and this project presents CCC ALUC with several issues at first impression.

After considering the presentation of the Applicant and the public testimony, CCC ALUC found they could not come to any determinations with regard to safety issues relative to aircraft operations, project compatibility with their CLUP, or mitigation measures without further information from the CEC, and possibly from CalTrans Division of Aeronautics. Specifically, CCC ALUC felt that they would need from the CEC further information and some analysis of the exhaust plumes from the proposed plant under various conditions.

Staff Query

SQ4. From the hearing, it appears that one or more of the four characteristics of a power plant plume may be causing the aircraft turbulence issues that have been observed: (1) upward draft velocity of the plume, (2) horizontal temperatures gradients in the horizontal flight path of an aircraft through the plume, (3) swirling motion of the plume (e.g., eddies, vortices), and (4) oxygen depletion and/or excess CO2 that can affect the chemical reaction in internal combustion engines. We would like to know which of these characteristics, or other characteristics of which we are not aware, are most relevant to assessing aircraft turbulence issues. We request that CEC staff consult with CalTrans Division of Aeronautics on this request.

Response:

Turbulence from an exhaust stack, including a power plant exhaust stack, is caused by a combination of exit velocity and buoyancy, due to above-ambient temperature, which forms a plume from the top of the stack. Upon leaving the stack, the exhaust plume spreads out and decreases in velocity as momentum is lost and thermal gradients decrease, thereby decreasing buoyancy. In order to obtain the worst-case impacts of a thermal plume from MEP, historical meteorological data were reviewed and modeled by Katestone Environmental, an independent consultant that has previously provided data and testimony to the California Energy Commission.

Based on their review and modeling of meteorological data and exhaust plumes, Katestone Environmental determined that for 26 hours out of an 8,760 hour year, an average vertical plume velocity of 9.62 mph (846.5 fpm, 4.3 m/s) could occur up to maximum elevations between the flight pattern altitude (954 feet AGL) and 1,309 feet AGL, assuming all four gas turbines are operating at their maximum capacity. The highest level that a velocity of 9.62 mph (846.5 fpm, 4.3 m/s) could be sustained in any given hour was 1,309 feet AGL. For this velocity to occur at this elevation, winds in the area would have to be less than 1 mph up to an elevation of 985 feet AGL. Even with such low wind velocities, the temperature of the exhaust plume dissipates fairly quickly. Based on an 840ºF discharge temperature and an approximate 65ºF ambient temperature (the ambient temperature for the maximum plume rise hour), plume temperature is below 200°F at 188 feet AGL, below 120ºF at 320 feet AGL, and is at ambient conditions of approximately 65ºF at 750 feet AGL. For conditions of higher wind velocities, the elevations at which 200ºF, 120ºF, and 70ºF are attained would be even lower, since the wind promotes mixing and diffusion of the thermal gradients.

Similarly, oxygen content in the exhaust plume at this extreme condition also increases as the plume mixes with ambient air. The exhaust plume has an oxygen content of 14.5 percent as it leaves the stack. At 188 feet AGL, the oxygen content increases to approximately 20.2 percent, at 320 feet AGL the oxygen content is estimated at 20.7 percent, and at 450 feet AGL it reaches approximately 20.85 percent, which is almost equal to ambient O_2 concentrations of 20.95 percent. As indicated in Attachment DR52-9, internal combustion aircraft engines can operate with an ambient oxygen level of 18.6 percent, while turbine engines can operate with lower levels of oxygen. Therefore, an aircraft engine would have sufficient oxygen to operate within the MEP plume at an elevation less than 188 feet AGL.

It should be noted that even for the worst-case predicted hour, the average plume velocity at the Traffic Pattern Altitude (1,079 feet AMSL) remains well within the range of light turbulence at approximately 10.8 mph (959 fpm, 4.87 m/s) Therefore, should an aircraft stray out of the arrival or departure traffic patterns and not follow "see and avoid" procedures, during even the worst-case meteorological conditions, the aircraft would only experience light turbulence, and would only experience said light turbulence for the few seconds it takes to fly through the plume.

Therefore, based on the analysis of plume characteristics and meteorological data, an aircraft flying through the combined plume of all four gas turbines at the Traffic Pattern Altitude or greater would only experience light turbulence with average vertical velocities of 10.8 mph under worst-case conditions. The temperature experienced by an aircraft flying through the plume at the Traffic Pattern Altitude would be ambient temperature; to experience a temperature of 120ºF, an aircraft would have to be flying at an elevation of only 320 feet AGL. The oxygen content in the exhaust plume a short distance above the stack (less than 188 feet AGL) will be very close to ambient levels, and therefore an aircraft could fly through the exhaust plume and still have enough oxygen to operate its engines.

Staff Query

SQ5. We would like the CEC to perform a calm-wind analysis of the amount of aircraft turbulence that the plume at the Mariposa plant would likely cause at the following elevations of aircraft overflight: 1200 ft, 1000 ft, 800 ft, 600 ft, and 400 ft. The analysis should provide one or more parameters at each altitude that may be used to assess the potential for turbulence. We presume the parameters will pertain to the characteristic(s) identified in Request #1 (SQ4). We would like to know if the plumes from the four stacks will remain distinct or merge together at some altitude, and if so, the estimated value of that altitude, as well as the likely impact of any merged plume.

Response:

Based on the Katestone Environmental study and modeling of ambient meteorological data, the following average vertical plume velocities were predicted for the worst-case 1-hour period in the year modeled (out of 8,760 hours). Ambient wind conditions during this 1-hour period were predicted to be less than 1.0 mph at elevations up to 985 feet AGL, a very calm wind condition. Under these extremely rare conditions, 1 hour out of 8,760 hours per year, the combined plume from all four gas turbines operating at maximum load would have the average vertical velocities shown in Table SQ5-1 (refer to Figure B7 in Attachment DR52-6). In addition, the hypothetical calm wind (zero wind) velocity, case is also shown in Table SQ5-1 and is based upon Figure 13 in Attachment DR52-6.

TABLE SQ5-1
Average Vertical Velocities of Combined Plume from All Four Gas Turbines Operating At Maximum Load

Elevation	Average Velocity	Turbulence Characterization
Worst-case Predicted Meteorological Conditions		
1,200 feet AGL	10.4 mph (916 fpm, 4.65 m/s)	76% of the upper limit of light turbulence
1,000 feet AGL	11.3 mph (998 fpm, 5.07 m/s)	83% of the upper limit of light turbulence
800 feet AGL	12.0 mph (1053 fpm, 5.35 m/s)	88% of the upper limit of light turbulence
600 feet AGL	12.6 mph (1104 fpm, 5.61 m/s)	92% of the upper limit of light turbulence
400 feet AGL	14.0 mph (1220 fpm, 6.26 m/s)	1.7% above the upper limit of light turbulence
Zero Wind Conditions		
1,200 feet AGL	11.2 mph (986 fpm, 5.01 m/s)	82% of the upper limit of light turbulence
1,000 feet AGL	11.7 mph (1,030 fpm, 5.23 m/s)	86% of the upper limit of light turbulence
800 feet AGL	12.3 mph (1,082 fpm, 5.50 m/s)	90% of the upper limit of light turbulence
600 feet AGL	13.2 mph (1,162 fpm, 5.90 m/s)	97% of the upper limit of light turbulence
400 feet AGL	14.4 mph (1,267 fpm, 6.44 m/s)	5.6% above the upper limit of light turbulence

Because both of these evaluations have similar low horizontal wind velocities, they produce fairly similar results. The formation of the four plumes as to distinct and merged configurations can be seen in Attachment DR52-7, where they are modeled with 5-mph and 10-mph winds, and 59°F and 112°F ambient temperatures.

It should be noted that existing power lines and power poles located just to the east and west of the MEP site are at elevations of approximately 300 feet AMSL. Therefore, maintaining the recommended 500 foot clearance will keep all aircraft at elevations of at least at 800 feet AMSL (approximately 675 feet AGL at the MEP site) and that even at 600 feet AGL, an aircraft would only experience light turbulence.

Staff Query

SQ6. In order for us to validate the CEC's methodology for plume analysis, we would like the CEC to perform the same type of plume analysis for the power plant on which Mr. Cathey performed his tests. With this, we will be able to correlate Mr. Cathey's test data with the parameters from the analysis. Please contact Mr. Cathey for the details about the power plant involved in his tests. Both information requests #1 and #2 (SQ4 and SQ5) may be done at the temperature conditions of Mr. Cathey's tests.

Response:

Mariposa Energy believes that the facility that Mr. Cathey overflew was the Calpine Sutter Energy Center. The Sutter facility is a 500-MW, air-cooled, combined-cycle facility with two gas turbines rated at 170 MW each, thus it is significantly different from the simple-cycle Mariposa facility that has no air-cooled condenser or cooling towers and whose gas turbines are rated at 50 MW each.

Mariposa Energy does not have any information pertaining to the tests that were conducted by Mr. Cathey. We have reviewed the publicly available information in the Russell City, Eastshore, and Blythe dockets and have not located any test protocols or test results. If tests were performed, and if the CEC Staff has access to the tests that were performed, the quantitative test results and the parameters under which those tests were done, then Mariposa Energy is willing to attempt to model those conditions. It is our understanding that specific flight path, plant operation conditions, and meteorological data were not documented.

Staff Query

SQ7. We request that CEC repeat request #1 (SQ4) with a wind of 12 knots. Approximately 54 percent of the time, "calm" winds of less than 8 knots from all directions prevail at the Byron airport. Approximately 23 percent of the time, there is wind from the southwest that blows in a range of 8 to 16 knots (average of 12 knots). This wind may have the potential to blow the powerplant plume toward the instrument approach of Byron's main Runway 30. We would like to know how far the plume is shifted at each of the test altitudes. While ultralights and gliders will likely use the shorter cross-wind runway 23 under this wind condition, larger aircraft will likely use the longer runway 30 because of its length.

Response:

Based on the attached Katestone Environmental analysis of the worst-case meteorological data at the MEP location, there are 26 hours in an 8,760-hour year during which an average vertical velocity of 9.6 mph (847 fpm, 4.3 m/s) is exceeded at the Flight Pattern Altitude of 1,079 feet AMSL. In the worst-case hour, an average vertical velocity of 9.6 mph (847 fpm, 4.3 m/s) can occur at an elevation of 1,309 feet AGL. Table SQ7-1 shows the vertical wind profile during this worst-case hour period (refer to Table B5 and Figure B3 in Attachment DR52-6)

TABLE SQ7-1
Vertical Wind Profile Corresponding to Worst-Case Hour in Katestone Environmental Analysis

Feet Above Ground Level	Horizontal Wind Velocity (mph)
33	0.7
82	0.7
164	0.7
328	0.4
492	0.2
656	0.000
820	0.2
984	0.7
1,312	1.6

Katestone Environmental determined the maximum extent (downwind distance) of the plume within which an average velocity of 9.6 mph (847 mph, 4.3 m/s) occurred during any hour of the year (during any wind conditions), for various elevation ranges (refer to Table 7 in Attachment DR52-6). The maximum downwind distance that a plume with an average velocity of 9.6 mph extended was 313 feet from the location of the stacks. The elevation that this maximum downwind plume extent occurred was between 800 and 1,000 feet AGL. Table SQ7-2 summarizes the maximum horizontal plume distance (extent) for various elevation ranges with all four gas turbines operating.

