UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

MAR 1 2 2018

MEMORANDUM

SUBJECT: Concurrence Request for Approval of Alternative Model: BLP/AERMOD Hybrid Approach for Modeling Buoyant Roofline Sources at the FMMI Copper Smelter in Miami, AZ

FROM: Rynda Kay, Physical Scientist Rynda Kay
Air Quality Analysis Office, Air Division, EPA Region IX

THRU: Meredith Kurpius, Associate Director
Air Division, EPA Region IX

TO: George Bridgers, Director of Model Clearinghouse
Air Quality Modeling Group, Office of Air Quality Planning and Standards

EPA Region IX is seeking concurrence from the Model Clearinghouse on a modeling approach using a combination of the Buoyant Line and Point Source model (BLP) and American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) to represent buoyant roofline sources from the Freeport-McMoran Incorporated (FMMI) copper smelter located in Miami, Arizona. Arizona Department of Environmental Quality (ADEQ) has sought approval under 40 CFR Part 51, Appendix W- Guideline on Air Quality Models, paragraph 3.2.2(b), condition (2) to use this alternative model in its 2010 1-hr SO_2 National Ambient Air Quality Standard (NAAQS) nonattainment area State Implementation Plan (SIP) for the Miami, AZ nonattainment area entitled "Arizona State Implementation Plan Revision: Miami Sulfur Dioxide Nonattainment Area for the 2010 SO_2 NAAQS" (2017 SO_2 Plan), submitted to the EPA on March 9, 2017. Justification for the alternative model is provided in the 2017 SO_2 Plan, Appendix C, "Modeling Technical Support Document for the Miami Sulfur Dioxide (SO_2) Nonattainment Area."

We have performed a technical review of ADEQ's submittal and propose that the use of the BLP/AERMOD hybrid alternative model should be granted in this case. A short technical analysis is included for your consideration. Please feel free to contact Meredith Kurpius at (415) 947-4534 or Rynda Kay at (415) 947-4118 if you have questions regarding our concurrence request.

Attachment.

EPA Region IX Technical Review of Arizona Department of Environmental Quality's Request to Use BLP/AERMOD Hybrid Approach

1. Regulatory Background

On June 22, 2010, the Environmental Protection Agency (EPA) strengthened the primary National Ambient Air Quality Standard (NAAQS) for sulfur dioxide (SO_2) by establishing a new 1-hour standard at a level of 75 parts per billion (ppb) (2010 1-hour SO_2 NAAQS). *See* 75 FR 35520. EPA designated the Miami area of Gila County, Arizona as a nonattainment area (Miami NAA or NAA) for the 2010 1-hour SO_2 NAAQS on August 5, 2013, effective as of October 4, 2013, based on measured violations of the standard using 2009-2011 data. *See* 78 FR 47191. Because of this designation, the Arizona Department of Environmental Quality (ADEQ) was required to develop a State Implementation Plan (SIP) revision to demonstrate attainment of the NAAQS within five years of the effective date of designation. This SIP revision was due on April 4, 2015. On March 18, 2016, the EPA found that the State of Arizona had failed to make this submittal. *See* 81 FR 14736.

On March 8, 2017, ADEQ adopted a SIP to address these requirements, entitled "Arizona State Implementation Plan Revision: Miami Sulfur Dioxide Nonattainment Area for the 2010 SO_2 NAAQS" (2017 SO_2 Plan) and on March 9, 2017, ADEQ submitted the plan to the EPA. As part of this submittal, ADEQ has requested approval of an alternate modeling approach to represent the buoyant roofline SO_2 sources at the Freeport-McMoran Incorporated (FMMI) copper smelter in Miami, AZ (Miami Smelter or Smelter). The EPA's "Guidance for 1-Hour SO_2 Nonattainment Area SIP Submissions," dated April 23, 2014 (2014 SO_2 Guidance), specifies that air quality modeling for 2010 1-hour SO_2 NAAQS nonattainment SIPs "would need to employ air quality dispersion models that properly address the source-oriented nature of SO_2" and are consistent with the EPA's Guideline on Air Quality Models, also published as Appendix W of 40 CFR Part 51 (Appendix W). *See* 2014 SO_2 Guidance, Appendix A, pp. A1-A2. Appendix A of Appendix W identifies models which are recommended and preferred for regulatory application and which have undergone evaluation exercises including statistical measures of model performance.

