Modeling Report for Site-Specific Alternative Model for 1-hour SO_2 Emissions of Conemaugh and Seward Impacts in Complex Terrain Along Laurel Ridge in Western Pennsylvania

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1. Introduction

The Seward Generating Station (Seward) and Conemaugh Generating Station (Conemaugh) are both coal-fired electric generating stations located in southeastern Indiana County, PA. The stations are situated approximately 2 miles (3.3 km) apart from each other (**Figure 1-1**) adjacent to the Conemaugh River. In this area, the river is the jurisdictional boundary between Indiana County and Westmoreland County, PA. The coal-fired boilers at the stations are significant point sources of sulfur dioxide (SO_2) emissions that can impact areas located within Indiana County and areas outside of Indiana County (i.e., portions of Westmoreland and Cambria Counties). Impacts within Indiana and portions of Armstrong counties were addressed in the Indiana, PA Nonattainment Area SO_2 National Ambient Air Quality Standard (NAAQS) State Implementation Plan (SIP) revision that was approved by the U.S. Environmental Protection Agency (EPA) in September 2024[1]. Following approval of that SIP revision, EPA finalized a study that evaluated impacts in areas outside of Indiana County. The study included a dispersion modeling effort that utilized recent actual emissions from the two stations and historic meteorological data that were generated from a meteorological monitoring site located between the two stations. The findings from that modeling effort resulted in EPA redesignating select portions of Westmoreland and Cambria Counties as non-attainment for the 2010 SO_2 NAAQS[2]. Within this area of interest (Cambria-Westmoreland area) lies a significant elevated terrain feature known as Laurel Ridge. As shown in **Figure 1-2**, this ridge is oriented northeast to southwest and is primarily located in eastern Westmoreland County and western Cambria County.

The significant rise in elevation that is presented by Laurel Ridge relative to the boiler exhaust stack heights at Seward and Conemaugh is much more pronounced than any other surrounding terrain feature within 20 km of the facilities. The vast majority of the ridge has terrain elevations above 600 meters above sea level (ASL), with some of the highest elevations nearing 1,000 meters ASL. These heights are considerably higher than the stack tops of Conemaugh (490 meters ASL) and Seward (513 meters ASL), thus meeting the definition of complex terrain relative to the emission sources being modeled.

On October 28, 2025, the Stations (Seward and Conemaugh) submitted a modeling protocol to EPA Region 3 to conduct a site-specific model performance evaluation that would determine whether an alternative model is more appropriate for 1-hour SO_2 modeling along Laurel Ridge (including the entire Westmoreland-Cambria non-attainment area). EPA Region 3 approved the September 28th, 2025 modeling protocol to evaluate the need for an alternative model on September 30, 2025.[3] This document executes the approach detailed in the modeling protocol and provides the results of the model performance analysis.

[1] Air Plan Approval; Pennsylvania; Attainment Plan for Indiana Nonattainment Area for the 2010 1-hour Sulfur Dioxide National Ambient Air Quality Standard. 89 FR 74836. Published September 13, 2024 with an effective date of October 15, 2024. Available at: https://www.federalregister.gov/documents/2024/09/13/2024-20598/air-plan-approval-pennsylvania-attainment-plan-for-the-indiana-nonattainment-area-for-the-2010

[2] Redesignation of Portions of Westmoreland and Cambria Counties, Pennsylvania for the 2010 Sulfur Dioxide National Ambient Air Quality Standards. 89 FR 101910. Published December 17, 2024 with an effective date of January 16, 2025. Available at: https://www.federalregister.gov/documents/2024/12/17/2024-29229/redesignation-of-portions-of-westmoreland-and-cambria-counties-pennsylvania-for-the-2010-sulfur

[3] Email communication from Tim Leon-Guerrero (EPA Region 3) and Christopher Warren (AECOM) on September 30, 2025.

Figure 1-1: Cambria-Westmoreland, PA 1-hour SO_2 NAAQS Modeling Area of Interest

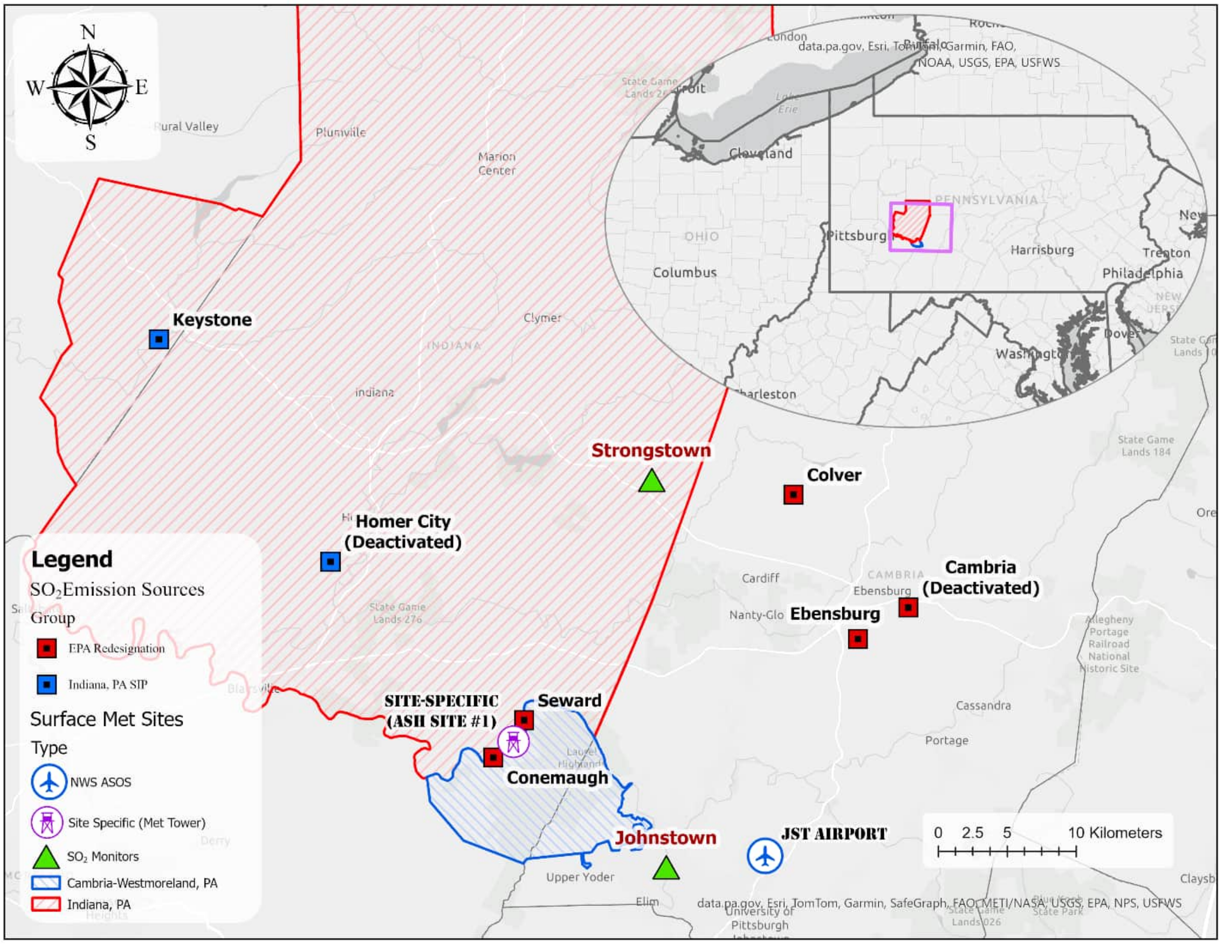
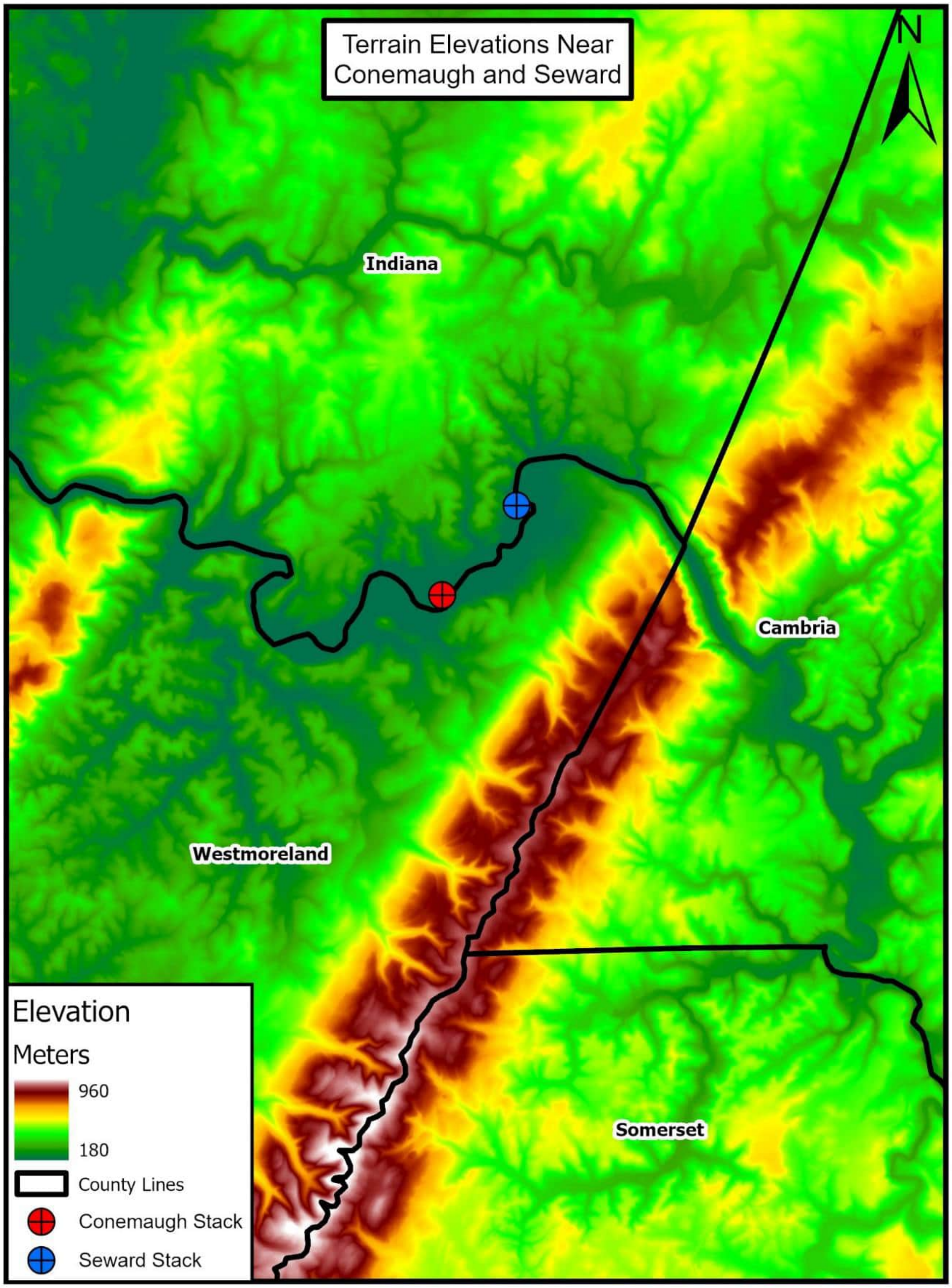


Figure 1-2: Elevation of Model Area of Interest



1.1 Unique Site-Specific Conditions

The topographic setting along with the orientation of the complex terrain relative to the SO_2 emission sources introduces unique challenges to dispersion modeling for this site-specific area. The first challenge involves strong wind directional shear. Given that the sources and the site-specific meteorological tower are located within the valley, the wind up to approximately 100 meters follows the terrain features and is predominantly from the southwest to northeast, as depicted in **Figure 1-3** (a and b)[4]. At higher levels, closer to stack top and above terrain heights the flow begins to turn more out of the west. This shift in direction with height is known as wind directional shear. While dispersion models, like AERMOD, are designed to account for this effect for steering the plume centerline, AERMOD does not consider the fact that the top and bottom of the rising plumes are being steered in different directions, thus resulting in additional horizontal spreading that AERMOD's formulation does not consider. In that respect, the horizontal plume extent can be underestimated by AERMOD.

There are other physical processes that act to expand the plume's horizontal spreading when it is forced to "wrap around" a complex terrain feature. Briggs (1982)[5] noted that the plume trajectory tends to favor the "grain" of the terrain rather than going across it. Another physical process in complex terrain is the enhancement of turbulence due to eddy formation created by the flow of air passing over and around terrain obstacles. Hanna (1980), see **Attachment A**, found that sigma-theta values increased by a factor of 1.6 during neutral conditions when the wind direction was perpendicular to the terrain.[6]

The current model formulation of AERMOD, in its regulatory form, is not configured to account for the shape of a complex terrain feature; the configuration is limited to the height of the top of the hill that each receptor is associated with. Accordingly, AERMOD configuration excludes the orientation of the terrain feature such as Laurel Ridge. For the critical case of plumes with insufficient kinetic energy (due to buoyancy / mechanical lift) to lift over the hilltop, AERMOD simply sends the plume "through" the hill and does not consider any additional dispersion due to the need for the plume to go around the hill whose shape is unaccounted for in the model. As shown in **Figure 1-3** (c and d), the predominant westerly flow at higher levels will orient the plumes from Conemaugh and Seward stacks more perpendicular to the higher Laurel Ridge terrain downwind. In contrast, Briggs' findings would indicate that the Seward and Conemaugh plumes should travel along and around the long axis of the hill, resulting in a substantial more pronounced "wrap around" effect than AERMOD would be capable of simulating.