TABLE SQ7-2
Maximum Horizontal Plume Distance (Extent) for Various Elevation Ranges with All Four Gas Turbines Operating

Height AGL (feet)	Maximum Horizontal Plume Extent (feet)
Less than 200	135
200 to 300	177
300 to 400	201
400 to 500	221
500 to 600	252
600 to 700	253
700 to 800	281
800 to 900	313
900 to 1,000	313
1,000 to 1,100	272
1,100 to 1,200	312
1,200 to 1,300	286
1,300 to 1,400	232

Because the Runway 30 approach is approximately 1 mile or 5,280 feet away, the maximum extent of the plume under any wind conditions will not come close to the flight path. The closest an aircraft should be to MEP is the western edge of the Aircraft Protective Surfaces, which is approximately 0.65 mile (3,783 feet) from the MEP site. If the aircraft is on an instrument approach, then a missed approach would be initiated if there is a ¾–scale needle deflection of the CDI, which equates to 1,340 feet off course. This places the aircraft 0.78 miles or 4,118 feet away from MEP. Therefore, the plume will not affect the approach to Runway 30.

In order to evaluate additional plume characteristics at wind velocities higher than those analyzed by Katestone Environmental, CH2M HILL was retained to perform a Computational Fluid Dynamic (CFD) analysis of the Mariposa Energy plumes (see Attachment DR52-7). CFD results also provide discrete results (peak velocities), rather than the average vertical velocity for the cross-section of a plume. This modeling effort was based on the same parameters that Katestone Environmental used for plant layout and exhaust stack characteristics, but assumed a fixed wind direction and idealized wind velocity profiles based on velocities of 5 and 10 mph at a height of 33 feet (10 meters). Instead of historical wind directions, it was assumed that the wind direction was perpendicular to the Runway 30 landing approach, since this wind direction would blow the plume most directly toward the Runway 30 approach. Based on these assumptions and a wind velocity of 5 mph, the maximum elevation at which a 9.62 mph vertical velocity can be sustained is 760 feet AGL (refer to Attachment DR52-7, Figure 1.2); however, an equivalent average plume velocity across a cross-section of the plume would occur at a much lower height. The CFD modeling shows that the maximum downwind horizontal distance from the stacks at which a 9.62 mph peak vertical velocity can be sustained is 663 feet (see Attachment DR52-7, Figure 1.1). This distance is greater than the maximum distance of 313 feet downwind because the CFD model presents discrete or peak velocities rather than the average across the plume and the 5 mph wind is elongating the plume. The turbulence level drops below 13.6 mph to light turbulence 44 feet from the stacks and disperses into ambient levels of vertical velocity by 1,100 feet from the stacks (see Attachment DR52-7, Figure 1.0).

When the wind velocity assumption is changed from 5 mph to 10 mph, still in a direction perpendicular to the Runway 30 approach, the maximum elevation at which a 9.62 mph vertical velocity can be sustained drops from 760 feet AGL at 5 mph to 122 feet AGL at 10 mph (refer to Attachment DR52-7, Figure 2.2). It should be noted that the assumed 10 mph wind velocity is slightly greater than the 9.62 mph vertical velocity; therefore it will have significant impact on the vertical velocity profile. With a wind velocity of 10 mph, the plume is “blown over” fairly quickly and the CFD modeling shows that a 9.62 mph vertical velocity can only be maintained up to 76 feet from the stacks (refer to Attachment DR52-7, Figure 2.1), versus 663 feet from the stacks with a 5 mph wind. The turbulence level disperses into ambient level of vertical velocity by 900 feet from the stacks (see Attachment DR52-7, Figure 2.0).

Based on the worst-case meteorological conditions determined by Katestone Environmental, the height at which a 9.62 mph average vertical velocity can be maintained is 1,309 feet AGL. Based on the idealized 5 and 10 mph wind cases assumed in the CH2M HILL CFD modeling, the maximum heights at which a 9.62 mph peak vertical velocity can be maintained are to 760 feet (5 mph wind) and 122 feet AGL (10 mph wind). At the same time, the distance from the stacks at which the 9.62 mph average vertical velocity can be maintained was determined to be 313 feet by the Katestone Environmental analysis. Based on the CFD modeling analysis, the 9.62 mph peak velocity extends to 663 feet horizontally with 5 mph winds and then drops to 76 feet from the stacks for 10 mph winds. With the Runway 30 centerline being 1 mile, or 5,280 feet, away and Runways 5 and 23 being 2.6 miles, or 13,725 feet, away from MEP, it is very unlikely that the plume from MEP, which blends into background ambient conditions at 900 feet to 1,100 feet from the stacks, would have any impact on these approaches or departures.

With wind velocities of 5 mph or greater, and a resulting elevation at which 9.62 mph peak vertical velocity occurs of 760 feet AGL or less, an aircraft flying at the Traffic Pattern Altitude of 1,079 feet AMSL (954 feet AGL above MEP) or higher will experience no significant impact from the MEP exhaust plumes since it will be experiencing at most light turbulence.

Staff Query

SQ8. We believe that Byron Airport is heavily accessed by pilots that are not based there and who in all likelihood will not be particular familiar with the Byron Airport's surrounding infrastructure. We would request development of clear scientific data regarding how one would effectively provide meaningful notice to pilots and other fliers regarding potential flying hazards of flying at less than 1000 feet above stacks such as those proposed here. We believe that it is the proponent/applicant's obligation to demonstrate how pilots unfamiliar with the surrounding infrastructure can be adequately notified of gases, plumes and their likely impact, so as to minimize the potential harm to the public.

Response:

Byron Airport Transient Aircraft Operations

Because Byron Airport is not equipped with an FAA control tower, the FAA does not perform traffic counts at that location. However, private companies do maintain and publish airport operational statistics with the assistance of airport management.

One such source of airport operational use data is AirNav, LLC under the title AirNav.com. AirNav.com, for the 12-month period ending January 29, 2004 indicates that of the total Byron Airport operations, 92 percent were local (attributed to locally based aircraft) with only 8 percent of total airport operations attributed to transient aircraft (aircraft not based at Byron Airport).[26]

Total Operations	164/day (59, 860/year)
General Aviation Local Operations	92%
General Aviation Transient Operations	8%

[26] AirNav.com, C83, Byron Airport, Airport Operational Statistics, December 2009

A second private source of airport operational use data is Flight Plan LLC, which operates under the title FltPlan.com. FltPlan.com, as of December 2009, lists Byron Airport (reported) operations as follows:[27]

Total Operations	60,050
General Aviation Local	55,000
General Aviation Transient	5,000
Military	50

Source: FltPlan.com, C83, Byron Airport Operations, December, 2009

According to FltPlan.com, Byron Airport transient operations account for only 8 percent of total operations. A third private source of airport operational use data is GCR & Associates. GCR reports Byron Airport operations equivalent to Flight Plan LLC, shown above.[28]

According to these three private sources of aviation data reporting, only 8 percent of Byron Airport operations are attributed to transient aircraft. Byron Airport is therefore not "heavily accessed" by pilots that are not based there and who in all likelihood will not be particularly familiar with the Byron Airport's surrounding infrastructure.

Providing Notice to Transient Pilots

Although Byron Airport is not heavily accessed by transient pilots, it would be prudent to notify transient pilots of the location of MEP and to advise against overflight of the stacks below 1,000 feet AGL.

Pilot Regulatory Responsibility for Pre-flight Action

Per 14 CFR Part 91 (Federal Aviation Regulation (FAR) Part 91), each pilot in command shall, before beginning a flight, become familiar with all available information concerning that flight.[29] The Airport Facility Directory (AF/D) or other privately produced flight guides, Aeronautical Charts, and Notices to Airmen (NOTAM) are the three principal means the FAA employs for notifying pilots of items of interest and/or safety in the National Airspace System.

One of the means by which pilots fulfill their regulatory pre-flight action responsibility is by consulting and utilizing these publications in the planning of their flights.

Airport Facility Directory (AF/D)

The Airport/Facility Directory (AF/D) is a pilot's manual that contains data on public use and joint use airports, seaplane bases, heliports, VFR airport sketches, NAVAIDs, communications data, weather data sources, airspace, special notices, and operational procedures. It also contains airport data such as airport hours of operation, types of fuel available, runway length and widths, lighting codes, etc. Each AF/D is published every 56 days.

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[27] FltPlan.com, C83, Byron Airport Operations, December, 2009
[28] AirportIQ 5010, C83, Byron Airport Operations, December 2009
[29] 14 CFR Part 91 (FAR Part 91.103), Pre-Flight Action

Each year, under the Airport Master Record Program, the FAA conducts an inspection of all public airports, including Byron Airport. During the inspection, information is collected concerning the physical condition or status of the facility and includes obstructions and structures surrounding the airport as they relate to aircraft operations. The inspections are designed to enhance safety for the flying public. The data gathered form the basis for the federally-produced flight publications such as the AF/D and many privately produced flight guides.

Recommendation

Consistent with the recommendations in the MEP exhaust stack FAA Determination of No Hazard to Air Navigation, the Byron Airport operator may submit FAA Form 5010-1 *Airport Master Record* to the FAA requesting that the position and nature of MEP and associated exhaust stacks be included in the "airport remarks" section of the AF/D and other privately produced flight publications, including the recommendation to avoid overflight of the stacks at less than 1,000 feet AGL. This recommendation is also contained in the FAA Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes, January 2006.[30]

While it is the airport operator's responsibility to initiate this request with the FAA, Mariposa Energy is willing to assist with the information or other requirements that may be needed to implement such notification.

Aeronautical Charts

Aeronautical charts are designed for visual navigation by aircraft and contain an extensive selection of visual landmarks, airports, railroads, power lines, obstructions, and related data. The San Francisco Sectional Aeronautical Chart covers the geographical area surrounding the Byron Airport.

Visual Flight Rules (VFR)

Visual Flight Rules (VFR) are rules governing flight during periods of generally good visibility and limited cloud cover (i.e., periods during which a pilot has the ability to fly and navigate by looking out the windows of the airplane) and are predominantly employed by piston-powered general aviation pilots like most of the pilots who operate to and from Byron Airport. Aircraft flying under the VFR system are not required to be in contact with air traffic controllers and are responsible for their own separation from other aircraft. The VFR system is utilized almost exclusively by recreational pilots or low-flying piston-engine airplanes. The primary means of navigation for such aircraft is through the use of Sectional Aeronautical Charts.