Arizona's attainment demonstration uses AERMOD, the preferred model for most near-field regulatory applications, for all sources except buoyant line source emissions emanating from the Smelter building roofline. The State considers the Buoyant Line and Point Source model (BLP) as the preferred model for buoyant line sources for this application as it was the preferred model listed in Appendix W during 2017 SO_2 Plan development.[1] ADEQ has sought to use an alternative approach to BLP. Under 40 CFR 51.112(a)(2) and 40 CFR 51 Appendix W, section 3.2, if the preferred model is inappropriate for a particular application in a SIP, the model may be modified or another model substituted, if the EPA approves the modification or substitution. Appendix W, section 3.2.2 (b) requires that an alternative model be "evaluated from both a theoretical and a performance perspective before it is selected for use," and outlines several conditions under which an alternative model can be approved. ADEQ has sought approval for an alternative approach under Appendix W, section 3.2.2 (b), condition (2), where "a statistical

[1] EPA has since approved AERMOD with a newly incorporated BLP algorithm as the preferred model for these sources, as part of revisions to Appendix W promulgated in 2017. *See* 82 FR 5182 (January 17, 2017). ADEQ submitted its SIP to us on March 9, 2017, prior to the May 22, 2017effective date for the Appendix W revisions. *See* 82 FR 14324 (March 20, 2017)(revising effective date of Appendix W revisions).

performance evaluation has been conducted using measured air quality data, and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model in appendix A." The justification for the alternative model is provided in the 2017 SO_2 SIP, Appendix C, "Modeling Technical Support Document for the Miami Sulfur Dioxide (SO_2) Nonattainment Area" (Attainment TSD) and "Technical Memorandum, Additional Performance Evaluation of Dispersion Modeling Approaches Miami SO_2 Nonattainment Area State Implementation Plan (SIP)" (Performance Memo), dated February 5, 2018, and is summarized below.

2. **Facility Location and Description**

The Miami Smelter accounts for over 99.9% of SO_2 emissions in the Miami NAA. The Smelter is located 90 miles east of Phoenix, AZ, ~3,500 feet above mean sea level (ASL) in an area of very complex terrain (Figure 1). At the Smelter, copper sulfide ore concentrate is refined from 15-35% copper to anodes of copper with greater than 98.5% purity. SO_2 and other pollutants are released during the smelting process. A process description and the location of SO_2 emissions are described in the 2017 SO_2 SIP, Sections 4.1-4.2, pp. 35-42. SO_2 is emitted from a number of sources during the smelting process and is ultimately released or routed to roofline vents and stacks. In 2011, the facility potential to emit (PTE) was 10,600 tons per year (tpy) SO_2 and estimated actual emissions were 2,545 tpy SO_2. From May 2013 through December 2014, emissions through the roofline vents accounted for approximately 44% of the Smelter SO_2 emissions.

To meet the SO_2 NAAQS as well as other requirements, such as those outlined in the EPA's Regional Haze Federal Implementation Plan (79 FR 52420), FMMI is performing substantial upgrades to its facility (Smelter Upgrade Project) including new capture and control design and equipment, as well as existing smelting equipment replacement. *See* 2017 SO2 SIP, Section 4.3, pp. 43-46. These improvements will result in the reduction of potential SO_2 emissions from 10,600 tpy to 659 tpy SO_2.[2] Actual emissions are projected to be reduced to ~315 tpy.

The Miami Smelter is currently configured with five roof vents, which account for a significant proportion of the Smelter's current SO_2 emissions (Figure 2). The Smelter Upgrade Project will reconfigure and improve capture over the smelter building to capture additional fugitive emissions that were previously vented through the roofline. The pre- and post-retrofit sources are described in the Attainment TSD, Section 5.0.

[2]This PTE was derived by multiplying out the facility's 30-day rolling hourly emission limit of 142.45 lb/hr SO_2 for the entire year + 8 lb/hr of additional sources operating at the maximum capacity.