As discussed, the area downwind of the predominant flow of Conemaugh of Seward, which is dominated by Laurel Ridge, is unique and complex in terms of dispersion modeling. AERMOD with default options would not be an appropriate model as it would tend to underestimate the plume meandering, which can be exacerbated under light winds at night, and lead to an overprediction bias of ground-level concentrations. As a result, a site-specific alternative model is warranted to more appropriately address this issue.

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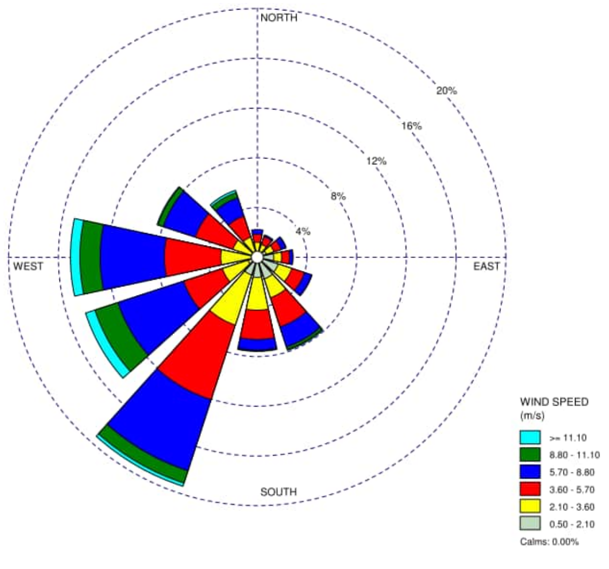
[4] Figure 1-3 (a) shows the winds at 150 meters from the Ash Valley Tower that collected data in the early 1990s. Figure 1-3 (b) illustrates the winds from the more recent 2015-2016 Ash Site #1 Tower at 100 meters. Together with the wind roses from the select SODAR level (Figure 1-3 (c and d)) show the change in wind patterns with height for this area.

[5] Briggs, G. A., S. Hanna, R. Hosker Jr., 1982. Handbook on Atmospheric Diffusion. Available at: https://www.researchgate.net/profile/Steven-Hanna/publication/236400832_Handbook_on_Atmospheric_Diffusion_of_Energy/links/588cab0daca272fa50df48af/Handbook-on-Atmospheric-Diffusion-of-Energy.pdf

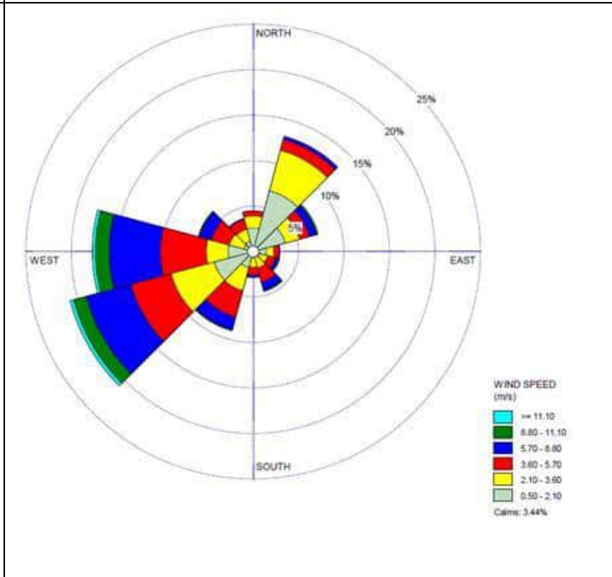
[6] Hanna, S. R., 1990. Lateral Dispersion in Light-Wind Stable Conditions. Il Nuovo Cimento C 13, 889-894. https://doi.org/10.1007/BF02514777

Figure 1-3: Wind Roses

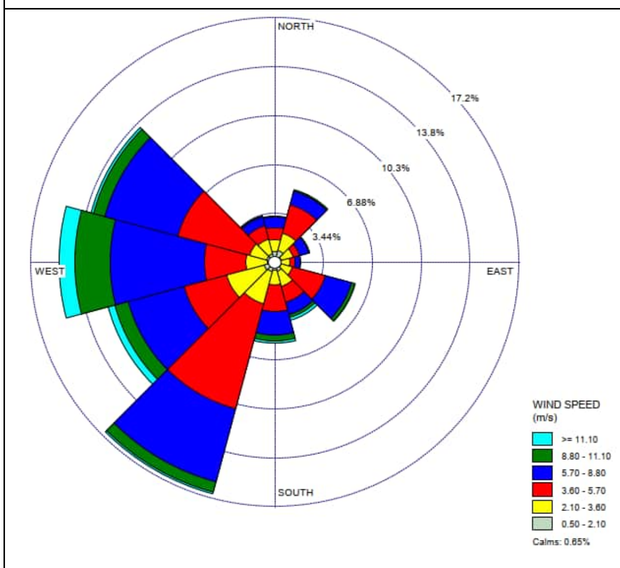
(a) Ash Valley Tower at 150-m



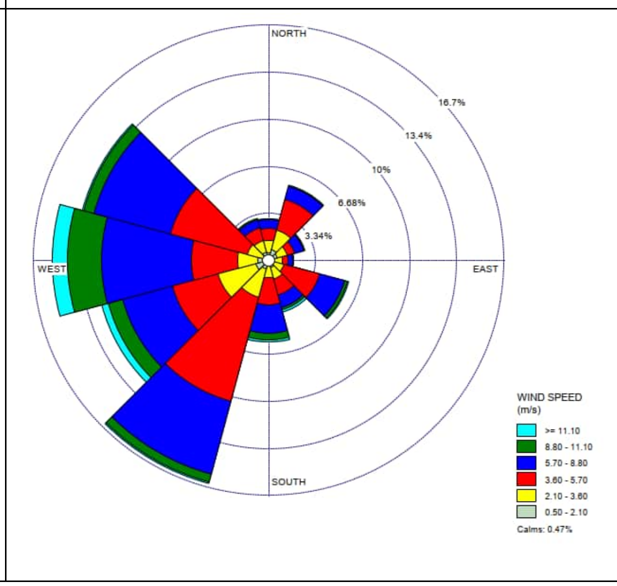
(b) Ash Site #1 Tower at 100-m



(c) Ash Site #1 SODAR at 350-m



(d) Ash Site #1 SODAR at 400-m



Note: SODAR winds from the southwest were affected by Conemaugh cooling tower plumes. That was documented in the Indiana, PA SIP. Therefore, the data underrepresents the frequency of southwesterly to westerly flow. Also, the base elevations between the Ash Valley Tower and Ash Site #1 are about 140 meters, with the Ash Valley Tower being at a higher base elevation.

1.2 Clean Data Determination Dispersion Modeling

Following enactment of the Clean Air Act (CAA) Amendments of 1990, EPA established the “Clean Data Policy” for the 1-hour ozone NAAQS[7]. The Clean Data Policy states that for a nonattainment area that can demonstrate attainment of the standard prior to the implementation of CAA nonattainment measures, that no additional control measures would be required so long as air quality continues to meet the standard. In an April 23, 2014 memorandum entitled “Guidance for 1-hour SO_2 Nonattainment Area SIP Submissions”, EPA provides guidance and a rationale for the application of the Clean Data Policy to the 2010 1-hour primary SO_2 NAAQS[8]. Under the Clean Data Policy, a state may notify EPA that it believes a nonattainment area is attaining the 2010 1-hour SO_2 NAAQS and request a Clean Data Determination (CDD).

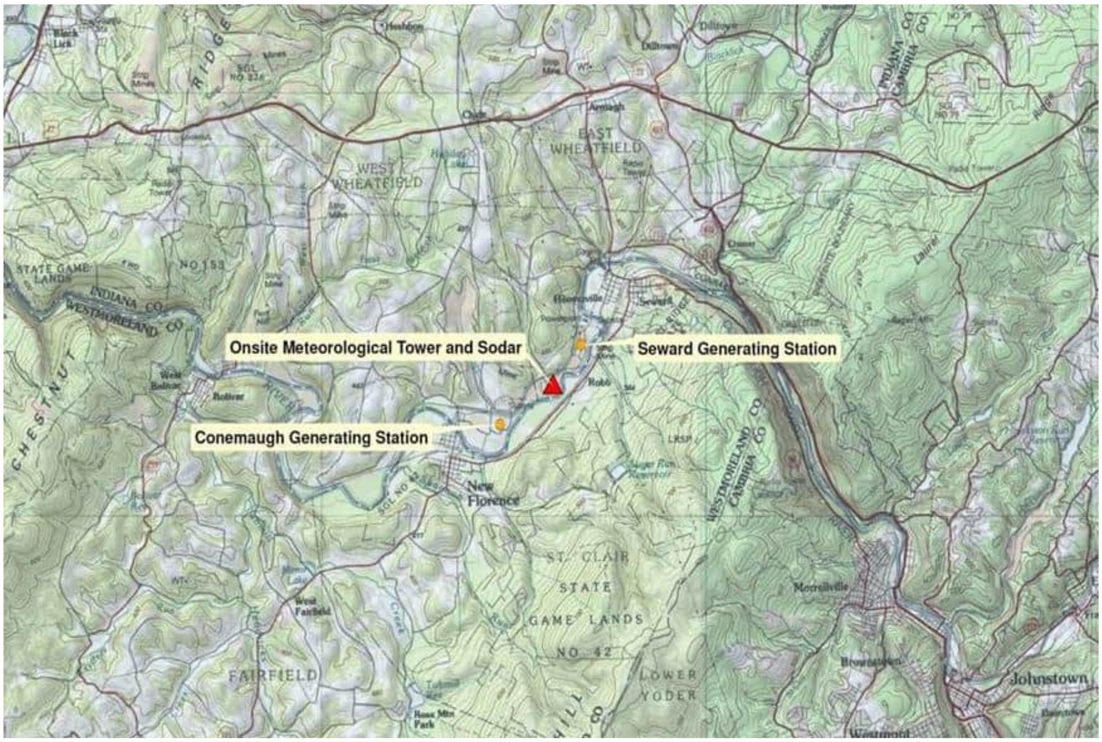
On April 8, 2025, the Pennsylvania Department of Environmental Protection (PA DEP) and EPA Region 3 informed Conemaugh and Seward that a CDD modeling demonstration is an available option to evaluate the 1-hour SO_2 NAAQS attainment status on and in the vicinity of Laurel Ridge (i.e., portions of Cambria-Westmoreland Counties). Conemaugh and Seward elected to proceed with a CDD approach. CDD modeling should involve the use of recent actual SO_2 emissions data and meteorological data from the Ash Site #1 tower and SOnic Detection And Ranging (SODAR).

The Ash Site #1 meteorological station was comprised of a multi-level tower equipped with sensors at 2, 10, 50, 75, and 100 meters (m) along with a SODAR wind profiling system (with measurements starting at 50 m and extending vertically in 50-m increments to 500 m). The location of Ash Site #1 was approximately halfway between the Seward Generating Station and Conemaugh Generating Station, as shown in **Figure 1-4**. Tower and SODAR turbulence measurements (both the standard deviation of the horizontal wind direction (sigma-theta) and the standard deviation of the vertical wind speed (sigma-w)) were collected in addition to the typical wind speed and direction, ambient temperature, and other meteorological measurements (e.g., atmospheric pressure, precipitation, etc.).

In an attempt to address concerns about potential model overprediction bias for impacts along the higher terrain of the ridge based on the discussion outlined in Section 1.1, the Stations proposed to evaluate the model’s performance and identify appropriate refinements based on a historical field study that involved the same primary SO_2 sources (Conemaugh and Seward) and SO_2 monitors located along the ridge within the CDD modeling area. The intention is to apply the refinements from the model performance evaluation that identify a better performing alternative model for this site-specific application and use it for the CDD modeling demonstration.

[7] 57 FR 13498, 13564 (April 16, 1992).
[8] Guidance for 1-hour SO_2 Nonattainment Area SIP Submissions. April 23, 2014. Available at: https://www.epa.gov/sites/default/files/2016-06/documents/20140423guidance_nonattainment_sip.pdf

Figure 1-4: Location of Ash Site #1 Meteorological Tower and SODAR



1.3 Purpose

The purpose of this modeling report is to address requirements in Appendix W (40 CFR, Part 51, available at 82 FR 5182 (Federal Register, November 29, 2024), Section 3.2.2 (b)) [9]. This section of Appendix W states that an alternative model shall be evaluated from both a theoretical and a performance perspective before it is selected for use. Any one of the following three (3) separate conditions may justify use of an alternative model:

1. If a demonstration can be made that the model produces concentration estimates equivalent to estimates obtained using a preferred model;
2. If 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 a given application than a comparable model in Addendum A; or
3. If there is no preferred model.