See and Avoid

Per FAR Part 91, under VFR a pilot is primarily responsible for navigation, obstacle clearance, and separation from other aircraft using the *see-and-avoid* concept.[31] To avoid collisions, the VFR pilot is expected to "see and avoid" obstacles and other aircraft. In

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[30] FAA Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes, p.15, January, 2006.

[31] 14 CFR Part 91 (FAR 91.113 (b))

accordance with the current FDC NOTAM described in the following paragraphs, pilots are required to "see and avoid" the airspace above or in proximity to power plants such MEP.

Recommendation

Consistent with the recommendations in the MEP exhaust stack FAA Determination of No Hazard to Air Navigation, the Byron Airport operator may make a request to the FAA, specifying that the MEP plant and stacks be depicted on the San Francisco Sectional Aeronautical Chart to assist pilots in avoiding the airspace above and adjacent to MEP. While it is the airport operator's responsibility to initiate this request with the FAA, Mariposa Energy is willing to assist with the information or other requirements that may be needed to implement such notification.

Notice to Airmen (NOTAM)

A Notice to Airmen (NOTAM) is a notice, essential to safety of flight, which contains information pertaining to the National Airspace System, the timely knowledge of which is essential to personnel concerned with flight operations.

One specific type of NOTAM pertaining to MEP is the Flight Data Center (FDC) NOTAM. An FDC NOTAM is regulatory in nature and issued to establish restrictions to flight and changes to charts or Instrument Approach Procedures. Pilots in violation of regulatory NOTAMs are subject to FAA enforcement action which could result in either suspension or revocation of their pilot certificate.

A national FDC NOTAM, which restricts pilots from overflying power plants and other structures, is currently active. Aircraft directly overflying power plants, when avoidable, are not in compliance with FDC NOTAM 4/0811. Although primarily intended for national security purposes, an unintended consequence is that this NOTAM also advises pilots against flying over or through exhaust plumes from a power plant. It reads as follows:

FDC 4/0811 FDC…SPECIAL NOTICE…THIS IS A RESTATEMENT OF A PREVIOUSLY ISSUED ADVISORY NOTICE. IN THE INTEREST OF NATIONAL SECURITY AND TO THE EXTENT PRACTICABLE, PILOTS ARE STRONGLY ADVISED TO AVOID THE AIRSPACE ABOVE, OR IN PROXIMITY TO SUCH SITES AS POWER PLANTS (NUCLEAR, HYDRO-ELECTRIC, OR COAL) DAMS, REFINERIES, INDUSTRIAL COMPLEXES, MILITARY FACILITIES, AND OTHER SIMILAR FACILITIES. PILOTS SHOULD NOT CIRCLE AS TO LOITER IN THE VICINITY OVER THESE TYPES OF FACILITIES.

Recommendation

Although the FDC NOTAM sufficiently restricts pilots from overflying power plants, the Byron Airport operator should request that the FAA issue a local NOTAM advising pilots of the location of the MEP stacks and specifying that if it is not practicable to avoid the airspace above MEP, to avoid overflight of the stacks at altitudes less than 1,000 feet AGL. Mariposa Energy is willing to assist the Byron Airport operator with the information or other requirements that may be needed to implement such notification

Regulatory Minimum Altitudes

FAR Part 91 specifies minimum flight altitudes for flight over congested, other than congested and sparsely populated areas. The minimum flight altitude specified over a congested area is 1,000 feet above the surface. Over other than congested areas, the minimum altitude is 500 feet above the surface. Over sparsely populated areas, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.[32] Federal Air Regulations prohibit flight closer than 500 feet to structures such as the MEP stacks. Since existing 305-foot-AMSL high-power transmission towers are located adjacent to the proposed MEP site, the minimum regulatory flight altitude above those towers (and the MEP site) is 805 feet AMSL.

Local Pilot Notification, Education, and Training

In its *Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes*, the FAA made the following recommendation: "Given the extremely low risk these plumes present, further mitigation is not required. However, the risk assessment team would offer that the FAA continue to enhance awareness programs that have been successful with similar hazards of acceptable risk levels. These programs include pilot and ATC personnel professional education, communication, advisement and avoidance strategies, and operational techniques."[33]

Recommendation

Although the FAA determined that exhaust plumes present an extremely low risk and that plume mitigation is not required, the FAA recommended that pilot awareness programs continue to be enhanced. It is therefore recommended that the Byron Airport operator make available the following to Byron Airport local pilots:

- Education on the nature and extent of industrial exhaust plumes.
- The FAA analysis of the safety risk associated with overflight of exhaust plumes by providing, to local pilots, a copy of the FAA *Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes*, January 2006.
- Plume avoidance strategies and operational techniques.

Summary

All pilots, whether conducting local or transient operations, prior to commencing a flight are required by Federal Air Regulations to become familiar with all available information concerning that flight.

In assisting pilots in fulfilling their regulatory responsibility, the FAA provides publications designed to notify pilots of items of interest in the National Airspace System. Three principal FAA publications are the Airport Facility Directory (AF/D), Aeronautical Charts, and Notices to Airmen (NOTAM).

These publications provide the pilot with information such as the location of power plants, the regulatory requirement to avoid the airspace over and adjacent to power plants, and if deemed necessary, advisories regarding minimum flight altitudes over exhaust plume stacks.

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[32] 14 CFR Part 91 (FAR Part 91.119) Minimum Safe Altitudes: General

[33] FAA Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes, p. 16, January, 2006

Pilots, in fulfilling their regulatory pre-flight action responsibility, consult and utilize these publications in the planning of their flights. The regulatory requirement to consult and utilize these publications will ensure that all pilots, both local and transient, are notified of the location of the MEP power plant and associated exhaust plumes. Mariposa Energy is willing to assist the Byron Airport operator with the information or other requirements that may be needed to implement such notifications to pilots.

Staff Query

SQ9. To assess potential impacts on ultralights and skydivers, we would like to know the locations of the average 120°F and average 200°F isotherms of the plume as a function of altitude, up to at least 6,000 feet if these isotherms extend beyond that altitude. A calm wind assumption and an ambient ground-level temperature of 80°F may be used. A simple two-dimensional plot of the right and left horizontal extents of each isotherm on the X-axis and altitude on the Y-axis is sufficient. This information will help us, the CEC, and the Airport director to develop pilot-notification-based mitigation measures.

In addition to safety issues, we look at building heights, visual hazards, and bird strike hazards in making compatibility determinations. There do not appear to be any height hazards with the project. As to possible visual hazards, the area around the Byron Airport is known to have Tule fog during the winter (mid November through to the start of March). Since Tule fog is a ground-level radiation cooling effect, it appears that the power plant plume would dissipate the Tule fog in the area around the site. However, it is not known whether the Tule fog would provide further cooling of the plume in addition to that assumed by Applicant's vapor-condensation analysis, and whether the plume would draw water content from the Tule fog, which, when added with the water content in the plume, would condense at a higher altitude of the plume, and whether such condensation would create a visual obstruction for aircraft. We would also request the CEC's and the applicant's opinion regarding this dynamic and whether there would be any visual impact and whether it would be hazardous.

And, we would request confirmation that there will not be an added effect with water content with the Tule Fog or extra cooling effect, and that the Applicant's vapor-condensation analysis is suitable for Tule fog conditions. If that analysis is not suitable, we would request a modified analysis.

Response:

Based on the Katestone Environmental analysis plume temperature data for the hour when the maximum plume height was predicted, the elevation at which a 200°F temperature would be encountered is approximately 188 feet AGL or 108 feet above the stacks (refer to Figure B5 in Attachment DR52-6). The elevation at which a 120°F temperature is encountered is approximately 320 feet AGL or 240 feet above the stacks. At elevations above 320 feet AGL or 240 feet above the stacks, the temperature will be below 120°F. The worst-case hour occurred at an ambient temperature of 65 °F; under other ambient weather conditions, the plume would not extend up to 1,309 feet AGL with an average vertical velocity of 9.62 mph, and therefore the elevations at which 120°F or 200°F temperatures occur are expected to be lower than those indicated above.

In order to further investigate the potential temperature gradients above MEP at varying wind speeds, CH2M HILL created a CFD model of the plume under two different wind regimes: Case 1 – a wind velocity of 5 mph at 33 feet AGL from a direction that is perpendicular to the approach to Runway 30; and Case 2 – a wind velocity of 10 mph at 33 feet AGL from a direction that is perpendicular to the approach to Runway 30. A direction perpendicular to the Runway 30 approach was chosen since that is the shortest distance between MEP and the Runway 30 approach and therefore the greatest impact would be seen with a perpendicular wind direction.

Assuming an annual average ambient temperature of 59°F and the Case 1 wind assumptions, the highest elevation at which the plume has a temperature of 200°F is expected at approximately 140 feet AGL, and the highest elevation that maintains a 120°F plume temperature is anticipated to be 163 feet AGL (refer to Figure 1.6 in Attachment DR52-7). For Case 2, the highest elevation at which the plume reaches a temperature of 200°F is approximately 110 feet AGL, and a 120°F is attained at 127 feet AGL (refer to Figure 2.6 in Attachment DR52-7).

The following table summarizes the results of the analysis for the maximum elevations at which the chosen temperatures occur. In accordance with FAA clearance requirements in rural areas, aircraft in close proximity to MEP would be required to maintain a minimum of 500-foot clearance above objects on land. Therefore, aircraft, including ultralights, and gliders, which are operated at 500 feet above ground level would experience temperatures at or near ambient conditions and would not be adversely impacted by the presence of an exhaust plume.

TABLE SQ9-1
Maximum Height Above Ground Level Where Study Temperatures Would Occur

Plume Temperature (ºF)	Katestone Analysis (calm wind)	CH2M HILL CFD – Case 1 (5-mph wind)	CH2M HILL CFD – Case 2 (10-mph wind)
120	320 feet	163 feet	127 feet
200	188 feet	140 feet	110 feet
Ambient Assumption	75ºF 0-3 mph	59ºF 5 mph	59ºF 10 mph

Tule fog is radiation fog, or ground fog, confined by local topography, and can last for several days. Although clear skies and calm conditions are necessary to initiate radiation fog, slight turbulent currents are also required to create radiation fog more than a few inches thick since air is a poor conductor of heat. Therefore, a wind speed of 3.5 to 5.8 mph (3 to 5 knots) will create sufficient slight turbulence to increase the thickness of the radiation fog. As the nocturnal cooling continues, the air temperatures continue to lower and the fog becomes thicker and denser. Vertical fog development can exceed 300 to 400 meters (980 to

1300 feet).[34] In the Central Valley, additional cold mountain air flows downslope into the valley during the night, and becomes confined by the Coast Ranges and the Sierra Nevada, because most areas in the Central Valley have little or no air drainage below the level of mountain passes. During prolonged tule fog events, the density and depth of the cold air creates a temperature inversion that can approach a depth of 1,000 feet. At the same time, the high pressure of the warmer air above the mountaintops presses down on the cold air trapped in the valley, resulting in a dense, immobile fog that can last for days or at times for weeks undisturbed. Once tule fog is formed, strong turbulence is necessary to break through the temperature inversion layer, such as a synoptic scale frontal passage.

