

APPENDIX 8.2C

# Nitrogen Deposition Impact Analysis on San Bruno Mountain

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## 8.2C.1 Calculation of Nitrogen Deposition Baseline

### 8.2C.1.1 General Methodology

The general methodology used in estimating the nitrogen deposition baseline is that relied upon by Dr. Stuart Weiss (1999). This method starts with deposition measurements reported by Blanchard, et al. (1996), and makes adjustments for location and surface composition. In this analysis, we make further adjustments to reflect reductions in ambient pollutant concentrations over the 10- to 15-year period since the data collection effort reflected in Blanchard's work.

The starting values for deposition are taken from Table 12 of Blanchard's report, and represent long-term average deposition rates, on a quarterly basis, for various species in Fremont, California. (Deposition data from Fremont, California, were used in this analysis because Fremont has the nearest available dry deposition monitoring station to the project site. Fremont and San Francisco are located in the same air basin [meaning the two locations share common air quality characteristics] and Fremont data were determined to be the most representative data available. Other monitoring sites are located in the Sacramento and San Joaquin valleys and southern California, farther from the project site and outside of the air basin.) These values are adjusted from their ionic bases to a nitrogen basis, and then are further adjusted for surface composition; location change; and recent pollution reduction efforts. Each of these adjustments is further discussed below.

### 8.2C.1.2 Surface Composition

Weiss notes that deposition rates vary as a function of surface composition. The data collected by Blanchard at Fremont represented an "urban mix" of surfaces, while the San Bruno Mountain is principally green grasslands during the fall and winter months. To address this type of difference, Weiss applied correction factors, obtained from Blanchard, to reflect different deposition rates during fall and winter months. Weiss provided similar correction factors for use in the analysis that was prepared in 2000 for grassland areas in the San Jose area. These same correction factors were applied, on a species-specific basis, to the first and fourth calendar quarter deposition rates, for this analysis.

### 8.2C.1.3 Location Differences

Weiss further adjusted the deposition rates measured in Fremont to reflect differing levels of ozone and nitrogen dioxide in the San Jose area. In particular, a factor of 1.3 was applied to deposition of  $\text{NO}_2$  and  $\text{NO}_3$  to reflect higher concentrations of nitrogen dioxide in San Jose as compared with Fremont. Similarly, a factor of 1.2 was applied to nitric acid ( $\text{HNO}_3$ ) deposition to reflect higher concentrations of ozone in San Martin (south of San Jose) as

compared with Fremont. For the current analysis, we looked at ozone and nitrogen dioxide data from Fremont and San Francisco. The data used to develop the correction factors are shown in Table 8.2C-1 (all tables appear at the end of this appendix). The revised analysis resulted in factors of 1.018 for nitrogen dioxide and 0.623 for ozone (reflecting lower concentrations of ozone in San Francisco than in Fremont).

### 8.2C.1.4 Recent Emission Reductions

To further refine the estimate, an additional correction factor was added that reflected the air quality improvements that have been observed in the Bay Area over the last 10 years. The original deposition measurements covered the period between 1988 and 1993 at Fremont. For that period of time, the California Air Resources Board (CARB) reported three relevant statistics for ozone (top four 8-hour average ozone levels; annual average ozone level; and annual average of daily maximum ozone level), and one relevant statistic for nitrogen dioxide (annual average). Each of these values is shown in Table 8.2C-1 for each year between 1988 and 1993, along with the average for the 6-year period.

For the most recent 3 years for which data are available (2002-2004), the only relevant ozone statistic available is the top four 8-hour average ozone levels. Consequently, we used the average of the top four 8-hour average ozone levels as a measure of the relative change in ozone concentrations between the two time periods (1988-93 vs. 2002-04). This metric is a good indicator of the relative severity of the ozone season and, by using multi-year averages, is a good indicator of the change in emissions loading in the region independent of year-to-year fluctuations in ambient concentrations due to meteorology.