A statistical performance evaluation (option 2) has been selected to justify the use of an alternative model for the modeling of portions of Cambria and Westmoreland Counties with SO_2 emissions from Seward and Conemaugh. The statistical performance evaluated was conducted using measured air quality data and is consistent with the approach described in the EPA-approved October 28, 2025 modeling protocol to conduct a site-specific model evaluation to support the use of an alternative model. The approach involved using a historical field study that was located in the same area of Laurel Ridge that involves the same key SO_2 emission sources and similar meteorological profiles. The previous study has the three key elements necessary to perform the statistical analysis; (1) concurrent hourly source emissions, (2) representative hourly meteorological data, and (3) hourly monitoring data. A description of the historical field study is discussed in the following section. The 2015-2021 Ash Site #1 data collection period lacks concurrently hourly SO_2 monitoring data.

[9] Guideline on Air Quality Models (Appendix W of 40 CFR Part 51). November 29, 2024. Available at: https://www.epa.gov/system/files/documents/2024-11/appendix_w-2024.pdf

2. Theoretical Technical Justification for Increasing the Minimum Sigma-v in AERMOD for this Site-Specific Application

During low wind speed (LWS) conditions, in both complex and simple terrain situations, the dispersion of pollutants is limited by diminished fresh air dilution. Anfossi et al. (2005)[10] noted that in LWS conditions, dispersion is characterized by meandering horizontal wind oscillations. Sagendorf and Dickson (1974)[11] and Wilson et al. (1976)[12] found that under LWS conditions, horizontal diffusion was enhanced because of the meander, and the resulting ground-level concentrations could be much lower than predicted by steady-state Gaussian plume models that did not account for the meander effect. It's worth pointing out that in the evaluation conducted by Anfossi et al., measured turbulence was used as input to the modeling, but for Sagendorf, Dickson, and Wilson et al., turbulence was not used to calculate sigma-v or effective wind speed. Therefore, irrespective of measured turbulence, model performance was improved by adjusting the meander effect for these studies involving complex terrain areas.

Anfossi et al. conducted an analysis of sonic anemometer data in low wind speed conditions, which they discuss as being wind speeds under 2 m/s (and especially under 0.5 m/s in stable conditions and 1.2 m/s in unstable conditions). These data, with instruments having near-zero starting wind speed thresholds, were taken in two locations: one site featured complex terrain near Graz, Austria; and the other site in simple terrain was near Tisby, Sweden. In general, these researchers consider that slow mesoscale motions (i.e., wind fluctuations with periods of 20-30 minutes) exist under all these meteorological conditions, but, as the small-scale turbulence decreases with low wind speeds, these slow mesoscale motions become the most important factor for the total variance observed in such conditions. Anfossi et al. further note that when the wind speed decreases below a certain threshold value (about 1.5 m/s), it is no longer possible to define a precise mean wind direction, and the wind direction oscillates with periods of the order of half-an-hour or more. This oscillation (meandering) seems to depend neither on topography (since it occurs also in flat terrain) nor on diurnal cycle or season. The slow mesoscale motions seem to set a lower limit for the horizontal wind component variance (the square of the standard deviation) as was also found by Hanna (1990), and not accounting for this effect can result in substantial under-predictions of plume spreading horizontally.

Other researchers have found that the amount of wind (and plume) meander in low-wind speed conditions is a function of the averaging time. For example, Finn et al. (2017)[13], Sun et al. (2012)[14], and Mortarini et al. (2016a)[15] found in recent tracer experiments in the very stable boundary layer with low wind speeds that crosswind turbulence motions could be small for time scales on the order of 10 minutes or less, comparable to classical results such as Project Prairie Grass. However, wind direction and plume behavior is also observed by these investigators to abruptly shift within a typical time frame of about 30 minutes by several tens of degrees, and then remain steady for another several minutes before shifting direction again. AERMOD attempts to model this situation by weighing the plume dispersion between a random state and a Gaussian distribution. However, the rapid, episodic wind direction shifts in plume direction that are now better documented and acknowledged warrant additional model treatment to avoid simulating plume meander that is too small.

As previously introduced in Section 1.1, plume meander can also be greatly affected by vertical shear, terrain induced eddies, and flow perpendicular to significant terrain features. A parameter that is used in the computation of the horizontal plume spreading in AERMOD (which accounts for meandering in low wind conditions) is the above-mentioned standard deviation of the crosswind component, sigma-v (σ_v), which can be parameterized as being

[10] Anfossi, D., D. Oettl, G. Degrazia, A. Goulart. 2005. An analysis of sonic anemometer observations in low wind speed conditions. *Boundary Layer Meteorology* 114, 179–203.

[11] Sagendorf, J. F. and Dickson, C. R. 1974. Diffusion under Low Windspeed, Inversion Conditions. NOAA Technical Memorandum 52, 89 pp. http://www.arl.noaa.gov/documents/reports/ARL-52.pdf.

[12] Wilson, R. B., Start, G. E., Dickson, C. R., and Ricks, N. R. 1976. Diffusion under low wind speed conditions near Oak Ridge, Tennessee, NOAA Technical Memorandum ERL ARL-61, 83 pp. http://www.arl.noaa.gov/documents/reports/ARL-61.pdf.

[13] Finn, D., K.L. Clawson, R.M. Eckman, R.G. Carter, J.D. Rich, B.R. Reese, S.A. Beard, M. Brewer, D. Davis, D. Clinger, Z. Gao, and H. Liu, 2017. Project Sagebrush Phase 2. NOAA 380 Tech. Memo OAR ARL-275, Air Resources Laboratory, Idaho Falls, ID. 392 pp, 381 https://doi.org/10.7289/V5/TM-OAR-ARL-275.

[14] Sun J., L. Mahrt, R. Banta, and Y.L. Pichugina, 2012. Turbulence regimes and turbulence intermittency in the stable boundary layer during CASES-99. *J. Atmos. Sci*. 69, 338-351. https://doi.org/10.1175/JAS-D-11-082.1.

[15] Mortarini L., M. Stefanello, G. Degrazia, D. Roberti, S. Trini Castelli, and D. Anfossi, 2016. Characterization of wind meandering in low-wind-speed conditions. *Bound.-Layer Meteorol*. 161, 165-182. https://doi.org/10.1007/s10546-016-0165-6.

proportional to the friction velocity, u* (Smedman, 1988; Mahrt, 1998)[16,17]. These investigators found that there was a minimum, non-zero value of σ_v that can be attributed to wind meandering over the course of a given hour. Hanna (1983)[18] found that the hourly-averaged σ_v has a non-zero minimum value of about 0.5 m/s as the wind speed approaches zero. Chowdhury et al. (2016)[19] noted, based upon research conducted by Hanna (1983) and Etling (1990)[20] that a minimum σ_v of 0.5 m/s is justified as a part of the formulation for the advanced puff model SCICHEM.

Introduced in AERMOD version 12345, LOWWIND1 and LOWWIND2 non-default options were introduced to address concerns regarding model performance under low wind speed conditions. LOWWIND1 and LOWWIND2 increased the minimum sigma-v value from 0.2 m/s (default) to 0.5 m/s and 0.3 m/s, respectively. Both were hardcoded values that the user could not modify. LOWWIND3 was later introduced in AERMOD version 15151 that also increased the minimum sigma-v to 0.3 m/s but included the use of the non-default FASTALL approach. In AERMOD 18181, a new LOW_WIND keyword option replaced the former LOWWIND1, LOWWIND2, and LOWWIND3 options. The LOW_WIND option, which is a non-default alpha option in AERMOD 24142, allows the user to specify values for minimum sigma-v, minimum horizontal wind speed, and maximum meander fraction.

As proposed in the October 28, 2025 modeling protocol, the non-regulatory LOW_WIND option was selected for this application (when modeling with the on-site meteorological data for high terrain areas on portions of Laurel Ridge) that specifies a minimum sigma-v of 0.5 m/s, based on Hanna (1990), with support from a site-specific field study, which is fulfilled here by the 1990-1991 study on Laurel Ridge. Besides the technical issues about meander in stable conditions discussed above, the LOW_WIND option has the effect of introducing more meander into the plume centerline concentration that results from complex terrain and wind shear effects that are characteristics of the perpendicular flow across the Conemaugh River Valley and into Laurel Ridge.

2.1 Prior Demonstration Using LOW_WIND AERMOD Option

A similar approach to using AERMOD with the LOW_WIND adjustment of the minimum sigma-v value for a rural modeling application was proposed in 2014 for an industrial facility in Tennessee (Eastman Chemical Company). A site-specific model performance evaluation study was conducted to model 1-hour SO_2 emissions from this facility. The evaluation used hourly data from a 100-meter tall tower and SODAR and the key SO_2 monitor was located in complex terrain that was oriented at an angle to the flow. After reviewing the modeling, EPA stated the following in their June 1, 2015 Approval of Alternative Model Request letter to Eastman Chemical:

> *"Based upon the site-specific model performance information provided by Eastman, it appears that use of the LOWWIND2 beta option with a single minimum sigma-v value of 0.4 m/s significantly improves model performance for the Ross N. Robinson, Meadowview, Skyland Drive, and B-267 monitors when compared to the regulatory default version. We are approving a minimum sigma-v value of 0.4 m/s (versus the current default value of 0.3 m/s associated with the beta LOWWIND3 option) for Eastman specific case due to the complex environment with very low wind speeds and nearby complex terrain. These influences are likely to result in significant vertical wind shear that could contribute to increased lateral plume dispersion."*

While this case in Tennessee ultimately pivoted from using the LOW_WIND alternative modeling approach to a reclassification of the environment from rural to urban[21], it still demonstrates EPA's willingness to accept a higher increased minimum sigma-v value in certain complex terrain areas where the lateral dispersion parameter in AERMOD is likely underestimated under low wind conditions. A copy of the approval letter from EPA is included in **Attachment B**.

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[16] Smedman, A. S. 1988. Observations of a Multi-Level Turbulence Structure in a Very Stable Atmospheric Boundary Layer. *Boundary Layer Meteorol. 66, 105–126.*
[17] Mahrt, L. 1998. Stratified Atmospheric Boundary Layers and Breakdown of Models. *Theor. Comput. Fluid Dyn.* 11, 263–279.
[18] Hanna, S. R. 1983. Lateral turbulence intensity and plume meandering during stable conditions, *J. Clim. Appl. Met.,* 22, 1424-1431.
[19] Chowdhury, B., R. I. Sykes, D. Henn, P. Karamchandani. 2016. SCICHEM Version 3.0 Technical Documentation. Available at https://sourceforge.net/projects/epri-dispersion/files/SCICHEM/SCICHEM-3.0_TechnicalDoc.pdf/download.
[20] Etling, D. 1990. On plume meandering under stable stratification, *Atm. Env.,* 24A, 1979-1985.
[21] In subsequent action for the Tennessee modeling application, EPA later considered an urban dispersion modeling approach which used the default AERMOD model. However, for the rural modeling approach, the larger minimum sigma-v clearly led to improved model performance.

3. Alternative Modeling Approach

The approach used to conduct dispersion modeling within the Cambria-Westmoreland area, as shown in **Figure 1-1**, involves the use of a site-specific alternative model. This site-specific alternative model uses the non-regulatory, LOW_WIND alpha option in AERMOD that enables the user to increase the minimum sigma-v from the default of 0.2 m/s. The revised value was based upon the 0.5 m/s from the 1990 Hanna paper and the outcome of a model performance evaluation using a field database that was conducted for the Laurel Ridge area.

The field dataset to be used is discussed in more detail below. It was conducted in the early 1990s and consisted of several SO_2 monitors, on-site meteorological tower, and the same key SO_2 sources that existed during the study are still in existence (i.e., Seward and Conemaugh). To demonstrate the applicability of the LOW_WIND option (increasing the minimum sigma-v value) to address the default model's bias, AERMOD with default regulatory options and the LOW_WIND option (minimum sigma-v of 0.5 m/s) will be run using the 1990 Laurel Ridge field study data.

Following the model performance evaluation between the regulatory model and the proposed alternative model (minimum sigma-v of 0.5 m/s) using the Laurel Ridge database, a second set of model runs was conducted. This second set of model runs used the same Laurel Ridge input data, except for the meteorological dataset. Instead, these model runs utilized the Ash Site #1 meteorological dataset (September 2015 through August 2016) that will be used for the CDD modeling. The purpose of this round of analyses was to demonstrate that the alternative model will still result in improved performance compared to the regulatory model with the CDD meteorological dataset that includes both measured sigma-theta and sigma-w parameters. The 2015-2016 meteorological data has a similar wind pattern at the 150-m level relative to the 1990-1991 data (see **Figure 1-3**), and since the evaluation considers comparisons of observed and modeled concentrations that are unpaired in time, the second meteorological database is a reasonable supplemental check on the superior model performance of the alternative model.