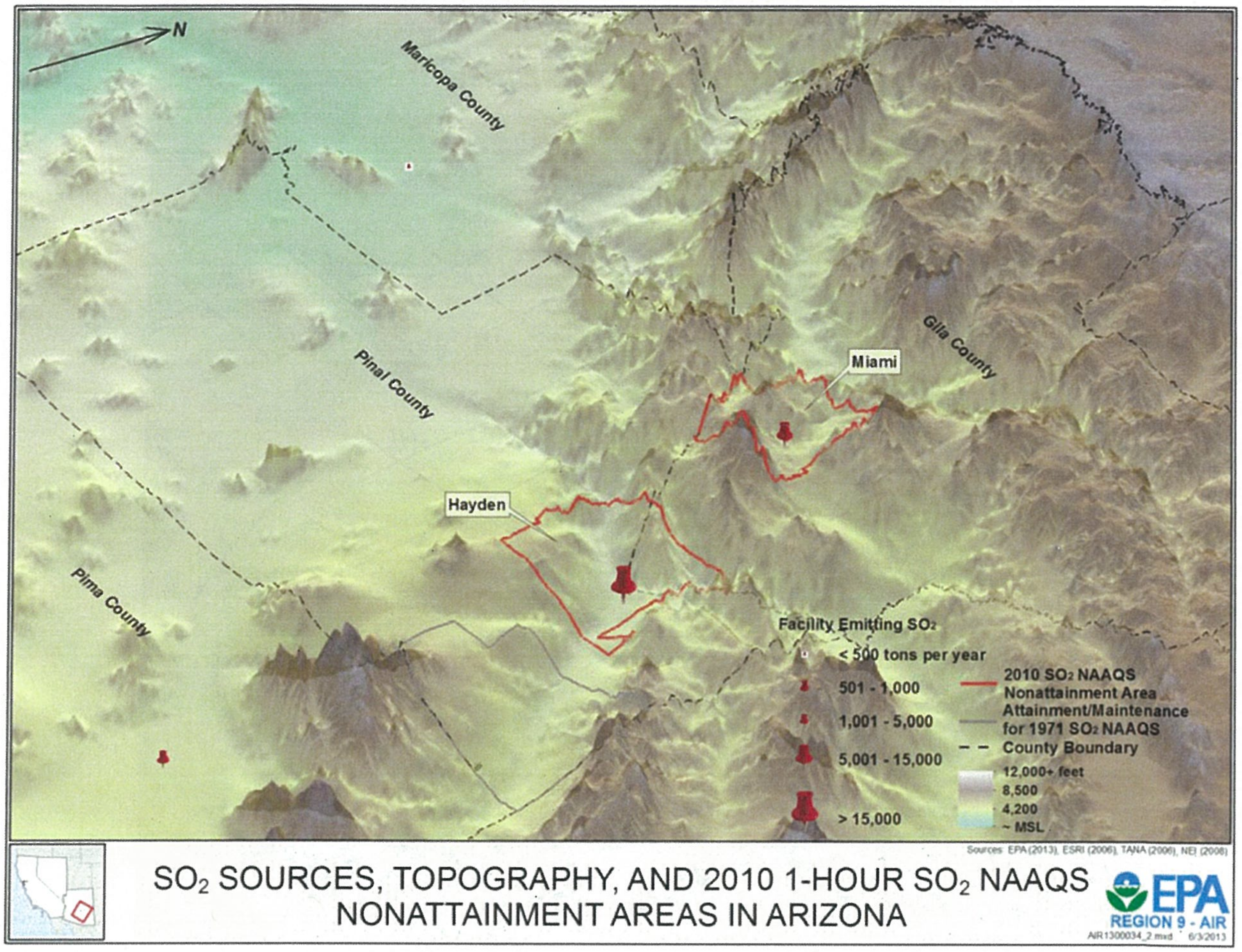

Figure 1. SO_2 sources, topography and 2010 1-hour SO_2 NAAQS Nonattainment Areas in Arizona.

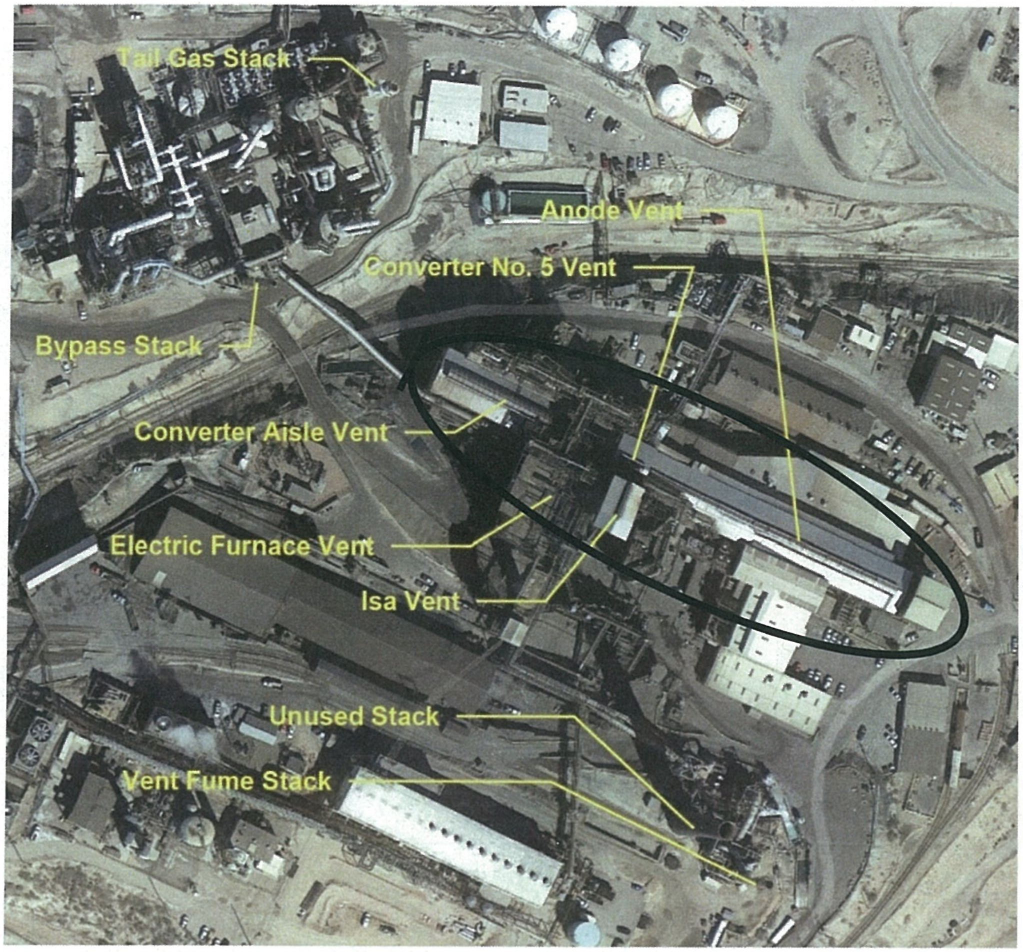

Figure 2. Miami smelter stacks and roofline vents. Roofline sources being modeled as buoyant line sources (black circle). Attainment TSD, Appendix H, Figure 1.