Using this metric, it was concluded that ozone levels in 2002-04 range from 3 percent higher to 12 percent lower than the levels observed in 1988-93 when the deposition data were collected. Similarly, looking at the change in annual average NO<sub>2</sub> concentrations, it was concluded that levels of this pollutant have been reduced 27 percent since the earlier period. Consequently, a final adjustment factor of 0.955 for ozone and 0.73 for nitrogen dioxide was applied. Consistent with Weiss' methodology, the ozone adjustment was applied to HNO<sub>3</sub>, and the NO<sub>2</sub> adjustment was applied to NO<sub>2</sub> and NO<sub>3</sub>.

In conclusion, the current best estimate of nitrogen deposition in the vicinity of San Bruno Mountain is 6.17 kilograms/hectare/year (kg/ha/year). This estimate is probably conservatively high, based on Weiss' statement that "[p]eninsula sites have lower deposition, 4-6 kg/ha/year" (Weiss, 1999). The results of our analysis, including all adjustment factors, are presented in Table 8.2C-2.

## 8.2C.2 Nitrogen Deposition Modeling Methodology

### 8.2C.2.1 Overview of Modeling Procedure

The SFERP modeling analysis used the Industrial Source Complex Short Term, Version 3 (ISCST3) model, to evaluate the project's air quality impacts. ISCST3 is a steady-state, mass-conserving, nonreactive (i.e., no chemistry) Gaussian plume dispersion model.

All three turbines were modeled. These are the only sources at the site with emissions of nitrogen-containing compounds. The calculation of nitrogen emissions for use in this modeling analysis are shown in Table 8.2C-3.

To produce conservative results (overestimates), conservative assumptions regarding the complex chemistry that occurs to produce nitrogen from  $\text{NO}_x$  and ammonia were used. These assumptions lead to an exceedingly conservative estimation of nitrogen deposition, because areas with the highest nitrogen emissions do not necessarily experience the greatest deposition effects, which usually occur far from the original nitrogen source. In addition, since mass is conserved in the model, all downwind calculations of nitrogen deposition, regardless of distance and formation rates, are overestimated by the model.

The ISCST3 model calculates atmospheric deposition of nitrogen by calculating the wet and dry fluxes of total nitrogen. This deposition is accomplished by using a resistance model for the dry deposition part, and by assigning scavenging coefficients for the wet removal process from rainout. As discussed below, depositional parameters are input into the model to calculate the deposition of nitrogen.

### 8.2C.2.2 Chemical Transformation of $\text{NO}_x$ Emissions

The oxidation of nitrogen oxides is a complicated process that can include a large variety of nitrogen compound, such as nitrogen dioxide ( $\text{NO}_2$ ), nitric acid ( $\text{HNO}_3$ ) and organic nitrates ( $\text{RNO}_3$ ) such as peroxyacetylnitrate (PAN). Atmospheric chemical reactions that occur in sunlight result in the formation of ozone and other compounds. Depending on atmospheric conditions, these reactions can start to occur within several hundred meters of the original  $\text{NO}_x$  source, or after the pollutants have been carried tens of kilometers downwind. Ultimately, some nitrogen oxides are converted to nitric acid vapor or particulate nitrates. Precipitation is one mechanism that removes these pollutants from the air. Forms of atmospherically-derived nitrogen are removed from the atmosphere both by wet deposition (rain) and dry deposition (direct uptake by vegetation and surfaces).

Ammonia ( $\text{NH}_3$ ) and ammonium ( $\text{NH}_4$ ) are other forms in which nitrogen occurs. Ammonia is a gas that becomes ammonium when dissolved in water, or when present in soils or airborne particles. Unlike  $\text{NO}_x$ , which forms during combustion, soil microorganisms naturally form ammonia and ammonium compounds from nitrogen and hydrogen.

In urban atmospheres, the oxidation rate of  $\text{NO}_x$  to  $\text{HNO}_3$  is estimated to be approximately 17 percent per hour, with a range of 10 to 30 percent per hour (CARB, 1986). Aerosol nitrates ( $\text{NO}_3$ ) are present, mainly in the form of ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ). Nitrate and ammonium are the predominant forms by which plants absorb nitrogen. In California, ammonium nitrate is the predominant airborne nitrate-bearing particle in the atmosphere (CARB, 1986). The SFERP analysis used the CARB estimate of 17 percent immediate conversion of  $\text{NO}_x$  to  $\text{HNO}_3$ .