While the power plant plume contributes heat and moisture to the ambient environment, the magnitude of these contributions are insignificant compared to the synoptic scale of the tule fog. Within the tule fog formation, the moisture in the power plant plume might combine with the moisture in the fog to form a condensed water vapor plume, but it would be indistinguishable from the ambient environment. Above the tule fog formation, the power plant plume would mix with drier air reducing the likelihood that a condensed water vapor plume would be visible. Furthermore, given the relatively low vertical plume velocities predicted by the CFD and TAPM models, penetration of the power plant plume above the tule fog layer would be unlikely because of the strong inversion layer that exists at the fog boundary.

Staff Query

SQ10. As to potential bird strike hazards, the area around the Byron Airport appears to have significant bird populations, including endangered species, waterfowl, and birds of prey. The Audubon.org website indicates the area around the Byron Airport as being an "important bird area." The adjacent Clifton Court Forebay is known to attracted waterfowl during the migration seasons. At this point, we do not know what bird populations, if any, are attracted to the Bethany Reservoir, which is near the project site. Most Contra Costa County studies, such as those associated with Byron Airport and the County's Habitat Conservation Plan, have focused on cataloging threatened and endangered bird species in the area, rather than all bird populations. Accordingly, our further research of all bird populations may be needed.

The congregation of birds around airports, particularly approach and departure paths, has the potential to increase bird strikes with aircraft. Larger birds, such as Canadian geese, waterfowl, and birds of prey, are of particular concern because of their weight. Two principal questions arose during our meeting. First, would birds be diverted away from the power plant plume (such as because of the plume's heat or effluent content), and would such diversion concentrate birds near the main runway approach path to the Byron Airport? Related to this are questions of whether birds are smart enough to sense the heat of a plume and avoid it, and whether they would expire if they are not smart to avoid a high temperature plume. Second, would birds of prey try to ride the rising plume at its cooler edges as part of their hunting activities? A third question flows from these

[34] Underwood, S. Jeffery, G. P. Ellrod and A. L. Kuhnert. 2004. Journal of Applied Meteorology, "A multiple-case analysis of nocturnal radiation-fog development in the central valley of California utilizing the goes nighttime fog product", American Meteorological Society (AMS), pages 297 – 311. February.

two principal questions: would the plume kill smaller birds, upon which birds of prey would feed upon, such as during down times of the power plant?

Response:

Thermal Plumes Attracting Birds

A literature search was conducted to determine if other facilities that generate thermal plumes had known issues with attracting or repelling birds. The literature search did not yield relevant results for bird behavior in relation to industrial thermal plumes. However, the data request letter from the ALUC identified an account of birds soaring over a power plant. This account addressed a flock of common ravens (*Corvus corax*) that habitually soared over a power plant in Anchorage, Alaska.[35] While it is difficult to draw definite conclusions from this account, one important point to be made in relation to it is that a power plant thermal plume from a tall stack on a cold Alaskan day would probably create a singular distinctive thermal front.

In comparison, in the relatively mild climate of central California, even in mid-winter, there are more thermal updrafts to be found throughout the landscape. While it is feasible that ravens may use the MEP stack plumes to gain lift when they incidentally encounter them, it is unlikely that they would be drawn from miles away specifically to use the plumes because there is abundant thermal lift to be found throughout the California Coast Range. It is speculated that in the Anchorage account, there are limited landscape-created thermal updrafts, so the ravens would have limited thermal updrafts to use beyond those created by the power plant.

While we are not aware of focused studies to assess bird attraction to power plant thermal plumes, we do know from general observation of construction and operation of numerous thermal electrical generation facilities that it is not common for birds to congregate above power plant stacks. We also have not observed mortality due to exhaust stacks. CH2M HILL has provided compliance support in recent years during the construction, commissioning, and operations of at least 11 power plants throughout California. Based both on this experience and recent discussions with California Energy Commission (CEC) Staff (refer to Attachment SQ10-1, Record of Conversation between Rick York, CEC Biological Resources Supervisor, and Gary Santolo of CH2M HILL on November 11, 2009), the attraction of birds to power plant exhaust plumes has not been an issue.

Migratory Bird Avoidance of Stacks

A literature search was conducted to determine any scientific studies or other information is available on the subject of migratory bird avoidance of power plant exhaust stacks and their plumes; however, no information on the subject was located.

Some information exists on bird collisions with cooling towers that may be appropriate for comparison. In general, birds have been known to collide with cooling towers but it is not a significant source of mortality. Most of the collisions with cooling towers have been by nocturnal migrating birds that are attracted to, or confused by the safety lighting. Also, the reports of bird strikes with cooling towers have been from extremely large cooling towers

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[35] http://www.youtube.com/watch?v=sJxTzAjeEbk

that are nearly 500 feet high and 400 feet wide.[36] In contrast, the MEP exhaust stacks are anticipated to be approximately 80 feet tall, and 12 feet wide, which is significantly smaller than a cooling tower. Therefore, it could be hypothesized that if cooling tower bird strikes are minimal, a stack that is 1/5th the height, and 1/20th the width would cause even fewer bird strikes. In addition, during daylight, birds fly around objects such as stacks and continue on their route. Finally, it is even more unlikely that birds would change their migration route to avoid the MEP 80-foot-tall stacks as the stacks are set in a small valley and are only approximately 40 feet higher than adjacent ridges.

The CEC has required avian collision studies for several power plant development projects to verify that the construction of transmission lines and other project features do not result in significant avian mortality. Results of avian collision studies conducted from 1998 through 2008 (for the Sutter Energy Center, Delta Energy Center, Los Medanos Energy Center, and Walnut Energy Center, all located within the Central Valley and Sacramento/San Joaquin Delta), show no collisions with the stacks at any of the sites. The studies at each site included 3 to 5 years of monitoring with ongoing requests from the plant managers to report any avian collisions with the stacks. No avian collisions with stacks have been reported.

Migratory Bird Avoidance of Plumes

During operations, the heat at the top of the stack would be hot enough (about 840ºF) to burn a bird, but it is presumed that birds would fly around both the stack, and associated plume. In the unlikely event a bird were to fly within the immediate plume while the plant was operational, the bird would succumb to the high temperatures. However, there is no literature information available identifying this as a known or recurring issue.

As the thermal plume rises, it cools rapidly from the original 840ºF at the top of the stack. It is anticipated that birds entering the cooler edges of the thermal plume would divert their flight pattern immediately adjacent to the plume, and then fly around the hottest parts of the plume until they have flown out of the immediate area of the thermal plume. The thermal plume reaches near-ambient temperatures within a few hundred feet from the exhaust stack, both vertically and horizontally. The birds in the area would most likely continue in the same migratory or commute patterns as before, flying around both the stack and the associated plume, and would not be expected to dramatically adjust their path to coincide with the Byron Airport approach to traffic pattern for Runway 30, approximately 1.0 mile away.

Birds in the Altamont Region

The MEP site is situated in northeastern Alameda County, on the western edge of the San Joaquin Valley, at the southern end of the Delta region, just north of Altamont Pass at the toe of the Diablo Range. At this intersection of so many different bird habitats, the avifauna is quite diverse. Over the past decade the East Contra Costa Christmas Bird Count has tallied 180 species,[37] and Breeding Bird Atlas[38] efforts have confirmed nesting of at least

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[36] Rybak, Edward J., William B. Jackson, and Stephen H. Vessey. 1973. *Impact of Cooling Towers on Bird Migration.* Wildlife Damage Management, Internet Center for Bird Control Seminars Proceedings. University of Nebraska, Lincoln.

[37] http://audubon2.org/cbchist/count_table.html

[38] http://www.flyingemu.com/ccosta/

45 species in the area between the project site and Round Valley Regional Park. In addition, California's Central Valley is at the heart of the Pacific Flyway, an avian interstate system of sorts that supports the migration of millions of birds of hundreds of species during spring and fall.

Birds in the Region that use Thermal Fronts to Soar

- **American White Pelican**: Does not nest in the region, but non-breeding birds may be found any month of the year. White pelicans are a common and gregarious visitor to bays, lakes, and marshes, are often seen soaring in large flocks at high altitudes. It is unlikely that pelicans would be flying low enough over the site to detect or react in any way to the heat plumes at 500 to 750 feet above the top of the exhaust stacks. They are most likely to be seen already high overhead in migration, or as they commute to or from the reservoir or forebay. While it is feasible that pelicans may use the stack plumes to gain lift when they incidentally encounter them, it is unlikely that they would be drawn from miles away specifically to use the plumes because there is abundant thermal lift to be found throughout the region. It is expected that during low-altitude flight pelicans would adjust their flight patterns slightly to avoid a heat plume, but it is highly unlikely they would be pushed specifically to the airport that is 2.7 miles away, or the Runway 30 approach 1.0 mile away.

- **Double-Crested Cormorant**: A common and somewhat gregarious visitor to lakes, rivers, and reservoirs, occasionally even seen in irrigation ditches. These birds soar much less frequently than pelicans, and generally in much smaller groups. It is expected that cormorants would adjust their flight patterns slightly to avoid a heat plume, although it is highly unlikely that they would divert specifically to the airport that is 2.7 miles away, or the runway approach which is 1.0 mile away.

- **Herons and Egrets**: At least five species are year-round residents in the region, but only the great egret and great blue heron soar, and only rarely. They are more frequently seen in low-altitude flight commuting between roosting and feeding areas. It is expected that herons and egrets would adjust their flight patterns slightly to avoid a heat plume, but it is highly unlikely that they would divert specifically to the airport that is 2.7 miles away, or the runway approach which is 1.0 mile away.

- **Sandhill Crane**: A fairly common winter visitor to rice fields and open wetlands in the region. This species soars in groups on occasion, especially during spring and fall migration. They are most frequently seen commuting between feeding areas. It is expected that cranes would adjust their flight patterns slightly to avoid a heat plume, but it is highly unlikely that they would divert specifically to the airport 2.7 miles away, or the runway approach 1.0 mile away.