3. BLP/AERMOD Hybrid Approach-Technical Basis

The State used AERMOD for all emission sources except for those over the Smelter building roofline. As described in Section 1 above, BLP is considered the preferred model for the 2017 SO_2 SIP and ADEQ has sought to use an alternative approach to BLP. The State asserts that the use of BLP alone has several limitations that may affect the simulation of surface impacts from the Smelter's roof vents: BLP treats complex terrain differently than AERMOD; assumes all buildings are equally long and are equally separated; assumes roof vents are aligned parallel to each other and have identical buoyancies; uses Meteorological Processor for Regulatory Models (MPRM)/RAMMET meteorological files that use the Pasquill-Gifford (P-G) stability class procedure; does not have a calms processing routine; is limited to 100 receptors; and as discussed in the next section, BLP-predicted concentrations overestimate, when compared to higher elevation monitors in the Miami NAA, by a factor of 2-5.

To represent emissions from the Smelter roofline, the State proposes to use a combination of AERMOD and BLP (BLP/AERMOD Hybrid Approach):[3]

- Use the BLP model to estimate hourly line source final plume rise and sigma-z (σ_z) from the Smelter roof vents;
- Apply the BLP-predicted final plume heights and σ_z in AERMOD with hourly volume source approach. Then run AERMOD to predict SO_2 concentrations for comparison with the NAAQS.

This approach is described more fully in the Attainment TSD, Section 4.3. Input parameters into BLP include building and ridge vent size and location information as well as an average buoyancy parameter, which is calculated using exit temperature, exit velocity, and ambient air temperature. To calculate the average line source buoyancy parameter, ADEQ used results from a 2013 roofline study which measured these parameters, and modified the physical dimensions from the roofline study to reflect expected changes due to the Smelter Upgrade Project by the attainment year.

ADEQ modified the BLP source code to output hourly final plume heights and σ_z. Final plume heights were calculated at a 1 kilometer (km) distance from the smelter using a ring of receptors placed every 10 degrees. σ_z was similarly sampled at 250 meters (m) from the smelter center using a ring of receptors placed every 5 degrees. The 250 m distance is the representative minimum distance for receptors to clear the Smelter building and not overlay with a vent. ADEQ notes that this approach also ensures that the σ_z values account for plume interaction and downwash, while not diluting the plume. These parameters were used to initialize hourly volume sources above the roofline in AERMOD as described in Sections 5.2.3 and 5.2.5 of the Attainment TSD.

Region IX staff were concerned that placing volume sources instantaneously above the smelter building would not accurately represent the initial location of the sources and would neglect gradual plume rise and downwash. During plan development, ADEQ provided additional analysis to support this modeling approach, including information concerning the choice of final plume height and σ_z, the effect of downwash and near field impacts, the lack of gradual plume rise in this approach, and whether proposed controls adequately address high concentrations registered at the Miami Townsite monitor located in the valley below the smelter. The additional analysis and discussion can be found in the Attainment TSD, Section 5.2.3.2, Appendices D and L, and are summarized below.

ADEQ performed a number of sensitivity analyses to justify using final plume height at 1 km and σ_z at 250 m. *See* Attainment TSD, Appendix D. The analysis showed that a 1 km receptor distance represents final plume height and that σ_z does not change markedly with this distance from the smelter, suggesting excessive dilution would not be an issue. *See* Attainment TSD, Appendix D, Table 1A-1B and 3A-3B. The topography of the region and existing monitoring suggest that elevated 1-hour concentrations are expected to impact adjacent topography where final plume rise has been achieved, therefore, gradual plume rise would not affect predicted

[3] All other sources were modeled using AERMOD version 14134, with regulatory default options. The State later repeated the simulation using AERMOD version 16216r, and showed no difference in predicted concentrations.

concentrations (Figure 3). Additionally, the approach adequately captures observations at existing monitors at elevation as described in Section 4 below.

The Miami Townsite SO_2 monitor, however, is located in the valley below the smelter and is not affected by buoyant roofline emissions. *See* Figure 3 and Attainment TSD, Figure 5-6. To examine the effect of downwash on receptors near the smelter boundary, ADEQ ran BLP with and without downwash. Concentrations at receptors near the smelter did not change, suggesting if there are any ground level impacts due to downwash they fall within the facility boundary (i.e., the ambient air boundary) or do not occur at all. ADEQ found that high concentrations at the Miami Townsite monitor are due to morning inversion breakup fumigation conditions not represented in AERMOD or BLP. ADEQ used AERSCREEN in fumigation mode to assess contributions at those locations. *See* Attainment TSD, Appendix L. The analysis shows that stack sources are the major contributor to the elevated concentrations (whereas the roof vents are not) and that emission reductions from the Smelter Upgrade Project are sufficient to provide for attainment in these low-lying areas.