### 8.2C.2.3 Nitrogen Deposition Mechanisms

The ISCST3 wet and dry deposition modeling for gaseous pollutants is based on the algorithm contained in the CALPUFF dispersion model (USEPA, 1995), which Moore, et al., reviewed and evaluated (1995). The deposition flux,  $F_d$ , is calculated as the product of the concentration,  $\Pi_d$ , and a deposition velocity,  $v_d$ , computed at a reference height  $z_d$ :

The dry deposition algorithm is based on an approach that expresses the deposition velocity as the inverse sum of total resistance. The resistance represents the opposition to transporting the pollutant through the atmosphere to the surface. ISCST3 incorporates several resistance models that include aerodynamic resistance, canopy resistance, cuticle resistance, deposition layer resistance, mesophyll resistance, and stomatal action.

With wet deposition, gaseous pollutants are scavenged by dissolution into cloud droplets and precipitation. A scavenging ratio approach was used to model the deposition of gases through wet removal. In this approach, the flux of material to the surface through wet deposition ( $F_w$ ) is the product of a scavenging ratio times the concentration, integrated in the vertical direction.

#### 8.2C.2.4 Model Inputs

To model gaseous deposition, the following inputs are required:

- The molecular diffusivity for the pollutant being modeled (cubic centimeters per second [cm<sup>2</sup>/s])
- The solubility enhancement factor ( $a^*$ ) for the pollutant
- The pollutant reactivity parameter
- The mesophyll resistance term ( $r_m$ ) for the pollutant (s/cm),
- The Henry's Law coefficient for the parameter

In addition to the above inputs, the dry and wet deposition algorithm also requires surface roughness length (cm), friction velocity (meters per second), Monin-Obukhov length (meters), leaf index ratio, precipitation type, and precipitation rate. Site-specific meteorology was used in this analysis and was based on the 1992 data set collected at the adjacent Potrero Power Plant. Hourly cloud cover, relative humidity and solar radiation data, which were required for the modeling analysis but were not available from the Potrero meteorological data set, were taken from San Francisco Airport (cloud cover and RH) and the nearest CIMIS station (solar radiation) in Fremont.

ISCST3 calculates depositional flux at user-specified locations, called receptors. Receptors were placed at 100-meter intervals throughout the park on along the park boundaries, producing more than 1100 locations where deposition was calculated in the model.

#### 8.2C.2.5 Results of the Modeling Analysis

The impact over the critical area was determined using the average deposition rate over the area. Impacts were modeled over the entire area of San Bruno Mountain.

The average modeled nitrogen deposition from the project over the area is estimated to be 0.0059 kg/ha/year, or less than 0.1 percent of existing background levels. The total nitrogen deposition is the project impact of 0.0059 kg/ha/year plus the background of 6.17 kg/ha/year equaling a total impact of 6.175 kg/ha/year. This modeling analysis does not take into account the NO<sub>x</sub> emission reduction credits being provided for the project, which will offset much of the nitrogen emissions increase from SFERP. The applicant will provide 47.5 tons per year of NO<sub>x</sub> ERCs, which will result in a 14.5-ton-per-year reduction

in nitrogen emissions. This represents 33 percent of the 44.4 tons per year of nitrogen from the new facility.

Modeling input and output files are being provided with the air quality modeling files on CD.

### 8.2C.3 Cumulative Impacts

Current nitrogen deposition background levels on San Bruno Mountain reflect the impacts of operation of the Hunters Point and Potrero power plants. Historical operation of those power plants provides a baseline for the assessment of potential future cumulative impacts.

Three potential future operating scenarios were evaluated. As discussed in Appendix 8.1F, the City considers it highly unlikely that the Hunters Point power plant will continue to operate beyond 2007. However, one of the future operating scenarios assumes continued operation of the Hunters Point power plant to conservatively overestimate future nitrogen deposition impacts.