- **Gulls**: A diverse group with as many as eight species regularly seen in the area through the winter and spring seasons. California and ring-billed gulls are by far the most abundant and long-staying gull species in the area, with at least a few non-breeding individuals staying at reservoirs, lakes, and ponds through the summer. Large numbers of gulls commute from roosting areas to feeding grounds and back daily, and on warm days they will sometimes soar to great heights together. It is not anticipated that gulls would use the thermal plumes produced by MEP, as there is plenty of thermal lift to be found in the area. It is expected that commuting gulls would adjust their flight patterns slightly to avoid a heat plume, but it is highly unlikely that they would divert specifically to the airport 2.7 miles away, or the runway approach 1.0 mile away

- **Swifts and Swallows**: These birds are small, but spend much of their time in the air and often in great numbers. Huge flocks of swallows congregate through the summer months and spend warm afternoons hawking insects from ground level to heights beyond sight. Four species have been confirmed nesting in the immediate area, and as many as six species can be found together in swirling masses overhead. There is only one resident species of swift in the area, with two others occurring as uncommon migrants during brief periods in the spring and fall. Swallows and swifts are much more numerous in the region during summer when warm air and thermal updrafts are plentiful, and for this reason it is unlikely that they would single out the heat plume from a power plant stack.
- **Common Raven**: An increasingly common resident in the Altamont area that spends much of its life scavenging, soaring, and seemingly playing in warm air currents. While it is feasible that ravens may use the stack plumes to gain lift when they incidentally encounter them, it is unlikely that they would be drawn from miles away specifically to use the plumes because there is abundant thermal lift to be found throughout the California Coast Range (the lack of which we theorize may explain the attraction of ravens to the power plant plume on a cold day in Anchorage).
- **Turkey Vulture**: A common year-round resident that uses thermals as it soars to great heights in search of carrion. While it is feasible that vultures may use the stack plumes to gain lift when they incidentally encounter them, it is unlikely that they would be drawn from miles away specifically to use the plumes because there is abundant thermal lift to be found throughout the California Coast Range. The same could be said for all the raptor species to follow (osprey through falcons).
- **Osprey**: A relatively uncommon visitor to reservoirs and canals, more common on the coast than in the Altamont area, but often seen there in migration. Spends most of its time patrolling rather low over bodies of water in search of fish, but does occasionally ride thermals to greater heights on warm afternoons.
- **White-tailed Kite**: Formerly known as "black-shouldered kite," this State Fully Protected species is a fairly common resident in open areas near water with scattered trees/shrubs. It spends most of its time hover-hunting and patrolling low over grassland areas, but will occasionally ride thermals to greater heights on warm afternoons.
- **Northern Harrier**: Formerly known as "marsh hawk," this California Special Concern species is a fairly common resident in grasslands, marshes, and agricultural areas. It spends most of its time patrolling low over grassland areas, but will occasionally ride thermals to greater heights on warm afternoons.
- **Eagles**: The two species of North American eagles are uncommon visitors to the Altamont area. Golden eagles are State Fully Protected and are known to winter in the Altamont Hills in greater numbers than bald eagles, and a few nest in the Diablo Range. They forage across large areas of the Coast hills, while federally delisted, State

Endangered bald eagles are primarily a winter visitor from the north to reservoirs and lakes. Both species regularly soar to great heights.

- **Hawks**: Seven species occur in the area, but red-tailed hawk is by far the most common. The State Threatened Swainson's hawk has also been confirmed nesting in the area. The uncommon ferruginous and rough-legged hawks are winter visitors from the north. These four species all soar extensively as part of their daily foraging routine, as well as employing some hover-hunting tactics in grasslands and over road margins. Cooper's, sharp-shinned, and red-shouldered hawks are woodland species that do most of their foraging by maneuvering through densely vegetated areas. However, they will soar to great heights; red-shouldered hawks often for territorial advertisement reasons, and the other two often in migration.

- **Falcons**: Four species occur in the area, but American kestrel is by far the most common. Formerly known as "sparrow hawks," kestrels are pigeon-sized birds that heavily employ hovering while hunting in grasslands and road margins, and are less apt to soar to great heights. The two large falcon species are much less common, but also occur in the area. The California Special Concern status prairie falcon and the very recently federally delisted, State Endangered peregrine falcon use thermals to gain altitude, then ambush their prey in dramatic high-speed dives. Merlins are an uncommon winter visitor from the north that streak low across the landscape, scaring up small birds, which are their favored prey item.

Birds in the Region that often Congregate in Large Numbers

- **Waterfowl**: This diverse group includes tundra swan, five species of geese, and about 20 species of ducks that inhabit or migrate through the region along the Pacific Flyway. Waterfowl make up the highest percentage of aircraft-damaging aviation collisions, owing mainly to their size, weight, and gregarious nature. They are most frequently seen commuting between feeding areas. It is expected that waterfowl would adjust their flight patterns slightly to avoid a heat plume, but it is highly unlikely that they would divert specifically to the airport approach 1.0 mile away.

- **Shorebirds**: A wide variety of this diverse group may be found migrating through the area in tight, swiftly flying flocks. Their abundance and occurrence are largely tied to rainfall amounts that affect the condition of their traditional stopover sites at mudflats and agricultural areas. Most species are sparrow- to pigeon-sized, but a few of the most abundant and long-staying species, such as long-billed curlew and greater yellowlegs, are crow-sized or slightly larger. None of these species soar, and their speed and agility in flight suggest that they would adjust tightly around an encountered heat plume rather than be diverted miles off course because of it.

- **Pigeons and Doves**: These birds can gather in huge numbers in suburban neighborhoods and agricultural areas. Mourning doves (and the newly arrived introduced Eurasian collared-dove) tend to operate at lower altitudes and in smaller concentrations than pigeons. Rock pigeons, which are the familiar introduced city pigeons, are celebrated aerialists that can form flocks in the thousands and are almost always found around human-made structures of all sorts, urban and rural. These species are far more likely to already live near Byron Airport's runways than to be rerouted there from a high flight encounter with a heat plume

- **Owls**: Four species of owls are known to reside in the project area. Great horned and western screech owls are largely non-migratory woodland species that are not prone to high-altitude flight. Burrowing owls are a ground-dwelling grassland species and are most active at dawn and dusk. Their flights are usually short and very low, though they do frequently hover-forage at about 15 to -30 feet off the ground. This species is far more likely to already live near Byron Airport's runways than to be rerouted there from a high flight encounter with a heat plume. Barn owls, on the other hand, frequently operate at higher altitudes and theoretically may encounter the heat plume from a stack. Still, in this instance it is more likely that an owl would simply fly closely around the plume. As mentioned previously, there are more likely to be barn owls living closely to or on Byron Airport's property, and the scenario of one being diverted 1.0 mile from the heat plume is unlikely.
- **Kingbirds and Pipits**: These are open country songbirds that are commonly found at airports in alternate seasons; kingbirds in spring and summer, and pipits in fall and winter. Kingbirds are flycatchers that like to sit on telephone wires, barb-wire fences, and even the navigational beacons that frame runways, frequently sallying out for insects. Typically they are only found in pairs and small family groups, but in spring and fall dozens may appear at a time as they arrive from or depart to the tropics. Pipits are gregarious ground foragers that frequently choose runways and roadsides to scrounge for insects. Both these species are more likely to already occupy Byron Airport than to be diverted there by the heat plume from a stack.
- **Crows and Magpies**: Social and abundant, crows form enormous communal roost groups that can make long daily commutes between roost and forage areas. Magpies may be among them, and some form smaller roost groups of their own. These are among the most intelligent bird species and very adaptable to human alteration of the landscape. Crows and magpies do not typically soar and it is unlikely that they would be interested in using the thermal plume to gain altitude.
- **Blackbirds and Starlings**: These birds can form staggeringly huge flocks, especially in agricultural areas, where their masses are often seen twisting and turning through the sky like a massive cloud of smoke. These birds would not be attracted by a thermal plume because they do not soar, and it is likely that a large flock of them encountering the plume would adjust around it tightly and proceed on their intended flight path.

Conclusions

Based on literature searches, anecdotal evidence, and known bird behavior, it is anticipated that the MEP exhaust stacks and thermal plumes would not cause a change in behavior for migrating and local birds to the area. MEP and its associated plume would neither attract nor repel birds. Specific responses for each of the questions presented by the ALUC are addressed below.

1. *Would birds be diverted away from the power plant plume (such as because of the plume's heat or effluent content), and would such diversion concentrate birds near the main runway approach path to the Byron airport?*

It is not anticipated that migration patterns in the area would be altered significantly as a result of the power plant plume. Instead, birds passing through the thermal plume would fly within their comfort temperature, and then shift their pattern slightly to avoid high heat. The migratory pattern coinciding with MEP would likely move slightly around the stack and plume itself, but would not move 1.0 mile to the east over the Byron Airport approach or 2.7 miles to the Byron Airport runways.

2. *Related to the diversion, are birds smart enough to sense the heat of a plume and avoid it, and would they (the birds) expire if they are not smart enough to avoid a high temperature plume?*

Birds have a tendency to avoid those items that can cause them extreme pain or death. If a bird were to fly into a higher temperature as a result of a thermal plume, it is anticipated that the bird would move around the high heat areas, but continue moving in the same direction as originally planned.

3. *Would birds of prey try to ride the rising plume at its cooler edges as part of their hunting activities?*

Many bird species are attracted to thermal fronts that they use to gain lift. However, the plume from the stack is unlikely to be large enough to cause significant large numbers of birds to congregate above the plant at heights that planes might be flying (i.e., 1,000 feet AGL). It is not common to see birds drawn to power plant exhaust plumes. Also the intermittent nature of the plume would tend to discourage birds from anticipating its presence.

In addition, although there is a possibility that birds of prey may use the thermal plume for thermal lift, with the exceptional quantity of thermal plumes in the area generated by the surrounding landscape, it is anticipated that birds of prey would only visit the MEP thermal plumes periodically, much as they currently do throughout the area at “natural” thermal fronts.

4. *Would the plume kill smaller birds, upon which birds of prey would feed upon, such as during down times of the power plant?*

As discussed earlier, similar to most mammals, birds have a strong survival instinct and would not exclusively fly through a high heat thermal plume given a choice. Therefore, the likelihood of small birds available for scavenging in the area would be minimal. Based on our experience visiting and working at power plant sites across California, bird kills are not a common occurrence at existing operational power plants.

Staff Query

SQ11. To help us evaluate potential mitigating measure for this particular power plant, what equipment could be added to cool and/or spread out the plume to reduce temperature and turbulence to overflying aircraft? Would widening the stacks and increasing their heights reduce upward draft velocity? Can a small variably-controlled amount of water be sprayed at the top of the stack to visually mark the first 200 to 400 feet of the plume?

Response:

Cooling or Spreading Out the Plume

Cooling the plume would require the use of a cooling media, such as the injection of water or ambient air into the stacks, or extracting heat from the stack. Spreading out the plume would require changing the operational design of the gas turbines or installing larger diameter and taller stacks.