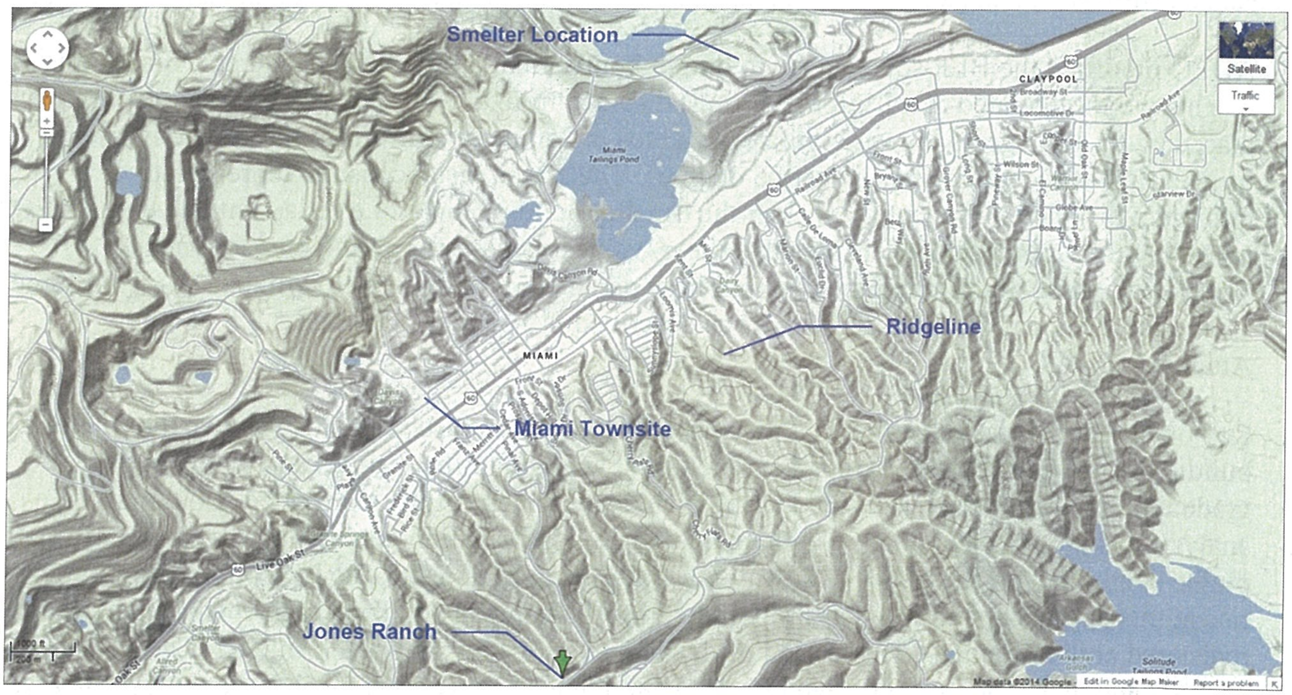

Figure 3. Ambient Monitor Locations Relative to the Miami Smelter. Attainment TSD, Appendix C, Figure 3.

4. BLP/AERMOD Hybrid Approach Performance Evaluation

Under Appendix W, paragraph 3.2.2(a), condition (2), a statistical performance evaluation is required to demonstrate that a proposed alternative model performs better for the given application than a comparable preferred model. The State's performance evaluation for the BLP/AERMOD Hybrid approach can be found in the Attainment TSD, Appendix C and the Performance Memo and is summarized below. The evaluation was conducted using several statistical measures documented in "Protocol for Determining the Best Performing Model," EPA-454/R-92-025, December 1992.

FMMI and ADEQ evaluated the following modeling approaches based on the implementation of BLP and AERMOD:

- BLP simulation for buoyant line sources, AERMOD for all other sources (preferred model in this case) (Additive BLP/AERMOD)[4]
- AERMOD only for all sources (AERMOD only)[5]
- BLP/AERMOD Hybrid Approach (alternative model)

FMMI's model evaluation was based on observations and continuous hourly emissions measured from May 2013-April 2014. Emission data include hourly emission rate, plume temperature, and plume velocity or flowrate, which were used as input into AERMOD. In all modeling approaches, actual hourly emissions data were input to AERMOD. The BLP model is not equipped to read hourly emission rates, but can produce output of hourly predicted concentrations at each receptor. For the Additive BLP/AERMOD approach, BLP was run with roof vent sources set to 1 gram/second, then hourly emission rates were applied to predict hourly concentrations. The buoyancy factor in BLP is fixed, so average plume temperature and velocity were used in the BLP runs.

Hourly meteorological data were collected onsite from May 2013-April 2014 and used as input into AERMET and MPRM. Additional surface observations (cloud cover, atmospheric pressure for the period were obtained through the National Weather Service (NWS) site located in Safford, Arizona. Upper air observations were obtained for this time period from the NWS site in Tucson, Arizona. ADEQ placed receptors within 100 meters of each monitor location for comparison.