In the first scenario, it was assumed that both Potrero and Hunters Point power plants would continue to operate at historical levels (that is, future annual heat input to each unit would be equal to the average annual heat input over the past three years), that the boilers at each plant would meet the 2006 NO<sub>x</sub> regulatory limit of 0.018 pounds/Million British Thermal Units (lb/MMBtu) using selective catalytic reduction (SCR) systems with 10 ppm ammonia slip, and that no additional controls would be installed on the peaking turbines. In the second scenario, it was assumed that the Potrero power plant would continue to operate at historical levels, with Boiler 3 controlled using SCR to meet the District's regulatory NO<sub>x</sub> limit (0.018 lb NO<sub>x</sub>/MMBtu effective 1/1/06) with 10 ppm ammonia slip (corrected to 3 percent O<sub>2</sub>), and that the Hunters Point power plant would be shut down. In the third scenario, it was assumed that both the Potrero and Hunters Point power plants would be shut down. All scenarios include the NO<sub>x</sub> reductions from the offsets to be provided for SFERP.

Calculations for each scenario are shown in Table 8.2C-4. These calculations show that even with SFERP and continued operation of the Hunters Point and Potrero power plants with SCR control, there will be a net reduction of over 52 tons per year of nitrogen emissions in southeast San Francisco. Even with the addition of SFERP and the continued operation of the Potrero power plant, the shutdown of Hunters Point will result in a net reduction in nitrogen emissions of approximately 86 tons per year. If both the Potrero and Hunters Point power plants are shut down, the area will see a net reduction in nitrogen emissions of about 169 tons per year.

### 8.2C.4 References

Blanchard, C.; Michaels, H.; and Tanenbaum, S. 1996. *Regional Estimates of Acid Deposition Fluxes in California for 1985-1994*. Contract number 93-332. Sacramento, California: California Air Resources Board, April.

California Air Resources Board (CARB) (1986): *Dry Deposition of Acidic Gases and Particles*, February 1986.

Moore, G., P. Ryan, D. Schwede, and D. Strimaitis, 1995: Model performance evaluation of gaseous dry deposition algorithms. Paper 95-TA34.02, 88th Annual Meeting & Exhibition of the Air and Waste Management Association, San Antonio, Texas, June 18-23.

U.S. Environmental Protection Agency (1995): Interagency Workgroup on Air Quality Modeling (IWAQM): Assessment of Phase 1 Recommendations Regarding the Use of MESOPUFF II. EPA-454/R-95-006.

Weiss, S. 1999. "Cars, Cows and Checkerspot Butterflies Nitrogen Deposition and Management of Nutrient-Poor Grasslands for a Threatened Species." *Conservation Biology* 13: 1476-1486.

**Table 8.2C-1  
San Francisco Electric Reliability Project  
Nitrogen Deposition Analysis - Related Air Quality Data**

Year	Fremont - Chapel				San Francisco - Arkansas St				Ratio - San Francisco:Fremont			
	Avg of Top 4 8-hr Avg O3 ppm	Ann Avg O3 ppm	Ann Avg Daily Max O3 ppm	Ann Avg NO2 ppm	Avg of Top 4 8-hr Avg O3 ppm	Ann Avg O3 ppm	Ann Avg Daily Max O3 ppm	Ann Avg NO2 ppm	Avg of Top 4 8-hr Avg O3 ppm	Ann Avg O3 ppm	Ann Avg Daily Max O3 ppm	Ann Avg NO2 ppm
1988	0.086	0.019	0.043	0.026	0.060			0.026	0.692	0.000	0.000	1.000
1989	0.081	0.018	0.041	0.025	0.053			0.026	0.657	0.000	0.000	1.040
1990	0.073	0.017	0.039	0.023	0.050			0.021	0.682	0.000	0.000	0.913
1991	0.074	0.019	0.040	0.024	0.044			0.024	0.598	0.000	0.000	1.000
1992	0.074	0.017	0.039	0.021	0.047			0.022	0.639	0.000	0.000	1.048
1993	0.091	0.020	0.043	0.022	0.045			0.024	0.489	0.000	0.000	1.091
<b>Average</b>	0.080	0.018	0.041	0.024	0.050			0.024	0.623	0.000	0.000	1.014
2002	0.066			0.019	0.046			0.019				
2003	0.077			0.017	0.054			0.018				
2004	0.067			0.014	0.053			0.016				
<b>Average</b>	0.070			0.017	0.051			0.018	0.731			1.060
<b>Change: 2002-2004 vs 1988-93</b>	-12%			-29%	3%			-26%				