4. Field Study Description

In the early 1990s, a field study was conducted by TRC to determine suitable modeling approaches, especially in elevated terrain, for several coal-fired electric generating stations located in Indiana and Armstrong Counties, Pennsylvania (funded by Penelec, the former owner and operator of the four stations that were the focus of the 1990-era modeling study). Ten (10) ambient air SO_2 monitors were deployed in 1990 in the vicinity of the Keystone, Homer City, Seward, and Conemaugh stations, with several of the monitors located in areas on Laurel Ridge, as shown in **Figure 4-1**. The purpose of this study was to evaluate alternative modeling approaches for estimating air quality impacts from the stations in areas that included elevated terrain on Laurel Ridge and Chestnut Ridge. At the time the study was conducted, the 1-hour SO_2 NAAQS had not yet been established (it was promulgated in 2010). As a result, the analysis conducted by TRC focused on 3-hour, 24-hour, and annual average time periods. However, hourly averaged emissions data (collected by state-of-the-art Continuous Emissions Monitoring Systems (CEMS) at the time) and hourly averaged monitored concentrations were collected. Consequently, the ability to conduct 1-hour averaged modeling is readily available.

The one-year field study database includes the following elements:

- One year (August 1, 1990 to July 31, 1991) of hourly measurements of SO_2 concentrations from ten (10) monitors with four (4) sited along high terrain of Laurel Ridge (Baldwin Creek, Powdermill Run, Sugar Run, and Terrys Run);
- One year of tall-tower meteorological data from the 150-m Ash Valley meteorological tower (location is shown in **Figure 4-1**); and
- One year of hourly SO_2 emissions and stack exhaust data from the stations involved in the study.

Additional details on the study can be obtained from the 1993 and 2003 TRC reports that are provided as **Attachment C** and **Attachment D**, respectively, to this modeling report.

Of the 10 monitors shown in **Figure 4-1**, there are four monitors to the west and south that are not relevant for this area of Laurel Ridge (Luciusboro, Marshall Heights, Penn View, and Bear Cave). For Laurel Ridge itself (see the local area in **Figure 4-2**), the Rager Mountain monitor should not be included in the evaluation because it was situated well to the northeast of the stations and is located in an area beyond the current modeled impact area of concern. The Little Mill Creek monitor was located in the Johnstown, PA airshed southeast of the ridge centerline, and it is the closest monitor to the city. During the 1990-1991 period, this airshed experienced substantial undocumented SO_2 emissions from a sprawling Bethlehem Steel mill, coke oven works, wire manufacturing, and other associated industries (see the photo in **Figure 4-3** as an example of the industrial activity); the steel operations closed in 1992). EPA was involved in litigation at the time with Bethlehem Steel due to air quality violations,[22] including excess sulfur emissions. Due to the local impacts of those sources on any monitor on the southeast side of Laurel Ridge, the Little Mill Creek monitor was not included in this model evaluation exercise because impacts at that monitor more than any other were likely influenced by undocumented large SO_2 sources in Johnstown. Therefore, monitors on Laurel Ridge that were selected for this model evaluation study as they would be impacted by Conemaugh and Seward stations rather than steel mills in Johnstown included the following four (4) sites: Powdermill Run, Baldwin Creek, Sugar Run, and Terrys Run.

The primary SO_2 emission sources were the coal-fired boilers at the Keystone, Homer City, Seward, and Conemaugh stations which were not equipped with SO_2 flue gas desulphurization (FGD) systems at the time of the field study. The ambient air monitors were sited to detect peak impacts from the stations; extensive planning efforts were expended into the siting of the network of monitors. The monitors situated along Laurel Ridge were designed to capture impacts primarily from Conemaugh and Seward, given their closer proximity, as Homer City and Keystone were located more

[22] http://www.latimes.com/archives/la-xpm-1992-03-10-fi-3693-story.html#share=email~story. ("Bethlehem Steel Agrees to Fine on Pollution")

than 20 km and 40 km away from the ridge, respectively. A modeling and monitoring protocol was prepared by TRC and approved by PA DEP and EPA and are included in **Attachments C** and **D**, respectively[23,24].

In 1993, EPA formally requested this database from Penelec to use in its evaluation of a new model at that time, AERMOD. EPA said that they have

> "*…reviewed many data bases that have been collected throughout this county. We believe that the Indiana County SO_2 data base could provide an excellent test of the new model's capability to accurately predict multi-source impacts in complex terrain."*[25]

A copy of this 1993 database request from EPA is included in **Attachment E**. It turns out that this database, although sent to EPA, was not used by EPA in its AERMOD evaluations during the development of the AERMOD model. However, it was clear to EPA that it is a useful evaluation database, and is well suited to evaluate the performance of AERMOD.

4.1 Local Terrain Affecting Field Study

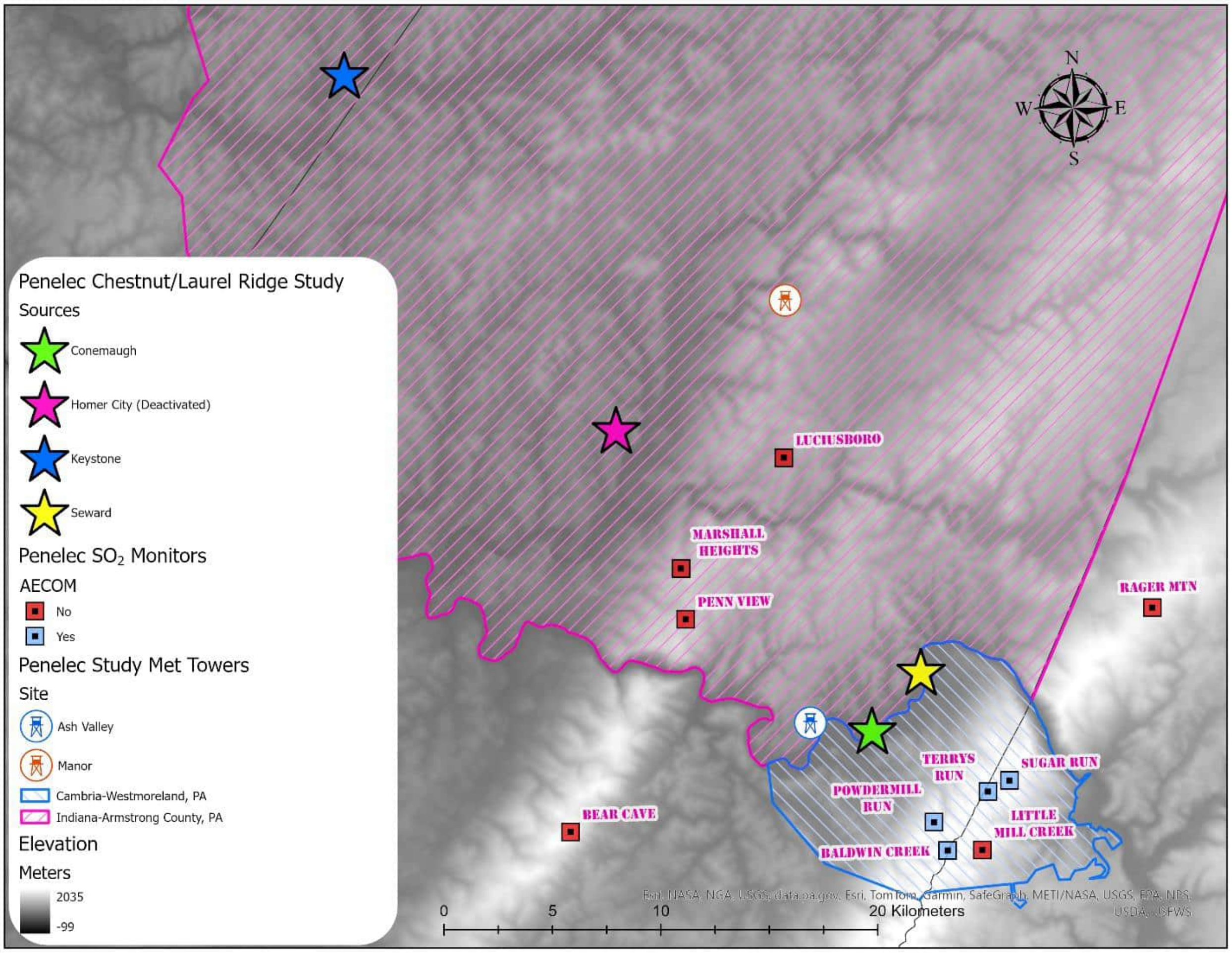
As previously discussed in Section 1.1, the location of the key SO_2 sources from the stacks at Conemaugh and Seward situated in the Conemaugh River Valley and the high, perpendicular (to the flow) terrain of Laurel Ridge to the east establishes a very unique dispersion environment. **Figure 4-4** illustrates the 1990 field study on a terrain map with a cross section extending west of Chestnut Ridge, passing through the Ash Valley meteorological tower collection site, across Laurel Ridge, and extending to the Johnstown SO_2 monitoring site. **Figure 4-5** shows the elevation profile path of the cross section and clearly shows the heights of the Conemaugh and Seward stacks are well below Laurel Ridge. This figure also provides a good illustration of the meteorological site relative to the localized terrain.

[23] TRC, 1993. Revised Final Report on the Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge. TRC. January 13, 1993.

[24] TRC, 2003. Final Report. AERMOD Modeling Analyses for SO2 NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania. TRC. March, 2003.

[25] US EPA, 1993. EPA letter to Mr. Vincent Brisini of PENELEC. US EPA Region III. June 3, 1993 (provided as Attachment E to this document).

Figure 4-1: Location of SO_2 Monitors, Meteorological Tower, and Sources for Historical Field Study



Note: Conemaugh, Seward and Keystone generating stations continue to operate today. Homer City decommissioned its units on July 1, 2023.

Figure 4-2: Focus of Field Study Near Laurel Ridge

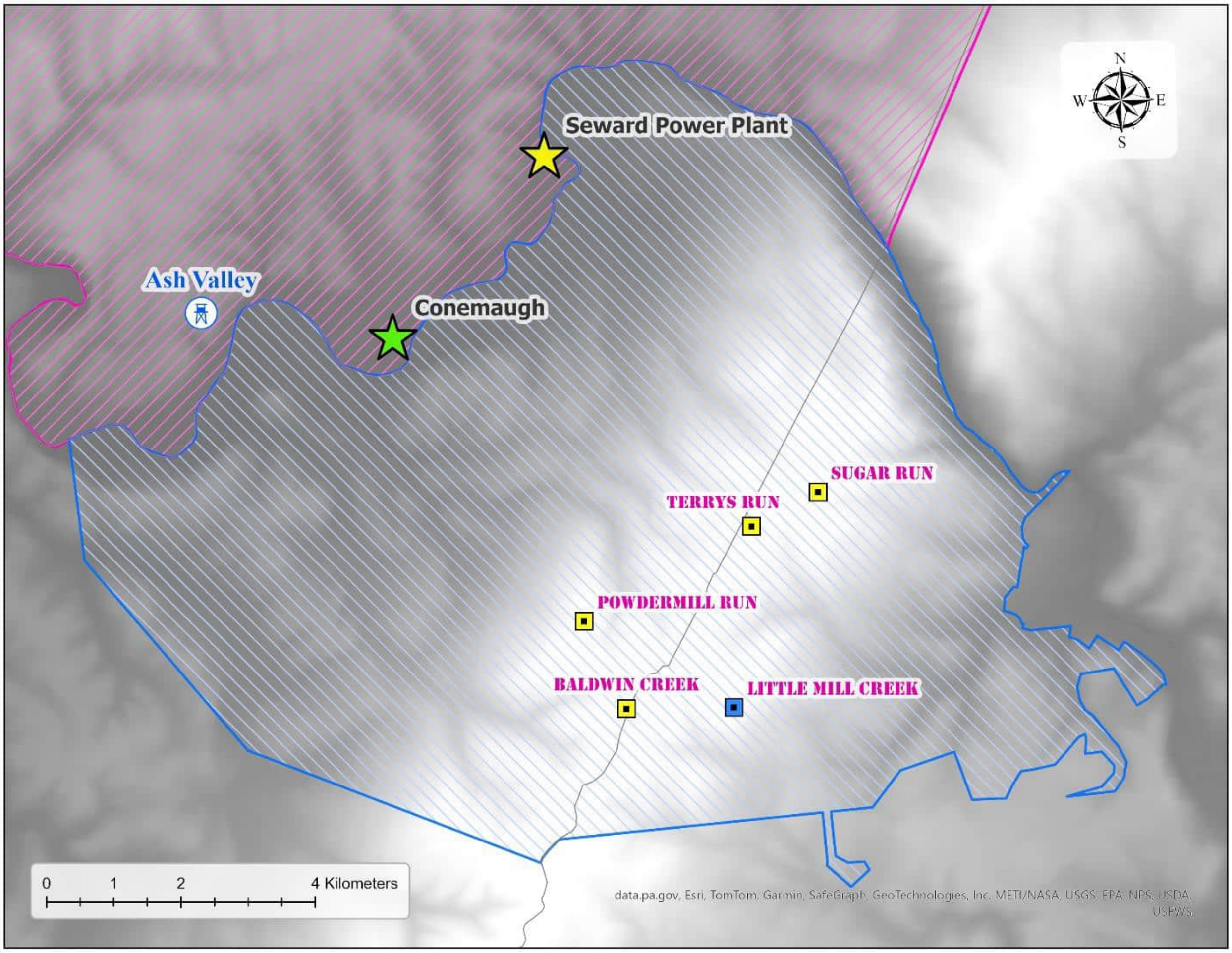


Figure 4-3: Johnstown, PA Industrial Activity during Period with Bethlehem Steel Production

Source: https://www.indarch.mtu.edu/view.php?viewtype=item&id=1332.