Three ambient SO_2 air quality monitors operate around the FMMI facility and were used in this evaluation: Jones Ranch (4,075 feet ASL), 3km from the smelter), Ridgeline (3,560 feet ASL, 1.6 km from the smelter), and Miami Townsite (3,419 feet ASL, 2 km from the smelter). Their locations are shown in Figure 3 above, which also references the Smelter location (3,560 feet ASL).

Given the release height of emissions (stack and roofline vent emissions with release heights 107 to 213 feet above ground level; ground level being the Smelter elevation (3,560 feet ASL)) and subsequent buoyant and momentum plume rise, the Jones Ranch site would be expected to measure higher concentrations due to Smelter roofline emissions than the other locations, as it is the only site located at a higher elevation than the smelter. For the year of record used in the model performance evaluation (May 2013 through April 2014), the 4th highest daily maximum 1-hour ambient SO_2 concentration measured at the Jones Ranch monitor location was considerably greater than the concentration measured at Ridgeline, as is evident by the measured values presented in Table 1. The 2010 1-hr SO_2 NAAQS design values (DVs) for 2014-2016 for the three sites were: Jones Ranch – 524 $\mu g/m^3$, Ridgeline- 383 $\mu g/m^3$ and Miami Townsite – 508

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[4] Two cases were tested for the Additive BLP/AERMOD approach. First, all roof vents were modeled together in one simulation, allowing for interaction between the plumes ("multi-vent") and is considered the preferred model in this case. A second sensitivity analysis was conducted where the roof vents were modelled separately and then summed together ("single-vent").

[5] Two cases were tested for the AERMOD-only simulations: AERMOD was run with, and without, downwash for roofline sources.

μg/m^3 (200 parts per billion (ppb), 146 ppb, and 194 ppb, respectively).

The measured concentrations presented in Table 1 illustrate the importance of the Jones Ranch site in establishing model performance. Despite the greater distance of the Jones Ranch monitor from the Smelter, the higher concentrations measured there are indicative of the monitor being located at an elevation that is representative of Smelter plume heights. As previously discussed, the Miami Townsite monitor, located on the valley floor to the south of the smelter, experiences high concentrations due to morning inversion break-up fumigation from the facility stacks, rather than roofline sources, so is included for completeness, but is not indicative of the alternative model performance (*see* Attainment TSD Appendix L).

Jones	540
Ridgeline	364
Miami Townsite	285

Table 1. Measured 4th Highest Daily 1-hour Maximum Ambient SO_2 Concentrations (μg/m^3) May 2013-April 2014. Attainment TSD, Appendix C, Table 1.

Table 2 provides a summary of the 4th highest measured and predicted 1-hour SO_2 concentrations during the time period May 2013 – April 2014. At the Jones Ranch monitor, the 4th high measured concentration was 540 μg/m^3 compared with the simulated concentration of 1370 μg/m^3 for the preferred model and 512 μg/m^3 for the alternative model. Corresponding Q-Q plots for the Jones Ranch and Ridgeline monitors are also shown in Figure 4 below.

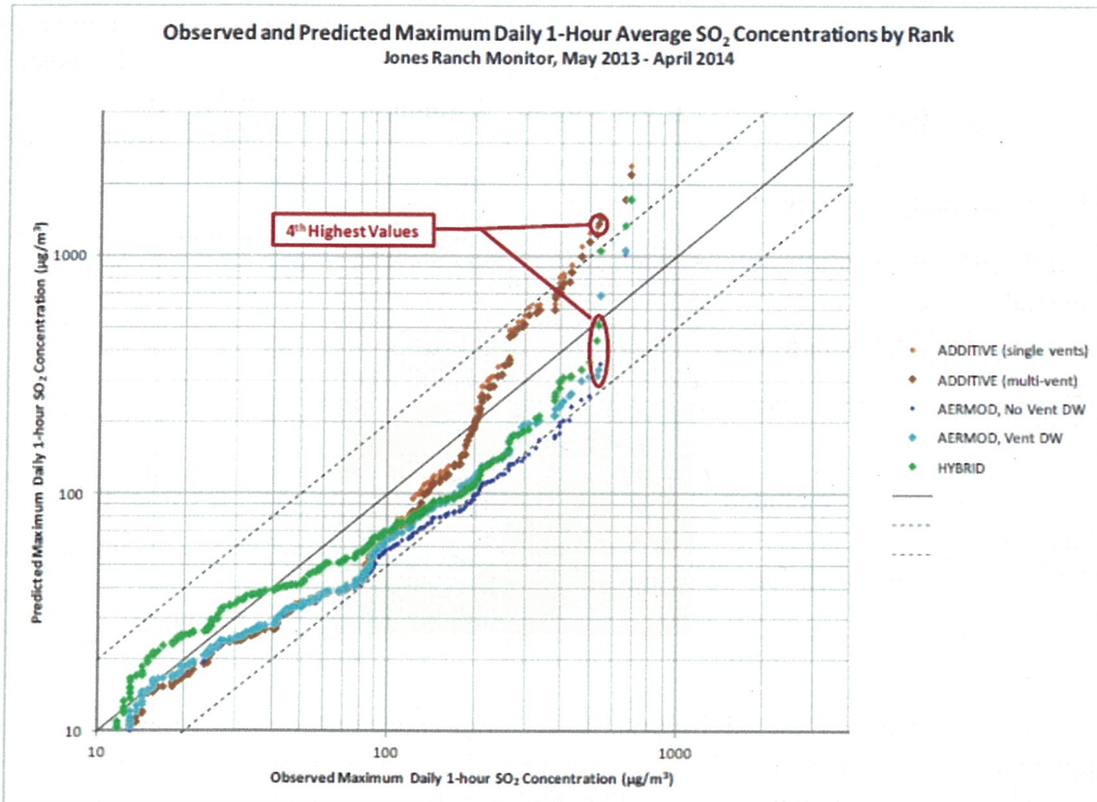
Description	Ambient Monitor Location			Highest Modeled Ground Level Concentration
	Jones Ranch	**Ridgeline**	Miami Townsite*	
Observed, Actual Measurements	**540**	**364**	285	NA
Additive BLP/AERMOD, multiple vent (preferred model)	**1370**	**879**	175	6362
Additive BLP/AERMOD, single vent	**1487**	**1850**	283	7981
BLP/AERMOD Hybrid (alternative model)	**512**	**228**	79	1752
AERMOD only, downwash included for roofline vents	**333**	**1484**	363	3830
AERMOD only, no downwash for roofline vents	**313**	**278**	112	2108