Cooling with water would require either the direct injection of water or an inline heat exchanger filled with water to absorb the heat. Direct injection of water would increase the relative humidity of the exhaust and, depending on ambient conditions, could cause the development of a locally visible plume that could cause concerns with local air traffic. In addition, direct water injection would increase facility water use, which would be counter to the State Water Resources Board and California Energy Commission policies to minimize water usage, thus conserving water for other uses. An inline heat exchanger would require a heat-sink into which the heat removed from the stack is dumped. The typical heat-sink would be a cooling tower that would require evaporative losses, which would emit a humid cooling tower exhaust into the ambient air. The humid exhaust could produce a visible plume that could cause concerns for local air traffic. Also, adding a heat transfer surface, such as a heat exchanger, into the exhaust stream of the gas turbine would increase the backpressure on the gas turbine and decrease the gas turbine's efficiency by increasing the heat rate of the gas turbine. As efficiency is decreased, it takes more fuel to produce the same power output, thus increasing the air emissions from the facility per unit of energy produced. Water injection, water heat absorption, or air injection to cool the exhaust stack would also use energy to operate the pumps and fans required to move the water or air. This energy would be consumed within the facility, thereby decreasing the amount of energy available for use by the electric grid, as well as decreasing efficiency and increasing fuel usage, leading to additional air emissions to produce the same net level of energy.

Larger-diameter stacks would decrease the exit stack velocity. However, to maintain BAAQMD, CARB, and EPA dispersion requirements, the larger diameter would require commensurately taller stacks that would be higher than 100 feet AGL and require additional review by the FAA and Airport Land Use Commission. Also larger and taller stacks would negatively affect the visual impact of MEP. Since the MEP exhaust plume is not under or near any designated approach, departure, or landing pattern, it is unlikely that aircraft will pass directly over the facility or close enough to be impacted by the plume. Should an aircraft pass over the facility, it would have to be below an elevation of 950 feet AGL with worst-case plume rise conditions to potentially experience more than light turbulence. With a Byron Airport Flight Pattern Altitude of 1,079 feet AMSL, most planes approaching the Byron Airport are 1,500 to 2,000 feet AMSL at 2.7 miles from the airport. Therefore the thermal plume would not affect them and there is no demonstrated need to decrease the thermal plume parameters from those currently proposed.

As discussed earlier, water could be injected into the plume to create a visible water vapor cloud; however, it would be difficult to maintain a consistent visible plume with constant height of 200 to 400 feet above the stacks because ambient temperature and humidity changes would change the condensation location. Finally, such a use of water would most likely not be approved by the California State Water Board and the California Energy Commission since it does not conserve water.

Attachment SQ10-1
Record of Conversation

CH2MHILL TELEPHONE CONVERSATION RECORD

Call To: Rick York/CEC

Phone No.: 916-654-3945 **Date:** November 11, 2009

Call From: Gary Santolo **Time:** 1:30 PM

Message Taken By: n/a

Subject: Mariposa Energy Project, Birds Attracted to Power Plants

On November 11th, Gary Santolo called Rick York regarding birds and their potential attraction to power plants. Mr. York informed G. Santolo that the size towers of the Mariposa Energy Center are probably not a problem. 200 foot plus towers, communication towers, and mirrored glass buildings may cause problems for birds. Mr. York stated that birds tend to avoid the towers and plumes and the plumes are more of an air quality issue than a bird issue. Mr. York did not think that there is any reason that birds would be attracted to the towers or plume at MEP and that the number of birds that are already around the airport [Byron Airport] are not going to be increased by the towers. Mr. York stated that these towers are not a bird issue.

Hal Yeager Letter (Staff Queries 12–17)

Background

Hal Yeager, vice chair of the Contra Costa County Airport Land Use Commission, wrote a letter independent from the commission to follow up on a few points in the commission's letter of November 30, 2009.

Staff Query

SQ12. For our Information Requests #2 and #4 (SQ5 and SQ7), it would be helpful to me if you could provide your analysis not only for the type of plane used by Mr. Cathey (as per Information Request #3 [SQ6]), but also for a helicopter, a sail plane (glider), and an ultralight (trike type). (This additional analysis does not have to be done for Information Request #3 [SQ6].).

Response:

As discussed in Staff Query 7, Mariposa Energy has not been able to locate specific documentation of the overflight by Mr. Cathey and the conditions under which the overflight was carried out. Based on a letter dated October 14, 2009, submitted to the CCC-ALUC by Mr. Cathey (MEP Docket No. 53640) and subsequent discussions with CEC Staff, we understand that Mr. Cathey overflew the Sutter Energy Center at 100 percent of peak capacity; however, the specific operating parameters, flight path, and meteorological conditions were not provided. The aircraft used was reportedly a Beechcraft Bonanza F33.

The average vertical velocities indicated in the response to Staff Query 5 do not change with aircraft type. The values presented in that response are based on the Katestone Environmental analysis to determine the historical meteorological conditions that will produce a vertical velocity of 9.62 mph (4.3 m/s) at the highest above ground level elevation, or 1,309 feet AGL. These velocities would not change with the type of aircraft that would fly into the plume. However, the responses on potential impacts on the various airframes that might inadvertently fly through the plume are evaluated by Senta Engineering, LLC and presented below.

In order to ascertain the potential impacts of the MEP exhaust plume on airframes and aircraft instantaneous velocities needed to be determined across the plume for the elevation to be considered. Attachment DR52-7, Figure A2.2 and Figure A2.3, contain such information for the worst case meteorological scenario presented by Katestone Environmental in Attachment DR52-6. Two elevations were evaluated, 950 feet AGL, the typical flight pattern elevation for Byron Airport; and 1309 feet AGL, the highest elevation at which an average vertical velocity of 9.62 mph can be maintained in the Katestone Environmental analysis. Since we are looking at aircraft and airframe impacts the 950 feet AGL data set was used by Senta Engineering in determining the impacts.

The aircraft evaluated included a Cessna 172, a Cessna Citation II, a Vans RV-6 and a powered parachute. Depending on the aircraft the load imparted by the plume ranged from +1.24g to +1.67g, while the load limits ranged from +6.0g to -1.75g indicating that the loads imparted by the MEP plume are well within the prescribed operating load limits of the aircraft. These are summarized in Table SQ12-1.

TABLE SQ12-1
Aircraft Operating Load Limits and Estimated Loads

	Cessna Citation II	Cessna 172	Vans RV-6	Powered Parachute
Load limit	+2.5g, -1.0g	Flaps Up: +3.8g, -1.52g Flaps Down: +3.0g	+6.0g, -3.0g; +4.4g, -1.75g*	+6.0g
Required per FARs	+2.5g, -1.0g See Appendix A	See Appendix A	n/a	n/a
Load imparted by plume	1.31 to 1.51	1.38 to 1.67	1.31 to 1.56	1.24

* +6.0g, -3.0g at or below aerobatic gross weights; +4.4g, -1.75g between aerobatic gross weight to maximum design gross weights (www.vansaircraft.com)

The critical gust case (see Attachment DR52-9) was also utilized to evaluate the potential of an asymmetric vertical velocity gradient across the wingspan of an aircraft. This could result from one wing being affected by the plume, while the other wing has still not entered the plume and is not affected by the plume. The previously determined critical gust case was utilized to calculate the maximum rolling moment coefficient and then the required neutralizing aileron deflection for a Cessna 172, a Beech 99 and a Learjet 24. The neutralizing aileron deflections ranged from 5.0 to 6.7 degrees, while the maximum aileron deflections are from 14 to 20 degrees, depending upon the aircraft. These results are summarized in Table SQ12-2.

TABLE SQ12-2
Maximum Rolling Moments

Aircraft	Maximum Rolling Moment Coefficient	Neutralizing Aileron Deflection (degrees)	Maximum Aileron Deflection Available* (degrees up / down)
Cessna 172	0.0178	5.7	20 / 14
Beech 99	0.0182	6.7	18 / 20
Learjet 24	0.0131	5.0	18 / 18

*Source: Federal Aviation Administration Type Certificate Data Sheets, http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/MainFrame?OpenFrameSet, accessed June 2010.

The aileron input required to counter the roll upset imparted by the MEP plume is well within the aileron operating range of all evaluated aircraft.

Staff Query

SQ13. With regard to our Information Request #6 (SQ9), the Applicant presented information at our November 5, 2009 meeting indicating that the temperature of the plume cooled to the ambient temperature at an elevation of 1,000 ft. This relatively rapid cooling suggests that one major cooling component might be radiation cooling through the emission of infrared radiation. Such radiation, if

> present, could be absorbed by the polymer material used in the wings of most ultralight aircraft (polymers are long chain molecules, and therefore tend absorb infrared radiation). I think it would be helpful to us if your technical staff could explain to us what mechanisms are involved in cooling the plume (radiation cooling, convective and diffusive mixing of ambient air, etc.) and the amount of energy/power dissipated by each mechanism. If your technical staff can also make an assessment as to the potential impact on the polymer wings of ultralights, that would be helpful.

Response:

MEP's plume cools relatively quickly due to diffusive mixing created by both forced convection, based on the velocity of the plume out of the stack, and natural convection due to the temperature difference between the exhaust plume and ambient air. The cooling of the exhaust plume is due to several heat, mass, and momentum transfer phenomena taking place simultaneously. These mechanisms dissipate more thermal energy than the amount of infrared radiation that would be absorbed by an aircraft. If infrared radiation were a major temperature/energy loss mechanism, then the heat from the plume would be detectable. However, a person standing on the ground near the exhaust stack would not notice any significant radiated heat from the top of the stack. This rapid mixing is reflected in the graphs and plots of plume temperature versus elevation and plume oxygen content versus elevation, as shown in the attached Katestone Environmental (calm wind) and CH2M HILL (5 mph and 10 mph) reports, Attachments DR52-7 and DR52-6, respectively.

The materials used for aircraft wings for ultralights or powered parachutes are either fiberglass or polymer materials such as Dacron. Fiberglass has a melting temperature based on the plastic/polyester used in making the fiberglass and can range from 221 to 320 degrees Fahrenheit. The material used for cloth wings and parachutes is typically Dacron or other polyester materials which have a melting temperature of approximately 500 degrees Fahrenheit. In order for the wings or parachutes to reach these temperatures, they would have to be exposed to these temperatures through convective and conductive heat transfer, which would require the wings to stay in the plume for an extended period at very low elevation. To be exposed to 200°F temperatures from the plume, the aircraft or parachute would have to be below a height of 188 feet AGL (108 feet above the stacks) or lower based on the Katestone Environmental analysis, depending on ambient conditions. At these low elevations, the plume diameter is rather small, as depicted in the TAPM and CFD analyses. At elevations below 200 feet AGL, the plume boundary is predicted to extend to an average of 87 feet and a maximum of 135 feet from the stacks, depending on wind conditions (Attachment DR52-6, Table 7). Based on a fairly slow flight speed of 50 mph, an aircraft would only be in the exhaust plume for fewer than two seconds at an elevation below 200 feet AGL. This is not enough residence time within the exhaust plume to materially impact the integrity of the wings. Moreover, no aircraft should be operating 200 feet AGL in the vicinity, as the existing high-voltage power lines running to the east and west of the project site have heights of approximately 150 feet AGL and 305 AMSL.