**Table 8.2C-2  
Nitrogen Deposition - Baseline Calculation  
San Francisco Electric Reliability Project**

	Gas-Phase Species			Particulate		Total
	HNO3	NO2	NH3	NO3	NH4	
<b>1st Calendar Quarter</b>						
Fremont Data (88-94)	3.220	9.010	1.110	0.740	0.160	14.240 kg/ha-year (from Blanchard et al, Table 12)
Fremont Data (88-94)	0.716	2.742	0.914	0.167	0.124	4.663 kg/ha-year (as N)
Grassland Adjustment	1.058	1.805	3.189	2.364	3.187	ratio
Adjusted Fremont Data (88-94)	0.757	4.949	2.915	0.395	0.397	9.413 kg/ha-year (as N)
Fremont -> SFERP Adjustments for ozone	0.623					ratio
for NO2		1.014		1.014		ratio
Adjusted SFERP (88-94)	0.472	5.018	2.915	0.400	0.397	9.202 kg/ha-year (as N)
Current Year Adjustment (88-94 to 02-04) for ozone	0.955					ratio
for NO2		0.730		0.730		ratio
Adjusted SFERP Baseline (02-04)	0.450	3.663	2.915	0.292	0.397	7.718 kg/ha-year (as N)
<b>2nd Calendar Quarter</b>						
Fremont Data (88-94)	5.940	7.790	1.010	0.730	0.100	15.570 kg/ha-year (from Blanchard et al, Table 12)
Fremont Data (88-94)	1.320	2.371	0.832	0.165	0.078	4.765 kg/ha-year (as N)
Grassland Adjustment	1.000	1.000	1.000	1.000	1.000	ratio
Adjusted Fremont Data (88-94)	1.320	2.371	0.832	0.165	0.078	4.765 kg/ha-year (as N)
Fremont -> SFERP Adjustments for ozone	0.623					ratio
for NO2		0.730		0.730		ratio
Adjusted SFERP (88-94)	0.822	1.731	0.832	0.120	0.078	3.583 kg/ha-year (as N)
Current Year Adjustment (88-94 to 02-04) for ozone	0.955					ratio
for NO2		0.730		0.730		ratio
Adjusted SFERP Baseline (02-04)	0.785	1.263	0.832	0.088	0.078	3.046 kg/ha-year (as N)
<b>3rd Calendar Quarter</b>						
Fremont Data (88-94)	10.770	9.290	1.200	0.860	0.170	22.290 kg/ha-year (from Blanchard et al, Table 12)
Fremont Data (88-94)	2.393	2.827	0.988	0.194	0.132	6.535 kg/ha-year (as N)
Grassland Adjustment	1.000	1.000	1.000	1.000	1.000	ratio
Adjusted Fremont Data (88-94)	2.393	2.827	0.988	0.194	0.132	6.535 kg/ha-year (as N)
Fremont -> SFERP Adjustments for ozone	0.623					ratio
for NO2		1.014		1.014		ratio
Adjusted SFERP (88-94)	1.491	2.867	0.988	0.197	0.132	5.675 kg/ha-year (as N)
Current Year Adjustment (88-94 to 02-04) for ozone	0.955					ratio
for NO2		0.730		0.730		ratio
Adjusted SFERP Baseline (02-04)	1.424	2.093	0.988	0.144	0.132	4.781 kg/ha-year (as N)
<b>4th Calendar Quarter</b>						
Fremont Data (88-94)	2.820	11.600	1.110	1.350	0.230	17.110 kg/ha-year (from Blanchard et al, Table 12)
Fremont Data (88-94)	0.627	3.530	0.914	0.305	0.179	5.555 kg/ha-year (as N)
Grassland Adjustment	1.058	1.805	3.189	2.364	3.187	ratio
Adjusted Fremont Data (88-94)	0.663	6.371	2.915	0.721	0.570	11.240 kg/ha-year (as N)
Fremont -> SFERP Adjustments for ozone	0.623					ratio
for NO2		1.014		1.014		ratio
Adjusted SFERP (88-94)	0.413	6.460	2.915	0.731	0.570	11.090 kg/ha-year (as N)
Current Year Adjustment (88-94 to 02-04) for ozone	0.955					ratio
for NO2		0.730		0.730		ratio
Adjusted SFERP Baseline (02-04)	0.394	4.716	2.915	0.533	0.570	9.129 kg/ha-year (as N)
<b>Annual Average</b>						
Adjusted SFERP Baseline (02-04)						6.169 kg/ha-year (as N)