Figure 4-4: Map of Laurel Ridge Study and Elevation Cross-Section Path

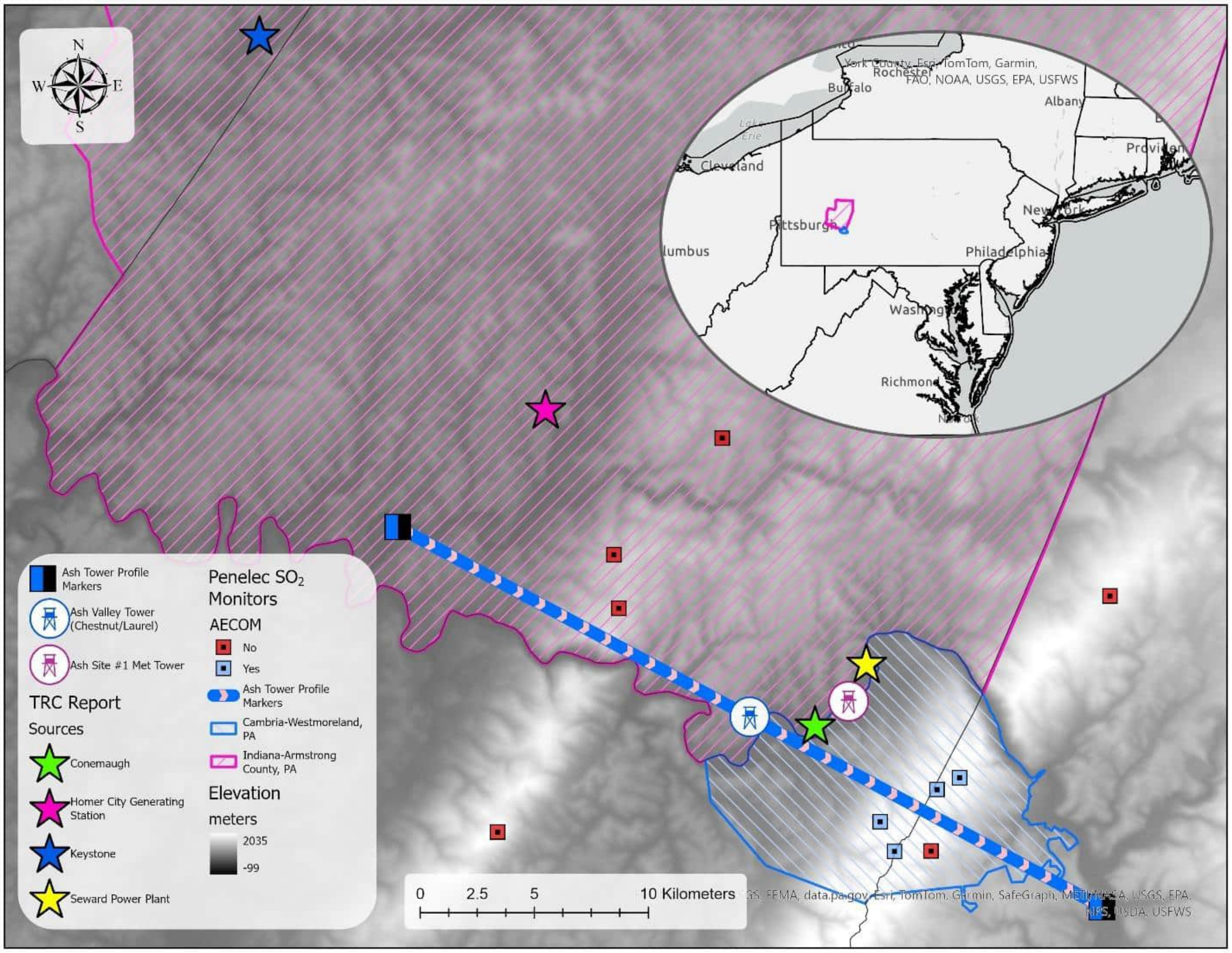
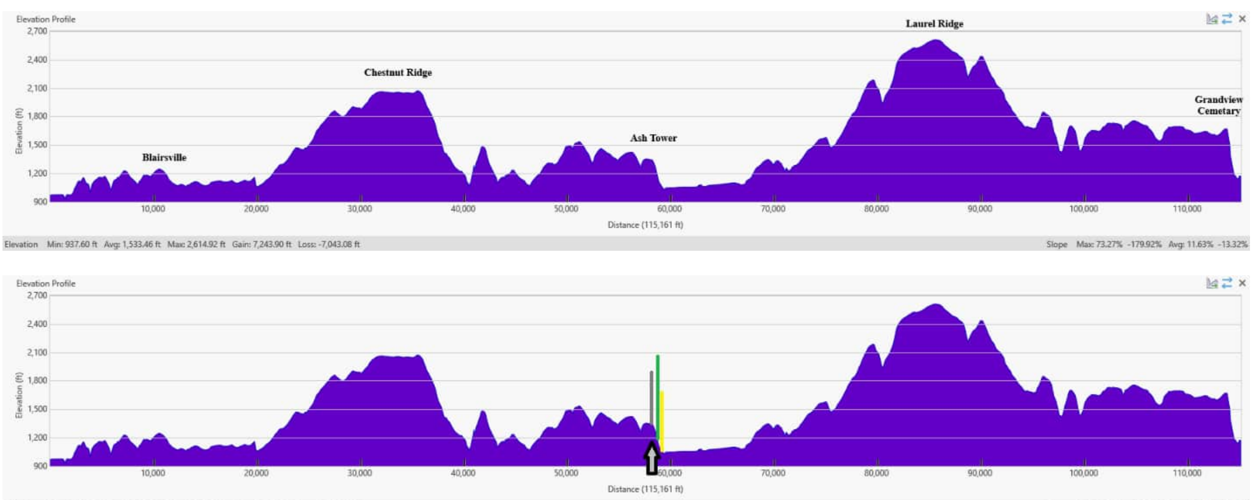


Figure 4-5: Cross-Section Profile Path



5. Modeling Procedures Using Historical 1990 Laurel Ridge Study

5.1 Dispersion Model Selection

The 1990 Laurel Ridge modeling analysis utilized the AERMOD dispersion model[26] (Version 24142), released December 2024, and the current version at the time the analysis was conducted. The AERMOD modeling system consists of two preprocessors and the dispersion model. AERMET is the meteorological pre-processor component and AERMAP is the terrain pre-processor component that characterizes the terrain and generates receptor elevations along with critical hill heights for those receptors.

Two separate model runs, each with the following options applied were conducted:

1) AERMOD default option (regulatory model)
2) AERMOD alpha option with LOW_WIND, minimum sigma-v = 0.5 m/s (alternative model)

Both model runs utilized the same model inputs (i.e., meteorology, emissions, etc.) as described below.

5.2 Land Use Classification

One of the factors affecting input parameters to dispersion models is the selection of either rural or urban conditions near the source site and the meteorological site(s). The choice of rural or urban for dispersion conditions at the source site depends upon the land use characteristics within 3 kilometers of the facility being modeled (Appendix W to 40 CFR Part 51)[27]. Factors that affect the rural/urban choice, and thus the dispersion, include the extent of vegetated surface area, the water surface area, types of industry and commerce, and building types and heights within this area.

According to Section 7.2.1.1 of EPA's Appendix W, either a land use (Auer method) or a population density procedure should be used in determining the selection of urban vs. rural dispersion. For this application, the Auer method was selected.

Using the Auer method recommended by the US EPA (US EPA, 2024a), urban land use types are classified as categories I1, I2, C1, R2, and R3. **Table 5-1** describes these categories and maps them to reasonably equivalent USGS Annual National Land Cover Database (NLCD) categories. While the Auer method and NLCD do not use the same terms to define their categories, the similarities between the five Auer categories and NLCD categories 23 and 24 are apparent. Thus, it is reasonable to classify annual NLCD categories 23 and 24 as urban land use.

The annual NLCD data were processed with US EPA's AERSURFACE processor (version 24142) to determine the different land use types within 3 km of the Stations. AERSURFACE is typically used to process the annual NLCD data for input to AERMET, the AERMOD model's meteorological data processor. In this case, AERSURFACE output in the form of the pixel count for each of the annual NLCD's land use types will be used to determine the total pixel count of urban land use types within 3 km.

As noted above, urban land use types were assumed to be NLCD categories 23 and 24: "Developed, Medium Intensity" and "Developed, High Intensity", respectively. The pixel count for these categories was less than 4% for Conemaugh and less than 2% for Seward of the total pixel count for all categories. Thus, the overwhelming majority (>95%) of the 3 km area around the Stations can be classified as rural land use and AERMOD was not applied with any urban source options. **Table 5-2** and **Table 5-3** provide the pixel counts as reported in the AERSURFACE output along with respective percentages for the annual NLCD years during the study period (1990 and 1991) for Conemaugh and Seward stations, respectively.

[26] See the AERMOD system documentation at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod.
[27] EPA's Guideline on Air Quality Models, available at https://www.epa.gov/system/files/documents/2024-11/appendix_w-2024.pdf.

Table 5-1: Comparison of Auer and NLCD Land Use Categories

Auer Urban Land Use Categories[1]			USGS Annual NLCD Categories[2]	
Type	**Use and Structure**	**Vegetation**	**Category**	**Description**
R2	Dense single/multi-family	< 30%	23	Developed, Medium Intensity – Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
R3	Multi-family, two story	< 35%	24	Developed, High Intensity – Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
I1	Heavy Industrial	< 5%		
I2	Light/moderate industrial	< 5%		
C1	Commercial	< 15%		

Notes:
(1) EPA's Guideline on Air Quality Models, available at https://www.epa.gov/system/files/documents/2024-11/appendix_w-2024.pdf
(2) *Multi-Resolution Land Characteristics Consortium (MRLC).*
https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description

Table 5-2: Land Cover Within 3 km of Conemaugh Station AERSURFACE Log File

		NLCD 1990		NLCD 1991	
USGS Annual NLCD Category	Description	Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%
11	Open Water	582	1.85%	557	1.77%
12	Perennial Ice/Snow	0	0.00%	0	0.00%
21	Developed, Open Space	1990	6.34%	1980	6.30%
22	Developed, Low Intensity	1545	4.92%	1548	4.93%
23	**Developed, Medium Intensity**	**670**	**2.13%**	**685**	**2.18%**
24	**Developed, High Intensity**	**236**	**0.75%**	**236**	**0.75%**
31	Barren Land (Rock/Sand/Clay)	1041	3.31%	1037	3.30%
32	Unconsolidated Shore	0	0.00%	0	0.00%
41	Deciduous Forest	22981	73.16%	22989	73.19%
42	Evergreen Forest	4	0.01%	4	0.01%
43	Mixed Forest	876	2.79%	876	2.79%
51	Dwarf Scrub	0	0.00%	0	0.00%
52	Shrub/Scrub	1	0.00%	0	0.00%
71	Grasslands/Herbaceous	99	0.32%	111	0.35%
72	Sedge/Herbaceous	0	0.00%	0	0.00%
73	Lichens	0	0.00%	0	0.00%
74	Moss	0	0.00%	0	0.00%
81	Pasture/Hay	1091	3.47%	1093	3.48%
82	Cultivated Crops	0	0.00%	0	0.00%
90	Woody Wetlands	290	0.92%	291	0.93%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%
95	Emergent Herbaceous Wetland	4	0.01%	3	0.01%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%
	Total	**31410**	**100%**	**31410**	**100%**

Urban land use types are shown in red, bold text.

Table 5-3: Land Cover Within 3 km of Seward Station AERSURFACE Log File

		NLCD 1990		NLCD 1991	
USGS Annual NLCD Category	**Description**	**Pixel counts**	**Percent of Total Pixels**	**Pixel counts**	**Percent of Total Pixels**
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%
11	Open Water	666	2.12%	660	2.10%
12	Perennial Ice/Snow	0	0.00%	0	0.00%
21	Developed, Open Space	2409	7.67%	2406	7.66%
22	Developed, Low Intensity	1537	4.89%	1540	4.90%
23	**Developed, Medium Intensity**	**379**	**1.21%**	**375**	**1.19%**
24	**Developed, High Intensity**	**29**	**0.09%**	**29**	**0.09%**
31	Barren Land (Rock/Sand/Clay)	812	2.58%	806	2.57%
32	Unconsolidated Shore	0	0.00%	0	0.00%
41	Deciduous Forest	23601	75.13%	23605	75.15%
42	Evergreen Forest	4	0.01%	4	0.01%
43	Mixed Forest	337	1.07%	337	1.07%
51	Dwarf Scrub	0	0.00%	0	0.00%
52	Shrub/Scrub	8	0.03%	5	0.02%
71	Grasslands/Herbaceous	127	0.40%	131	0.42%
72	Sedge/Herbaceous	0	0.00%	0	0.00%
73	Lichens	0	0.00%	0	0.00%
74	Moss	0	0.00%	0	0.00%
81	Pasture/Hay	1278	4.07%	1288	4.10%
82	Cultivated Crops	0	0.00%	0	0.00%
90	Woody Wetlands	220	0.70%	222	0.71%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%
95	Emergent Herbaceous Wetland	5	0.02%	4	0.01%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%
	Total	**31412**	**100%**	**31412**	**100%**

Urban land use types are shown in red, bold text.