With windier conditions the 200°F temperatures occur at even lower altitudes: (1) for the 5 mph horizontal wind condition, the 200°F temperature occurs at 140 feet AGL; and (2) for the 10 mph horizontal wind condition, the 200°F temperature occurs at 110 feet AGL. With stacks at approximately 80 feet AGL, aircraft would need to be within 60 feet to 30 feet above the top of the stacks, which is a highly unlikely scenario.

Staff Query

SQ14. As with regard to our Information Request #6 (SQ9), has your technical staff ever looked at a plume using an infrared imaging camera or night vision camera? If so, photographs of relevant plumes would be helpful.

Response:

MEP has not looked at any exhaust plumes with infrared imaging cameras or night vision cameras and therefore has no photographs of plumes to present.

Staff Query

SQ15. With regard to our Information Request #7 (SQ10), in power plants similar to Mariposa that the CEC has permitted, has there been any observation of elevated levels of dead birds around such power plants, of birds of prey circling around such power plants, or of any type of unusual bird activity around such power plants (and the nature thereof)? Has the CEC ever actively sought such information?

Response:

While we are not aware of focused studies to assess bird attraction to power plant thermal plumes, we do know from general observation of construction and operation of numerous thermal electrical generation facilities that it is not common for birds to congregate above power plant stacks. We also have not observed mortality due to exhaust stacks. CH2M HILL has provided compliance support in recent years during the construction, commissioning, and operations of at least 11 power plants throughout California. Based both on this experience and recent discussions with California Energy Commission (CEC) Staff (personal communication between Rick York, CEC Biological Resources Supervisor, and Gary Santolo of CH2M HILL on November 11, 2009), the attraction of birds to power plant exhaust plumes has not been an issue.

Many bird species are attracted to thermal fronts that they use to gain lift. However, the plume from the stack is unlikely to be large enough to cause significant large numbers of birds to congregate above the plant at heights that planes might be flying (i.e., 1,000 feet AGL). It is not common to see birds drawn to power plant exhaust plumes. Also, the intermittent nature of the plume would tend to discourage birds from anticipating its presence.

In addition, although there is a possibility that birds of prey may use the thermal plume for thermal lift, with the exceptional quantity of thermal plumes in the area generated by the surrounding landscape, it is anticipated that birds of prey would only visit the MEP thermal plumes periodically, much as they currently do throughout the area at "natural" thermal fronts.

For a more detailed discussion of bird issues, please see the response to Staff Query 10.

Staff Query

SQ16. With regard to our Information Request #7 (SQ10), a Google search for birds and power plants found the following YouTube video of birds circling a power plant plume in Anchorage Alaska:

"Birds Attracted to Power Plant"
http://www.youtube.com/watch?v=sJxTzAjeEbk

The activity seen in the video meets the threshold for triggering an investigation as to whether the activity constitutes a bird strike hazard. (CalTrans Division of Aeronautics may wish to give its opinion as to whether the activity constitutes a bird strike hazard.) Using Google Maps street view, I was able to identify the power plant as the #2 power plant of Anchorage Municipal Light and Power. A further Google search located the following blog article which might explain the activity shown in the video:

"Those big black birds… Ravens in the City"
http://www.farnorthscience.com/cold-quests/ravens-in-the-city/

The blog article has not been authenticated. It alleges that ravens fly into Anchorage in the morning, feed at the dump and local fast food restaurants, and then play in the plume at power plant #2 in the afternoon and evening. The article references an Alaska State biologist, Rick Sinnott, whom the CEC could contact to authenticate the activity.

Ravens are relatively large birds, and large congregations in the air would pose a bird strike hazard. While there are no fast food restaurants in the Byron area, the Altamont Landfill is located approximately 3 miles to the west of the Mariposa project site. As I understand, the Altamont Landfill receives garbage from the counties of Alameda and San Francisco, and is relatively large. I could not readily find, on the Internet, any accounting of ravens at the Altamont Landfill. All that I could find so far on Raven accounts in the Altamont area was contained in the CEC's Report 500-2008-080 entitled "Range Management Practices To Reduce Wind Turbine Impacts On Burrowing Owls And Other Raptors In The Altamont Pass Wind Resource Area, California."

With that background, it would be helpful if the CEC technical staff could: (1) contact Mr. Sinnott to authenticate the above activity, (2) make an assessment of the raven population in the Altamont area (such as consulting with the Altamont Land Fill operators, its regulators, East Bay Parks Staff, and/or staff at the Bethany Reservoir), (3) ask Mr. Sinnott and/or other biologists if the ravens in the Altamont area would be able to detect or find the plume and if they would be tempted to play in it. With regard to the latter, Mr. Sinnott may be able to tell us the distances between the dump, fast food restaurants, and the #2 powerplant in Anchorage, and we may be able to compare these distances to the distance between the Altamont Landfill and the Mariposa site.

Response:

MEP has no information on raven counts in the Altamont Pass area and would look to the CEC Staff for that information as it may be contained in various avian studies that have been conducted in the Altamont Pass Wind Resource Area. The Altamont Landfill is on the western slope of the Altamont Pass and any ravens using that landfill as a scavenging source would find other naturally occurring thermals much closer to that potential food source as the prevailing winds push up over the Altamont Pass. In addition, the Altamont Landfill seems to keep fairly tight control on covering items soon after they are deposited, since during our many trips on Altamont Pass and Vasco Roads, we have not observed a significant raven presence. The common raven is an increasingly common resident in the Altamont area that spends much of its life scavenging, soaring, and seemingly playing in warm air currents. While it is feasible that ravens may use the stack plumes to gain lift when they incidentally encounter them, it is unlikely that they would be drawn from miles away specifically to use the plumes because there is abundant thermal lift to be found throughout the California Coast Range (the lack of which we theorize may explain the attraction of ravens to the power plant plume on a cold day in Anchorage).

For a more detailed discussion of bird issues, please see the response to Staff Query 10.

Staff Query

SQ17. Finally, I searched for other public-use airports that allow ultralight flight operations. I found very few throughout the country. It seems that the FAA allows airport operators to ban or restrict ultralight operations, and most do. (Most public use airports indicate on their websites that an ultralight operator has to seek prior permission from the airport operator to land at the facility, which indicates that regular operations are not permitted.) As such, it appears that the Byron Airport is one of the very few public-use airports that allow ultralight operations. When the County built the Byron Airport, it took over private airpark for ultralights and sail planes (gliders), and the County promised that those operations could continue at the public-use airport. This, I think, explains why Byron is one of a very few public-use airports that allows these operations.

Response:

Pilots operating Ultralight Vehicles are governed by the provisions of FAR Part 103, *Ultralight Vehicles*. FAR Part 103 prohibits Ultralight pilots from operating an Ultralight Vehicle in areas designated in a Notice to Airmen (NOTAM).[39]

A Notice to Airmen (NOTAM) is a notice, essential to safety of flight, which contains information pertaining to the National Airspace System, the timely knowledge of which is essential to personnel concerned with flight operations.

One specific type of NOTAM pertaining to MEP is the Flight Data Center (FDC) NOTAM. An FDC NOTAM is regulatory in nature and issued to establish restrictions to flight and changes to charts or Instrument Approach Procedures.

A national FDC NOTAM is currently active that restricts pilots from overflying and/or loitering in proximity to power plants and other structures. Although primarily intended for national security purposes, an unintended consequence is that this NOTAM also advised pilots against flying over or through exhaust plumes. It reads as follows:

FDC 4/0811 FDC…SPECIAL NOTICE…THIS IS A RESTATEMENT OF A PREVIOUSLY ISSUED ADVISORY NOTICE. IN THE INTEREST OF NATIONAL SECURITY AND

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39 14 CFR (FAR) Part 103.20 Flight Restrictions in the proximity of certain areas designated by Notice to Airmen

TO THE EXTENT PRACTICABLE, PILOTS ARE STRONGLY ADVISED TO AVOID THE AIRSPACE ABOVE, OR IN PROXIMITY TO SUCH SITES AS POWER PLANTS (NUCLEAR, HYDRO-ELECTRIC, OR COAL) DAMS, REFINERIES, INDUSTRIAL COMPLEXES, MILITARY FACILITIES, AND OTHER SIMILAR FACILITIES. PILOTS SHOULD NOT CIRCLE AS TO LOITER IN THE VICINITY OVER THESE TYPES OF FACILITIES.

Overflight of power plants (and associated exhaust plumes) by Ultralight pilots is not only prohibited by direct reference in regulatory NOTAM FDC 4/0811 FDC, but also by the regulatory requirement found in FAR Part 103, which prohibits pilots of ultralight vehicles from operating an ultralight vehicle in areas designated in such a NOTAM.

FAR Part 103 also prohibits pilots of ultralight vehicles from operating their ultralight vehicle in a manner that creates a hazard to people or property.[40] To preclude any inadvertent hazardous operation associated with overflight of exhaust plumes by pilots of ultralight vehicles, the Byron Airport operator could make available the following to Byron Airport local pilots:

- Education on the nature and extent of industrial exhaust plumes.
- The FAA analysis of the safety risk associated with overflight of exhaust plumes by providing, to local pilots, a copy of the FAA Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes, January 2006.
- Plume avoidance strategies and operational techniques.

The FAA provides publications designed to notify pilots of items of interest in the National Airspace System. In addition to the issuance of NOTAMs, the FAA provides publications such as the Airport Facility Directory (AF/D) and Aeronautical Charts, both of which provide pilots with information such as the location of power plants and associated exhaust plumes. Pilots, in fulfilling their pre-flight action responsibility, consult and utilize these publications in the planning of their flights.

Consulting and utilizing these FAA publications, as well as reviewing the recommended educational publications specified above and complying with Federal Air Regulations will ensure that all pilots of ultralight vehicles (as well as all pilots) are aware of the location of the MEP power plant and associated exhaust plumes and should preclude overflight of plumes by any and all aircraft.

Should an ultra light or powered parachute inadvertently pass through the MEP plume the loads imparted by the plume would be +1.24g for the powered parachute that has a load limit of +6.0g and between +1.31g to +1.56g for a Vans RV-6 that has a load limit of +4.4g to -1.75g up to the maximum design gross weight. Due to the slow air speed of 10 to 25 mph of ultra lights and powered parachutes these aircraft would generally experience only light turbulence when passing through the plume at an elevation of 950 feet AGL. As long as ultra lights and powered parachutes maintain the appropriate clearances, MEP should have no impact on their activities in and around the Byron Airport.

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[40] 14 CFR (FAR) Part 103 *Ultralight Vehicles*, Section 9 Hazardous Operations

Contra Costa County Board of Supervisors Letter (Staff Queries 18–22)

Staff Query

SQ18. We request evidence be provided showing that the FAA has cleared the project and does not have concerns about safety associated with over-flight of industrial exhaust plumes and placement of power plants near airports.