**Table 8.2C-3**  
**Nitrogen Deposition Emission Rates**  
**San Francisco Electric Reliability Project**

NOx emission rate =	13.27 tpy per turbine
N/NO2 molecular weight ratio (14/46) =	0.304347826
N emission rate from NO2 =	4.04 tpy per turbine
	0.1162 g/s per turbine
N emission rate for modeling contribution from NO2=	0.0197 g/s per turbine
NH3 emission rate =	13.08 tpy per turbine
N/NH3 molecular weight ratio (14/17) =	0.823529412
N emission rate from NH3 =	10.77 tpy per turbine
N emission rate for modeling contribution from NH3=	0.3099 g/s per turbine

Emission rates based on annual average values  
Use 17% conversion rate for N from NO2 only

**Table 8.2C-4  
San Francisco Electric Reliability Project  
Nitrogen Emissions: Cumulative Impacts**

**Scenario 1: Continued Operation of Potrero and Hunters Point  
at Historical Levels with SCR on Boilers**

Source	Emissions, tons per year				
	NOx	N from NOx	NH3	N from NH3	Total N
SFERP: Project Emissions	39.8	12.1	39.2	32.3	44.4
SFERP: NOx Offsets	-47.5	-14.5	--	--	-14.5
Hunters Point: Continued Historical Operation (1)	-104.2	-31.7	8.6	7.1	-24.6
Mirant Potrero: Continued Historical Operation (1)	-235.7	-71.7	16.8	13.8	-57.9
Total					-52.5

**Scenario 2: Shutdown of Hunters Point, Continued Operation of Potrero  
at Historical Levels with SCR on Boiler 3**

Source	Emissions, tons per year				
	NOx	N from NOx	NH3	N from NH3	Total N
SFERP: Project Emissions	39.8	12.1	39.2	32.3	44.4
SFERP: NOx Offsets	-47.5	-14.5	--	--	-14.5
Hunters Point: Plant Shutdown (2)	-190.1	-57.9	--	--	-57.9
Mirant Potrero: Continued Historical Operation (1)	-235.7	-71.7	16.8	13.8	-57.9
Total					-85.8

**Scenario 3: Shutdown of Hunters Point and Potrero**

Source	Emissions, tons per year				
	NOx	N from NOx	NH3	N from NH3	Total N
SFERP: Project Emissions	39.8	12.1	39.2	32.3	44.4
SFERP: NOx Offsets	-47.5	-14.5	--	--	-14.5
Hunters Point: Plant Shutdown (2)	-190.1	-57.9	--	--	-57.9
Mirant Potrero: Plant Shutdown (2)	-464.5	-141.4	--	--	-141.4
Total					-169.3

Notes:

1. Based on average emissions and fuel use during 2001-2003, with boilers controlled to 0.018 lb NOx/MMBtu using SCR with ammonia slip rate of 10 ppm @ 3% O2 and no additional controls on peaking turbines.
2. Based on average emissions and fuel use during 2001-2003.