5.3 Meteorological Data Processing of 1990 Ash Valley Tower

The meteorological data required for input to AERMOD for the model evaluation was processed with the latest version of AERMET (version 24142) using default options in a single control file (i.e., Stages 1 and 2 processed in the same file). One year (August 1, 1990 to July 31, 1991) of meteorological observations from the 150-m Ash Valley tower meteorological tower along with one year of concurrent upper air data from Pittsburgh International Airport, PA (for cloud cover and pressure) was used as input to AERMET. Quarterly data capture from the Ash Valley dataset is above 96% for each quarter as shown in **Table 5-4**. **Figure 5-1** shows the meteorological tower location and measured parameters and the 150-meter wind rose is shown in **Figure 5-2**. AECOM used the TRC-generated meteorological database as input to AERMET for the on-site meteorological data component. Site-specific turbulence data (standard deviation of the horizontal wind direction (sigma-theta) was collected and therefore was included in the AERMET processing. Sigma-theta was available from the tower at the 10-meter level. As such, the ADJ_U* option was not used in conjunction with the on-site turbulence data, as recommended by EPA in Section IV (A)(2) of Appendix W.

AERMET creates two output files for input to AERMOD:

- SURFACE: a file with boundary layer parameters such as sensible heat flux, surface friction velocity, convective velocity scale, vertical potential temperature gradient in the 500-meter layer above the planetary boundary layer, and convective and mechanical mixing heights. Also provided are values of Monin-Obukhov length, surface roughness, albedo, Bowen ratio, wind speed, wind direction, temperature, and heights at which measurements were taken.
- PROFILE: a file containing multi-level meteorological data with wind speed, wind direction, temperature, sigma-theta (σ_θ) and sigma-w (σ_w) when such data are available. In this application, turbulence data (sigma-theta) was included as input.

For all meteorological data parameters included in the modeling, the hourly-averaged values from the dataset were used as input to AERMET. For modeling purposes, no replacements of calms were attempted; the meteorological tower instrumentation had a starting threshold level of 0.5 m/s and this information was provided as input to AERMET.

Table 5-4: Quarterly Meteorological Data Capture

Quarter	Month, Year	% Data Capture[1]
1	January – March, 1991	99.54%
2	April – June, 1991	96.15%
3	July 1991, August – September, 1990	98.69%
4	October – December, 1990	99.18%

[1] Data capture from AERMOD output.

Figure 5-1: Ash Valley Tower Parameters

Location Description	MSL (ft.)	Above Grade (ft.)	Parameters* Monitored
(a) Ash Valley 150 Meter Tower			
Tower UTM – N = 4472558.36			
– E = 661721.53			
Tower Base Plate	1401	–	–
Lower Sensor Level	1434	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1565	164 (50 m)	WD, WS
Upper Sensor Level	1695	292 (89 m)	WD, WS
Top Sensor Level	1893	492 (150 m)	WD, WS

* Parameter Identifiers

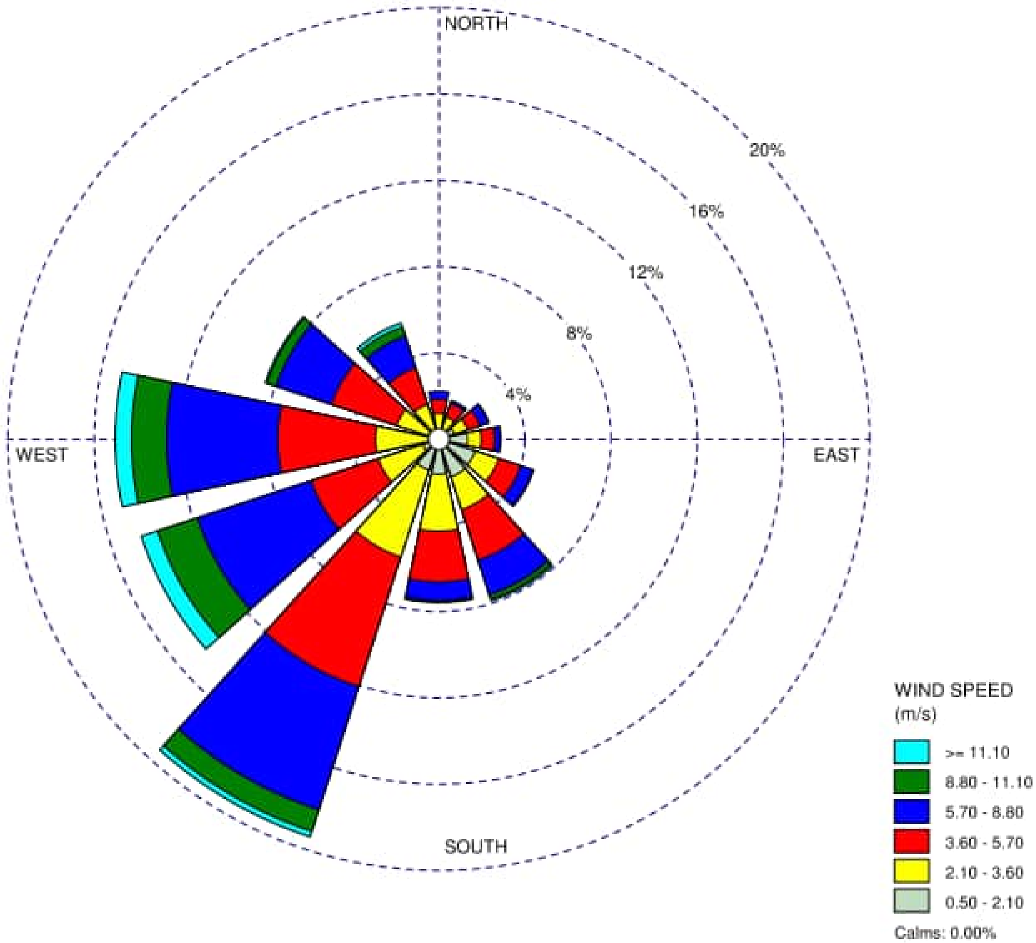
WD = wind direction
WDST = standard deviation of wind direction (sigma theta)
WS = wind speed
AT = ambient temperature

Note that this figure was taken from the 1993 TRC report.

Figure 5-2: Ash Valley Tower Wind Rose at 150 Meters

WIND ROSE PLOT:
Ash Valley Tower Wind Rose at 150 Meters

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 1/1/1990 - 00:00 End Date: 12/31/1990 - 23:00	MODELER:	
	CALM WINDS: 0.00%	TOTAL COUNT: 8101 hrs.	
	AVG. WIND SPEED: 4.97 m/s	DATE: 3/7/2017	PROJECT NO.:

AERMET requires specification of site characteristics including surface roughness (z_o), albedo (r), and Bowen ratio (B_o). These parameters were developed according to the guidance provided by EPA in the November 2024 version of the AERMOD Implementation Guide[28] (AIG). The AIG provides the following recommendations for determining the site characteristics:

1. The determination of the surface roughness length should be based on an inverse distance weighted geometric mean for a default upwind distance of 1 kilometer relative to the measurement site. Surface roughness length may be varied by sector to account for variations in land cover near the measurement site; however, the sector widths should be no smaller than 30 degrees.

2. The determination of the Bowen ratio should be based on a simple un-weighted geometric mean (i.e., no direction or distance dependency) for a representative domain, with a default domain defined by a 10-km by 10-km region centered on the measurement site.

3. The determination of the albedo should be based on a simple un-weighted arithmetic mean (i.e., no direction or distance dependency) for the same representative domain as defined for Bowen ratio, with a default domain defined by a 10-km by 10-km region centered on the measurement site.

The AIG recommends that the surface characteristics should be determined based on digitized land cover data. EPA has developed a tool called AERSURFACE that can be used to determine the site characteristics based on digitized land cover data in accordance with the recommendations from the AIG discussed above. AERSURFACE[29] incorporates look-up tables of representative surface characteristic values by land cover category and seasonal category. AERSURFACE was applied with the instructions provided in the AERSURFACE User's Guide.

Figure 5-3 shows an aerial photo (taken in 1994) of the area within about 1 kilometer of the tower location. AERSURFACE (Version 24142) was used to subjectively estimate surface characteristics (roughness, Bowen ratio, and albedo) around the Ash Valley tower, which are required inputs to AERMET. Digitized land cover data was obtained from the USGS National Land Cover Data archives[30] (NLCD). Since the meteorological data collection spanned across two calendar years (1990 and 1991), both annual-based NLCD files were processed. The NLCD 1990 was used to assign surface characteristics to the months of August through December, while the NLCD 1991 dataset was used for January through July. The NLCD files were downloaded from USGS on July 15, 2025 and were supplemented with the concurrent tree canopy and impervious surface data files.

In accordance with Section 3.1.1 of the AIG, a land cover analysis should be conducted to evaluate the representativeness of the surroundings of the meteorological tower and the sources to be modeled. To demonstrate this, land cover counts from the AERSURFACE log file for a 1-km radius from Conemaugh and Seward were compared to land cover counts for a 1-km radius from the Ash Valley site. Details of this analysis are presented in **Attachment F**. Furthermore, the annual average values of albedo and Bowen ratio were compared between the three (3) sites (Ash Valley, Conemaugh, and Seward). All three (3) sites revealed the same albedo value of 0.16 for both 1990 and 1991 land cover data files. For Bowen ratio, Ash Valley yielded 0.69 for both 1990 and 1991, while Conemaugh and Seward were both 0.70 for both land cover dataset years. Based on this analysis, the surrounding land cover is very similar between the Ash Valley site and the stations. Therefore, the location and ground cover around the meteorological dataset used in this model performance evaluation is representative of the sources modeled.

As recommended in the AIG for surface roughness, the 1-km radius circular area centered at the meteorological station site can be divided into sectors for the analysis. The last roughness parameter for defining sectors is the "roughness flag", which can be used to apply an adjustment factor to the default roughness values for the developed categories (21, 22, 23, 24) and for pasture (81) and cultivated crops (82) categories. For the developed categories, HighZo would be used for sectors that have buildings/structures while for sectors that do not have buildings/structures and/or are predominantly paved surfaces, LowZo was used. Based on visual inspection of the aerial and land cover within 1 km of the Ash Valley meteorological tower, all sectors were assigned LowZo. Five (5) sectors were identified through visual inspection and professional judgement. These sectors are shown on the land cover imagery (**Figure 5-4**).

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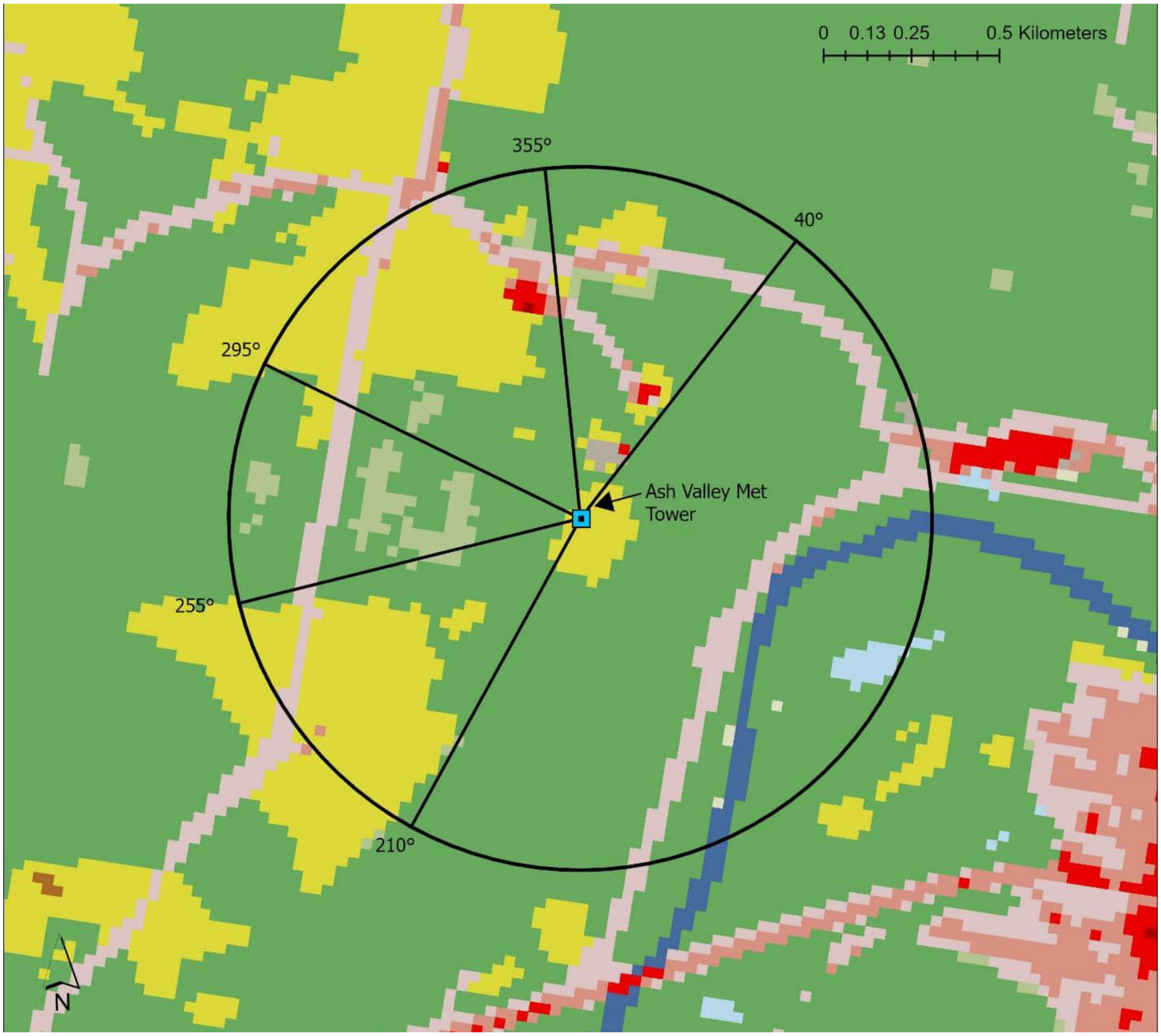
[28] Available at https://www3.epa.gov/ttn/scram/models/aermod/aermod_implementation_guide.pdf.
[29] Documentation available at http://www.epa.gov/ttn/scram/dispersion_related.htm#aersurface.
[30] See additional information at http://landcover.usgs.gov/natllandcover.php.