Notes:

- Listed concentrations are the 4th highest daily 1-hour concentration in a 1-year period.
- "Highest Modeled Ground Level Concentration" refers to the highest predicted concentration for all ambient air beyond the facility fenceline, not just the ambient monitor locations.
- Green shading indicates model result is within a factor of 1.5 of observation.
- Orange shading indicates model result is within a factor of 2 of observation.
- Red shading indicates model result is beyond a factor of 2 of observation.

* As described above, Miami Townsite monitor is not indicative of alternative model performance.

Table 2. Summary Comparison of Measured and Predicted 1-hour Ambient SO_2 Concentrations ($\mu g/m^3$). This table was modified from Attainment TSD, Appendix C, Table 2.



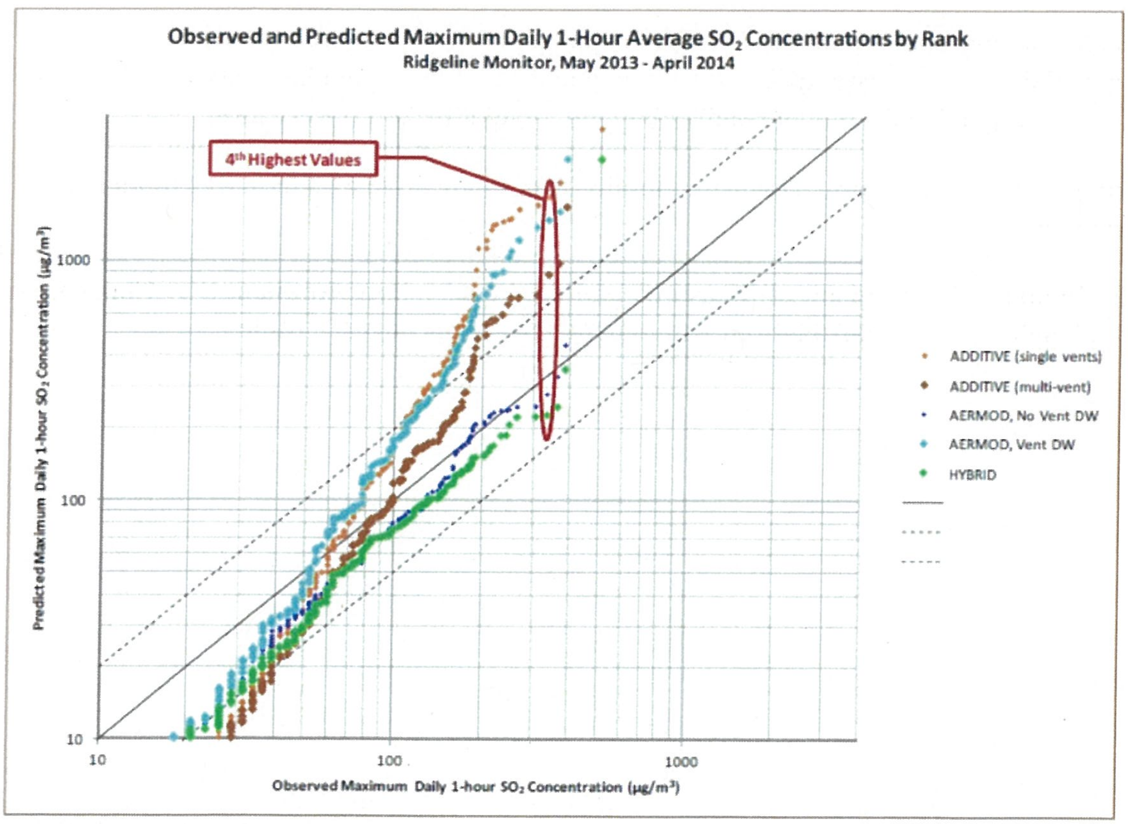


Figure 4. Q-Q Plots for Jones Ranch (top) and Ridgeline (bottom) monitors, Modeling TSD, Appendix C, Figure 4.