Response:

FAA Safety Study Report – DOT-FAA-AFS-420-06-1 "Safety Risk Analysis of Aircraft Overflight of Industrial Exhaust Plumes" dated January 2006 concludes "hazard(s) associated with plume overflight represent an extremely low risk to aviation and the flying public." FAA deemed the risk associated with overflight of plumes to be "acceptable without restriction, limitation or further mitigation." In order to make an already safe condition even safer, FAA recommended continuance of training and awareness programs such as publication of power plant locations in the applicable Airport/Facility Directory and that a Notice to Airmen (NOTAM) be issued.

Additionally, in response to Data Request 51 submitted to the CEC, Mariposa Energy previously provided Determinations of No Hazard to Air Navigation issued by FAA for each of the four exhaust stacks and eight transmission poles associated with MEP. In the Determinations for the four exhaust stacks, FAA Flight Standards Division addressed the issue of thermal plumes and recommended that Mariposa Energy work with the Byron Airport to develop pilot education material and provide information on plume efflux rates at various altitudes at least as high as 1,000 feet above the source. These efflux rates are shown in the response to Staff Query #5 in Table SQ5-1. FAA also suggested that Byron Airport provide the MEP location and avoidance information in the listing for Byron Airport contained in the Airport/Facility Directory. These recommendations are consistent with the recommendations of the 2006 FAA Safety Risk Analysis.

Staff Query

SQ19. We request evidence that the project will not interfere with air navigation and will not pose a hazard to aeronautical activities due to its close proximity to the main precision instrument runway (Runway 30) nor hinder future instrument approach upgrades to any runway.

Response:

The MEP facility will be located 1.0 mile from the centerline of the RNAV (GPS) RWY 30 Final Approach Course. As discussed in detail in the response to Staff Query #1, the proposed MEP location is not hazardous to aircraft executing a precision or non-precision instrument approach and landing at Byron Airport. Pilots diverging from the centerline of the RNAV (GPS) RWY 30 Final Approach Course by 0.22 mile are required by the FAA to immediately initiate a missed approach, and air traffic controllers are required to instruct the pilot to initiate a missed approach whenever the completion of a safe approach is questionable because safety limits are exceeded or radical target deviations are observed. These required actions of both the pilot and the air traffic controller ensure against aircraft inadvertently overflying the MEP facility due to slight deviations from the final approach corridor. MEP will be located 1.0 mile from the centerline of the RNAV (GPS) RWY 30 Final Approach Course and 0.78 miles (4,118 feet) beyond the 0.22 mile limitation of excursions allowed by the FAA. Therefore the MEP location is not hazardous to aircraft executing a precision or non-precision instrument approach and landing at Byron Airport.

Byron Airport is equipped with one satellite-based Instrument Approach Procedure (IAP), the RNAV (GPS) RWY 30. The RNAV (GPS) RWY 30 is a precision-type IAP wherein all course guidance, both vertical and lateral, is provided by Global Positioning Satellites (GPS). This IAP may also be flown as a non-precision approach, if required. MEP will not hinder any future instrument approach upgrades to Runways 5, 12 or 23, since Runways 5 and 23 are approximately 2.7 miles away and Runway 12 is approximately 3.5 miles away. If an additional IAP was to be proposed for Runway 30, other than the current straight in approach, it most like would be consistent with the current pattern which is a right-hand pattern, indicating a possible approach from the northeast, over the Delta and Clifton Court Forebay and away from the MEP location. An approach from the southwest would require flying over the wind turbines and hills of the Mount Diablo Range and the Altamont Pass, many of which already encroach on the Airspace Protection Surfaces to the west of the Byron Airport, and therefore it is unlikely that a new IAP would be established from that direction.

Staff Query

SQ20. We request evidence that the project will not pose a hazard to aeronautical activities due to its close proximity to the established Byron Airport traffic pattern, both downwind leg and 45-degree pattern entrance, for Runways 5 and 23, as well as the departure path for Runway 12.

Response:

The standard 45 degree entry into the Runway 5 or 23 traffic patterns does not require aircraft to overfly MEP, and standard/typical traffic pattern entries would be approximately 1 mile from MEP. This issue is addressed in detail in the response to Staff Query #2. As indicated in the response to Staff Query #3, Runway 12 has a published straight out or left traffic pattern; therefore the standard departure procedure is to the southeast or east, directing aircraft on the opposite direction of the MEP location (see Figure SQ3-1). Even if an aircraft makes a non-standard departure on Runway 12 and once it reaches pattern altitude of 1,079 feet AMSL, makes a right "45" departure it would not overfly MEP (see Figure SQ3-2). Even if an aircraft should inadvertently overfly MEP at the pattern altitude of 1,079 feet AMSL (954 feet AGL), it would potentially experience light turbulence during most meteorological conditions and during worst-case conditions, a possible 26 hours out of 8,760 hours, may experience light to moderate turbulence; therefore MEP will not pose a hazard to aircraft landing on Runways 5 and 23 or departing from Runway 12. Refer to the response to Staff Query #3 for a more detailed discussion regarding these issues.

Staff Query

SQ21. We request evidence that the project will not pose a hazard to any of the various aeronautical activities at Byron Airport that include vintage military jet aircraft, corporate jet aircraft, single and twin piston aircraft, light sport aircraft, motorized parasail, ultra-light, and skydiving.

Response:

The presence of MEP will not significantly impact the flight operations for vintage military jet aircraft, corporate jet aircraft, single and twin piston aircraft, light sport aircraft, motorized parasail, ultralight, and skydiving or any other types of aircraft at the Byron Airport for the following reasons:

- The physical location of the facility is away from published FAA recommended and physically observed approaches, departures, or flight patterns for Byron Airport.
- The physical location of the facility is away from the skydiving and parachute landing area located west-northwest of Byron Airport.
- If an aircraft were to inadvertently overfly MEP, it would not be significantly impacted by the thermal plume from the facility since:
  - At the distance of 2.7 to 2.9 miles from the airport, most aircraft would be at elevations of 1,500 to 2,000 feet AGL. At these elevations, aircraft would be above altitudes at which they would experience exhaust plume impacts, even in a worst-case scenario.
  - Aircraft would have to be at an elevation below 954 feet AGL, flying directly over the MEP facility, during worst-case plume rise conditions, at speeds of 80 mph or greater to experience more than light turbulence.
  - Loads imparted to aircraft passing through the plume during the worst-case meteorological conditions of calm winds at an elevation of 954 feet AGL are well below load limits as indicated in Attachment DR52-9, Table 4.
  - The aileron deflection required to neutralize the maximum rolling coefficient is less than half of the available aileron deflection for the various aircraft listed in Attachment DR52-9, Table 5.
  - Aircraft at elevations of 320 feet AGL and higher, flying through the plume, would experience a plume temperature of 120°F or less, which would have no significant impact on the aircraft.
  - Piston, reciprocating engine, aircraft could fly at an elevation as low as 105 feet AGL or 25 feet above the top of the exhaust stacks, and still have enough oxygen, 18.6 percent, in the exhaust to operate their engines. Aircraft with turbine engines can operate at oxygen levels of 14 percent or less, which would allow them to be virtually above the mouth of the stacks and operate. The oxygen in the MEP exhaust stacks is estimated at 14.5 percent. However, aircraft elevations would be significantly higher than 105 feet AGL or 80 feet AGL due to the proximity of the site

to local high voltage power lines that are at approximately 150 feet AGL or 305 feet AMSL.

- The exhaust plume from MEP will not impact the Runway 30 instrument approach because the greatest extent of the plume with a vertical velocity exceeding light turbulence, 13.6 mph, is 115 feet horizontally from the stacks for any wind conditions (Attachment DR52-6, Table 8), 44 feet horizontally for a 5-mph wind scenario and 23 feet horizontally for a 10-mph wind scenario (Attachment DR52-7, Figures 1.1 and 2.1). With the Runway 30 approach being 1 mile (5,280 feet) from MEP and 0.78 miles (4,118 feet) from the point at which a missed approach would be initiated, it is improbable that a vertical velocity exceeding light turbulence due to MEP plumes would ever be experienced in the proximity of Runway 30.
- MEP has no visible exhaust plumes to serve as obstructions to aircraft navigation due to the lack of cooling towers or other exhaust plumes with high concentrations of water vapor.
- MEP has received from the FAA a Determination of No Hazard to Air Navigation for all four gas turbine exhaust stacks and all eight power poles connecting MEP to the PG&E Kelso Substation.
- As discussed in the response to Data Request #52, MEP exhaust plume exposure would not create a significant health risk to either aircraft pilots or aircraft passengers for any types of aircraft.

Based upon the attached reports and analysis MEP will not significantly impact aircraft or operations at Byron Airport.

Staff Query

SQ22. We request evidence be provided that the project meets all standards set forth in the Byron Airport Master Plan.

Response:

MEP will be in conformance with all standards set forth in both the Byron Airport Master Plan and Contra Costa County Airport Land Use Compatibility Plan. As indicated in the Airport Land Use Compatibility Plan, MEP is located within Compatibility Zone D, which limits any new construction greater than 100 feet AGL and requires Contra Cost County Airport Land Use Commission review of proposed structures over 100 feet AGL. All proposed MEP facilities are at or below 100 feet AGL and no structures approach any of the indicated Air Protection Surfaces.

The Byron Airport Master Plan focuses on aviation activity forecasts and future airport development plans. The current air field configuration (runways and taxiways) are deemed sufficient for the planning period; no current expansion plans are addressed in the plan. The Master Plan does recommend the following:

- Eventual upgrade of the instrument landing system to reduce the decision height and visibility requirements.

- Ultimate extension of Runway 12/30 to 6,000 feet from the current 4,500 feet with the extension being to the southeast.
- Ultimate extension of Runway 05/23 to 3,900 feet from the current 3,000 feet with the extension being to the east

MEP will not impact precision instrument landing system upgrades to reduce the decision height and visibility requirements since it is located approximately 1.0 mile from the precision instrument approach path and approximately 2.7 miles from the beginning or Runway 30. The extension of Runway 12/30 by 1,500 feet would not be impacted by MEP since the runway approach centerline would still be 1.0 mile northeast of MEP and an instrument landing missed approach procedure would be implemented if an aircraft is more the 1,350 feet (¾-scale needle deflection of the CDI) off course. The 900 foot extension of Runway 05/23 would move the mid-point of the approach pattern 450 feet the northeast; however this would not significantly impact the Runway 23 45-degree approach pattern since the centerline of the pattern is approximately 1.0 mile northwest of MEP.

Based on the current June 2005, "Final Report – Byron Airport Master Plan" prepared by Leigh Fisher Associates MEP will not significantly impact any of the proposed recommendations.