Figure 5-3: Area Surrounding the Ash Valley Tower in Year 1994

A red circle represents a 1-km radius around the Ash Valley Tower.

Figure 5-4: AERSURFACE Sectors Land Cover Data



In AERSURFACE, the various land cover categories are linked to a set of seasonal surface characteristics. As such, AERSURFACE requires specification of the seasonal category for each month of the year. The following five seasonal categories are supported by AERSURFACE,

1. Midsummer with lush vegetation;
2. Autumn with un-harvested cropland;
3. Late autumn after frost and harvest, or winter with no snow;
4. Winter with continuous snow on ground;
5. Transitional spring with partial green coverage or short annuals;

Consistent with the modeling conducted for the Indiana, PA SIP by EPA in their TSD[31], the following months were assigned to each season for the AERSUFACE processing. These include the following:

- Winter – November, December, January, February, and March;
- Spring – April and May;
- Summer – June, July, and August;
- Autumn – September and October.

For Bowen ratio, the land use values are linked to three categories of surface moisture corresponding to average, wet, and dry conditions. The surface moisture condition for the site may vary depending on the meteorological data period for which the surface characteristics were applied. AERSURFACE applies the surface moisture condition for the entire data period. Therefore, if the surface moisture condition varies significantly across the data period, then AERSURFACE can be applied multiple times to account for those variations.

As such, the surface moisture condition for each month was determined by comparing precipitation for the period of data to be processed to the 30-year climatological record, selecting “wet” conditions if precipitation is in the upper 30^{th}percentile, “dry” conditions if precipitation is in the lower 30^{th} percentile, and “average” conditions if precipitation is in the middle 40^{th} percentile. The 30-year precipitation dataset selected will be from 1960 – 1989 and was obtained from the National Climatic Data Center for Pennsylvania Climate Division 9[32]. The monthly precipitation totals for the modeled period, which is the Pennsylvania Climate Division 9 dataset for 1990 and 1991, was compared to the 30-year climate period. **Table 5-5** summarizes the monthly precipitation totals from Pennsylvania Climate Division 9 from 1960 through 1991. The monthly designations of surface moisture that were input to AERSURFACE are summarized in **Table 5-6**.

The closest available snow cover dataset that was used to determine winter months with snow versus winter months without snow was retrieved from the NCEI Daily Summaries Station Records.[33] **Table 5-7** summarizes the days with at least 1 inch of snow cover on the ground for the Derry 4 SW, PA site. Based on this data, no month was classified with snow cover as no month in the modeled period meets the “at least 50%” threshold criteria.

The default method for determining surface roughness length (ZORAD) was used, as recommended by EPA’s AERSURFACE User’s Guide[34].

[31] EPA’s Docket EPA-R03-OAR-2024-0024, see document EPA-R03-OAR-2024-0024-0014
[32] https://www1.ncdc.noaa.gov/pub/data/cirs/climdiv/
[33] https://www.weather.gov/wrh/climate?wfo=ctp
[34] https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/aersurface/aersurface_ug_v24142.pdf

Table 5-5: PA Climate Division 9 Monthly Precipitation (inches): 1960-1991

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1960	3.02	3.46	2.06	1.59	5.98	3.46	4.37	2.97	3.24	1.67	1.91	1.81	35.5
1961	2.20	3.76	4.31	5.83	3.09	4.69	4.98	3.04	2.06	2.82	3.64	2.54	43.0
1962	2.88	3.66	3.69	3.90	2.62	2.69	3.33	2.49	5.58	2.63	1.93	2.58	38.0
1963	1.73	2.27	5.83	2.40	2.11	3.53	3.42	2.70	1.61	0.38	4.19	1.96	32.1
1964	2.85	2.43	5.13	6.43	1.68	5.27	4.46	3.35	1.89	1.36	3.00	4.23	42.1
1965	4.33	2.64	3.89	2.60	2.39	1.83	2.33	3.42	4.36	3.29	2.60	0.90	34.6
1966	3.98	3.29	2.26	3.94	3.69	1.47	2.74	3.73	2.73	1.86	4.22	2.21	36.1
1967	0.95	2.64	6.39	3.86	5.56	1.34	4.89	3.78	2.88	2.81	2.78	2.72	40.6
1968	2.70	0.75	3.39	2.15	7.15	2.39	1.87	3.82	2.97	2.44	3.60	3.43	36.7
1969	2.46	0.85	1.31	3.74	2.74	3.43	6.55	3.27	1.87	2.34	2.77	4.66	36.0
1970	1.84	2.16	3.45	3.94	3.76	5.24	4.59	4.11	3.20	4.32	3.40	3.88	43.9
1971	3.01	4.17	2.63	1.02	4.29	3.46	4.90	3.95	5.00	1.44	2.90	3.41	40.2
1972	2.77	3.64	3.91	5.31	2.78	9.34	3.24	2.63	4.36	2.65	4.73	4.48	49.8
1973	2.22	2.38	3.34	5.47	4.56	4.16	2.96	3.47	4.32	3.80	3.32	3.38	43.4
1974	4.18	1.75	4.00	3.13	5.53	5.39	4.46	4.30	5.07	1.33	2.78	4.20	46.1
1975	4.12	4.06	4.34	3.00	4.12	4.85	2.33	6.69	6.04	3.30	2.11	3.38	48.3
1976	3.84	2.38	3.06	2.42	2.36	4.70	4.06	3.19	3.88	5.76	0.82	2.08	38.6
1977	1.64	1.30	4.83	4.03	2.52	3.64	6.42	4.12	3.60	2.98	3.02	3.11	41.2
1978	5.57	0.66	2.05	2.81	5.28	5.20	4.64	4.51	2.80	3.71	2.00	4.97	44.2
1979	4.96	3.32	2.09	3.78	4.87	2.24	5.37	5.42	4.85	3.79	3.14	2.11	45.9
1980	1.41	1.38	4.76	3.74	4.36	5.09	6.79	6.06	2.52	2.85	2.69	1.50	43.2
1981	0.94	4.25	2.01	5.61	3.05	6.69	5.39	2.05	4.55	3.43	1.52	2.59	42.1
1982	3.65	2.45	3.64	1.56	3.89	4.59	3.26	3.02	3.01	0.74	4.03	2.56	36.4
1983	1.32	1.53	3.50	5.14	6.07	4.14	3.13	2.86	2.74	3.95	4.13	4.13	42.6
1984	1.42	2.56	3.06	4.51	5.34	3.85	4.55	5.77	1.72	3.20	3.56	3.72	43.3
1985	1.75	1.72	4.84	2.01	5.94	3.06	5.39	3.28	1.02	2.64	11.08	2.24	45.0
1986	2.30	4.21	2.32	2.76	2.62	4.08	6.19	2.84	3.04	4.16	5.13	3.44	43.1
1987	2.66	0.72	2.61	4.96	4.08	4.31	3.07	5.58	4.97	1.72	2.62	2.81	40.1
1988	1.72	3.30	2.89	2.60	4.14	1.43	3.76	3.83	3.38	2.05	3.84	2.07	35.0
1989	2.60	3.67	5.69	2.07	6.49	7.11	3.74	2.14	4.42	3.12	2.43	1.80	45.3
1990	3.28	3.29	1.57	3.13	5.78	3.84	6.48	**3.48**	**5.45**	**4.30**	**2.04**	**7.21**	49.9
1991	**3.24**	**2.23**	**3.57**	**3.51**	**2.43**	**1.85**	**3.66**	2.20	2.54	1.14	3.04	4.26	33.7

Table 5-6: AERSURFACE Bowen Ratio Condition Designations

Year	Month	Bowen Ratio Category	Snow / No Snow
1990	August	Average	No Snow
1990	September	Wet	No Snow
1990	October	Wet	No Snow
1990	November	Dry	No Snow
1990	December	Wet	No Snow
1991	January	Wet	No Snow
1991	February	Average	No Snow
1991	March	Average	No Snow
1991	April	Average	No Snow
1991	May	Dry	No Snow
1991	June	Dry	No Snow
1991	July	Average	No Snow

Table 5-7: Monthly Snow Depth/Snow Cover Summary for Derry 4 SW, PA Station

Year	Month	Days in Month	Days with Snow Cover	Missing Days	Snow Days %
1990	November	30	0	0	0.0%
1990	December	31	3	0	9.7%
1991	January	31	9	2	29.0%
1991	February	28	6	1	21.4%
1991	March	31	5	1	16.1%

Notes: Station elevation is 323.1 meters

5.4 Modeled Receptors

For the model performance evaluation, receptors were located at the four (4) Laurel Ridge SO_2 monitoring sites (Baldwin Creek, Powdermill Run, Terry's Run, and Sugar Run). Consistent with Appendix W, a flagpole height of 0 meters was used. The location of the receptors of the four (4) Laurel Ridge monitors is shown on an aerial map in **Figure 5-5**.

AERMAP (version 24142), the AERMOD terrain preprocessor program, was used to calculate terrain elevations and critical hill heights for the modeled receptors (NAD83 datum and Zone 17 using USGS National Elevation Data (NED). The appropriate file for 1/3-arc-second, or 10-m, NED data was obtained from the Multi-Resolution Land Characteristics Consortium (MRLC) link at http://www.mrlc.gov/viewerjs/.[35] These are the same NED files that will be used for conduct the CDD modeling. Consistent with the AERMAP User's Guide[36], the AERMAP domain was sufficient to ensure that all significant nodes are included such that all terrain features that exceed a 10% elevation slope from any given receptor are considered. The NED files are referenced to Datum NAD83 (note all source locations and receptors were also referenced to NAD83 UTM Zone 17). The NED files are included in the electronic modeling archive that was submitted along with the final modeling report.

Table 5-8 summarizes the coordinates, elevation, and hill heights of each the four (4) receptors.

Table 5-8: Receptor Information of the Four Laurel Ridge Monitors

Monitor	Easting (m)	Northing (m)	Elevation[1] (m)	Hill Height[2] (m)
Baldwin Creek	668050.00	4466680.00	827.26	827.26
Powdermill Run	667420.00	4467980.00	780.70	780.70
Sugar Run[3]	670950.00	4470156.00	805.85	805.85
Terry's Run	669910.00	4469390.00	784.41	791.66

Notes: NAD83 UTM Zone 17; m = meters

[1] Elevations are based on USGS NED files (downloaded 7/17/25) and processed using EPA's AERMAP terrain pre-processor (version 24142).