Table 2 and the Figure 4 show that the alternative model approach (BLP/AERMOD Hybrid) most closely predicts measurements at the Jones Ranch location, which is the site most indicative of roofline sources, and is within a factor of two at the Ridgeline location. In contrast, the preferred model (Additive BLP/AERMOD) approach substantially over-predicts at both locations, suggesting the BLP/AERMOD Hybrid approach performs better than the preferred model for roofline buoyant sources for this particular application and topography. In the Performance Memo, ADEQ provided an additional statistical analysis following the methodology outlined in the Protocol for Determining the Best Performing Model. First, the State conducted a screening test followed by a composite performance measure (CPM), which includes both operational and scientific evaluations of model performance.

For the screening test, the fractional bias metric was calculated using the 25 highest observed and predicted values.[6]

$$FB = 2\left[\frac{OB - PR}{OB + PR}\right]$$

where FB = fractional bias,
OB = mean or standard deviation of the 25 highest observed values, and
PR = mean or standard deviation of the 25 highest predicted values

Models with FB values within +/- 0.67 are considered to perform at minimum operational levels. At the Jones Ranch and Ridgeline monitor the alternative model (BLP/AERMOD Hybrid) approach performed within the acceptable range, whereas the preferred model (Additive BLP/AERMOD) fell outside of this range. *See* Performance Memo, Figure 1.

Next, the State calculated the CPM. This calculation uses the robust estimate of highest concentration (RHC), a smoothed estimate of the highest concentration based on the tail exponential fit to the upper end of observed and predicted distributions.

$$RHC = X(n) + [\bar{X} - X(n)] \ln\left[\frac{3n - 1}{2}\right]$$

where RHC = robust highest concentration,
X(n) = nth largest value,
$\bar{X}$= average of the n-1 largest values, and
n = number of values exceeding the threshold value ($n \leq 26$).

The largest observation-based RHC and prediction-based RHC were used to calculate the operational absolute fractional biases (AFB_O) for each model (*see* Performance Memo, Table 1). The RHC for each monitoring location under a range of meteorological conditions was used to calculate the scientific absolute fractional biases (AFB_S) for each model (*see* Performance Memo, Table 2).

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[6] The State removed the highest three observed and predicted values, which they assert is appropriate due to the 4th high value being the relevant metric for the 2010 SO_2 NAAQS attainment test.

The CPM combines the operational and scientific performance evaluations:

$$\text{CPM} = \frac{2}{3}\text{AFB}_O + \frac{1}{3}\text{AFB}_S$$

The lower the value of CPM, the lower the fractional bias. Results show that the BLP/AERMOD hybrid (alternative model) performs best, with a CPM of 0.3.

Model	**CPM**	**AFBo**	**AFBs**
Multi-Vent Additive BLP/AERMOD	0.806	0.847	0.724
Single-Vent Additive BLP/AERMOD	0.976	1.119	0.691
Hybrid BLP/AERMOD	0.300	0.195	0.510
AERMOD, Roofline Vents with Downwash	0.747	0.830	0.581
AERMOD, Roofline Vents without Downwash	0.743	0.641	0.949

Table 3. Calculated CPM, Integrated Evaluation, Performance Memo, Table 3.

5. **Conclusion**

ADEQ has sought approval from EPA Region IX to use a hybrid modeling approach using BLP in combination with AERMOD to represent buoyant roofline sources for the FMMI copper smelter for its 2010 1-hr SO_2 Miami, AZ NAA SIP. Appendix W, paragraph 3.2.2(a) requires that an alternative model be "evaluated from both a theoretical and a performance perspective before it is selected for use," and outlines several conditions under which an alternative model can be approved. ADEQ has sought approval for this approach under Appendix W, section 3.2.2 (b), condition (2), where "a statistical performance evaluation has been conducted using measured air quality data, and the results of that evaluation indicate the alternative model performs better for the given application than a comparable model in appendix A."

ADEQ provided a statistical performance evaluation using measured air quality data at three monitoring locations within the NAA. As described in Section 4 above, the State compared 4th highs as well as Q-Q plots of hourly SO_2 concentrations and found the alternative model approach most closely predicts measurements at the Jones Ranch monitor, which is the site most indicative of roofline sources, and is within a factor of two at the Ridgeline location. In contrast, the preferred model approach substantially over-predicts at both locations. The State also provided a statistical analysis following the EPA's Protocol for Determining the Best Performing Model, that compares the fractional bias and CPM, and found the alternative performs better than the preferred model in this case. Additionally, ADEQ provided technical justification for the validity of the approach for the meteorology and topography affecting this area. EPA Region IX staff have reviewed the information provided by ADEQ, as summarized in this technical analysis, and agree that it adequately supports approval as an alternative model under Appendix W, Section 3.2.2(a) condition 2. EPA Region IX seeks Model Clearinghouse concurrence to approve ADEQ's alternative model request.