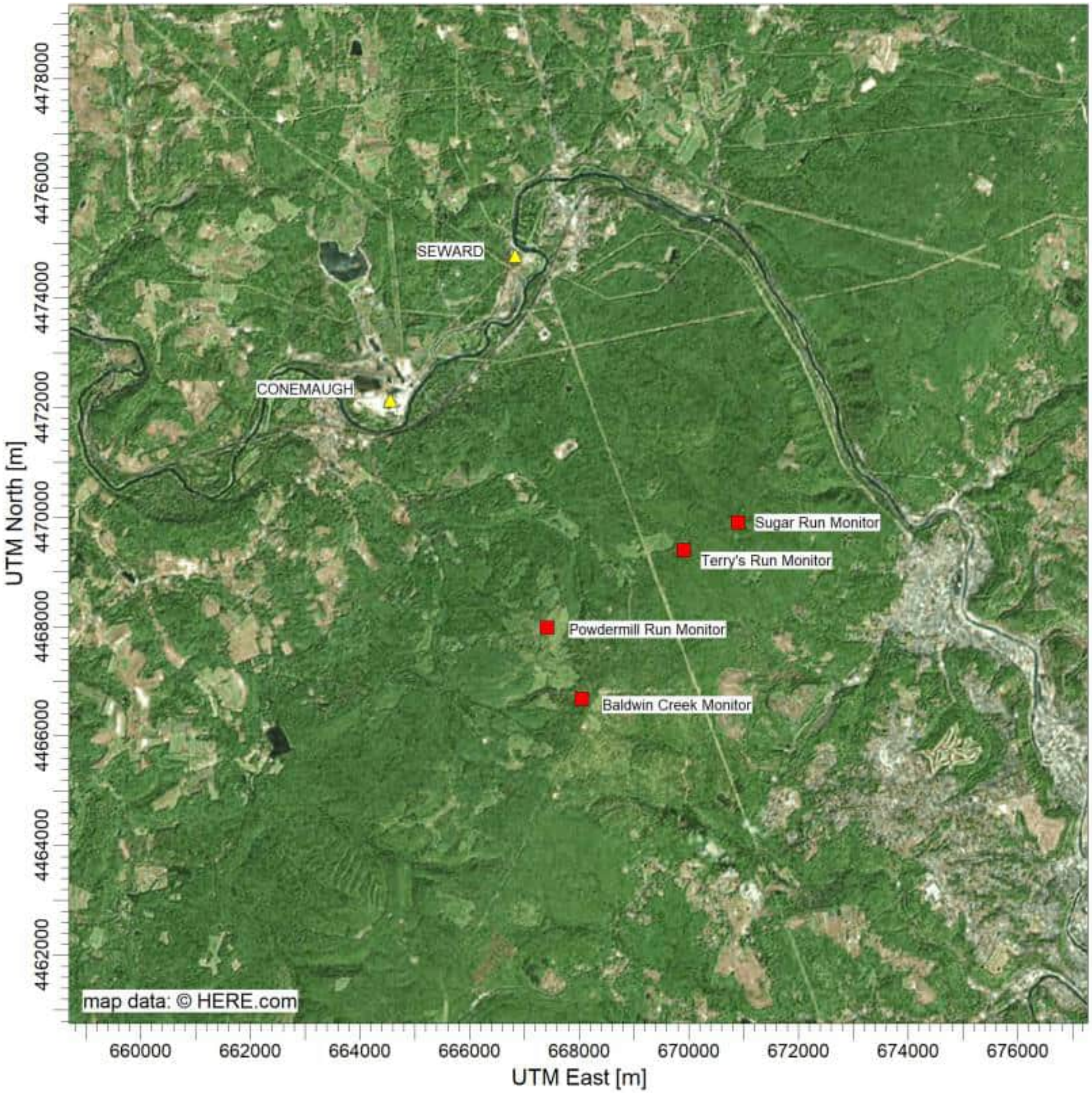
[2] Hill height refers to the height that represents significant terrain features that will have the greatest influence on dispersion for each individual model receptor.

[3] There is a slight change in the monitor coordinates from the TRC report as it was determined through inspection of arial imagery that the clearing used to site the monitor was actually farther to the south.

[35] The NED files were downloaded on July 17, 2025. Based on how the NED files are setup and the location of the modeling domain, there are two separate NEDs. The USGS modified dates are May 3, 2022 (n41w079 NED file) and December 1, 2021 (n41w080 NED file).

[36] EPA, 2024. AERMOD User's Guide. Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/aermap/aermap_userguide.pdf

Figure 5-5: Laurel Ridge Receptors (Monitored Locations)



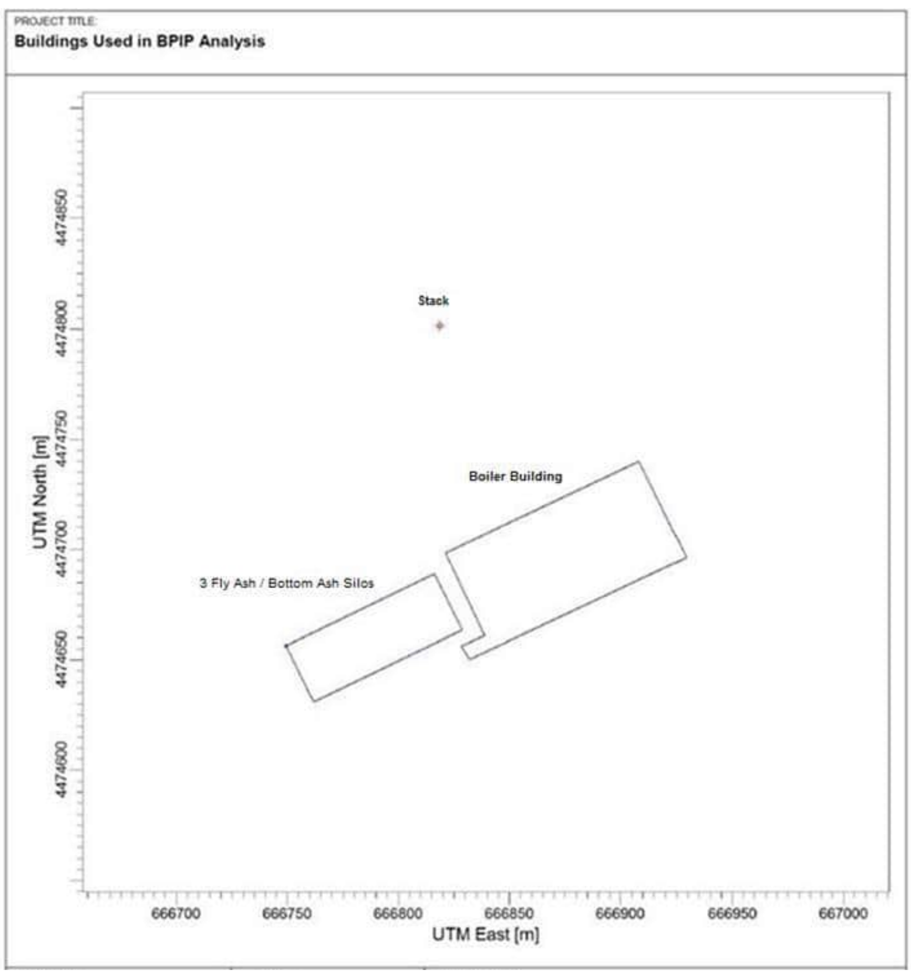
5.5 Modeled Stack Heights and Building Downwash

Consistent with guidance from EPA's SO_2 NAAQS Designations Modeling Technical Assistance Document (TAD)[37], actual stack heights were used so that the analysis more closely represents the actual ambient air quality conditions as influenced by the source. The potential for the source's plume to be affected by aerodynamic wakes created by the building(s) was also evaluated in the dispersion modeling analysis. Conemaugh's stacks that were in service during the 1990 study were both 1,000 feet tall[38]. This puts them beyond the height of downwash effects and therefore building-induced downwash was not applied.

The Seward stack was built after 1970 and was built to a height of 604 feet. Inputs to AERMOD for direction-specific building dimensions were calculated with the regulatory-approved version of the US EPA's Building Profile Input Program software (BPIP-PRIME version 04274) for the Seward stack. The locations and dimensions of the buildings/structures relative to the exhaust stacks for Seward is depicted in **Figure 5-6**.

It should be noted that the distance from Conemaugh and Seward stacks and the four (4) Laurel Ridge monitors are likely beyond the influence of building-induced downwash, given at least 5 km separates the sources and the closest monitor. Therefore, minor changes to the buildings would not have any appreciable effect on the model evaluation. To demonstrate this assumption, a separate model run was conducted that did not include downwash. This was compared to the run with downwash and the modeled concentrations were found to be identical between the two runs. The electronic modeling archive contains both runs with and without downwash for the default AERMOD scenario.

Figure 5-6: Seward Stack and Buildings for Plume Downwash



[37] EPA, 2016. Sulfur Dioxide (SO_2) National Ambient Air Quality Standards Designation Modeling Technical Assistance Document. August 2016. Available at: https://www.epa.gov/so2-pollution/technical-assistance-documents-implementing-2010-sulfur-dioxide-standard

[38] Commissioned in 1970 and 1971.

5.6 Emissions Data and Stack Parameters

The hourly SO_2 emissions and exhaust parameters (gas exit temperature and velocity) that were collected during the study were used as input to the model. SO_2 emissions were collected through the use of Continuous Emissions Monitoring Systems (CEMS) for Homer City, while Keystone, Conemaugh, and Seward utilized an alternative, but PA DEP-approved, SO_2 emissions monitoring and reporting procedures. For this alternative data collection approach, coal samplers were deployed to collect integrated coal samples for each 24-hour period (twice hourly for a total of 48 samples per day). Hourly emissions rates were computed using the 24-hour averaged fuel sampling sulfur content values from the Certified Coal Sampling and Analysis System in combination with heat rates and hourly load data. These data points are available concurrent with the meteorological data from August 1990 through July 1991. **Table 5-9** summarizes the static stack parameter information of the sources included in the modeling. Hourly emission rates used in the modeling are discussed later in Section 6.1.

The stack parameter calculations used to generate the hourly files to be used in the modeling were based on those described in the 1993 TRC Report. AECOM reconstructed the hourly SO_2 emissions and exhaust parameters for Keystone, Conemaugh, and Seward based on the 24-hour averaged fuel sampling values, hourly load data, and the procedures described in the 1993 TRC Report. During this reconstruction process, it was discovered that the hourly load data for Seward Units 12 and 14 were combined, as they both provided steam to a single turbine/generator (Stack 4). Seward Unit 15, the larger of the three Seward units and the study database, did contain hourly load and fuel sampling data specific to that unit, as it supported a second turbine/generator (Stack 5). Detailed calculations including the field study 24-hour averaged fuel sampling values and hourly load data files are included in the electronic modeling archive.

Table 5-9: Stack Parameters for the Evaluation Modeling Analysis

Source	UTM Coordinates (M)		Stack Height	Stack Diameter[1]	Stack Base Elevation
	Easting	Northing			
Conemaugh Unit 1	664,566.58	4,472,236.03	304.8 m[1] (1,000 ft)	8.3 m (27.2 ft)	331.77 m[3] (1,085.0 ft)
Conemaugh Unit 2	664,624.00	4,472,226.06	304.8 m[1] (1,000 ft)	8.3 m (27.2 ft)	331.71 m[3] (1,085.0 ft)
Seward Units 4 and 5[5]	666,818.48	4,474,801.48	184.1 m[4] (604 ft)	5.3 m (17.4 ft)	334.67 m[2] (1,098.0 ft)
Homer City Unit 1	652,744.07	4,486,392.88	243.8 m[1] (800 ft)	7.3 m (24.0 ft)	365.8 m[1] (1,200 ft)
Homer City Unit 2	652,758.60	4,486,342.52	243.8 m[1] (800 ft)	7.3 m (24.0 ft)	365.8 m[1] (1,200 ft)
Homer City Unit 3	652,734.16	4,486,255.51	370.6 m[1] (1,216 ft)	6.9 m (22.6 ft)	365.8 m[1] (1,200 ft)
Keystone Unit 1	640,186.32	4,502,350.41	243.8 m[1] (800 ft)	8.3 m (27.2 ft)	308.5 m[1] (1,012 ft)
Keystone Unit 2	640,230.15	4,502,398.22	243.8 m[1] (800 ft)	8.3 m (27.2 ft)	308.5 m[1] (1,012 ft)

[1] Table 2-1 of TRC Report (1993)
[2] Indiana County 1-hour SO_2 SIP (2024)
[3] Google Earth
[4] Seward provided data
[5] Unit 4 supported by boilers units 12 and 14. Unit 5 supported by boiler unit 15.

5.6.1 Comparison of Laurel Ridge SO_2 Emissions to State Reporting

Just as is done today, emissions reporting was performed in the 1990s. However, the level of detail and temporal resolution of currently reported (i.e., hourly) data was not required in the 1990s. Instead, annual data was reported to the states. The Stations obtained annual Air Information Management System (AIMS) reports for 1990 and 1991, the annual emissions reporting system at the time, from PADEP. AIMS reports were designed to track pollutants and manage air quality programs like Title V. Today, Annual Emission Statement (AES) Reports have replaced AIMS and reporting on an hourly scale for pollutants like SO_2 are done and managed through EPA's Clean Air Markets Program Data (CAMPD).

Table 5-10 presents a comparison of the total SO_2 emissions, by facility, from the Laurel Ridge database to the annual SO_2 emissions contained in the AIMS reports. Because there is a disconnect between the two dataset periods, Laurel Ridge is for a 1-year period from August 1990 through July 1991 and the AIMS are calendar years, the approach was taken to take five-twelfths of 1990 and seven-twelfths of 1991 and sum those up and use those values to compare to the Laurel Ridge emissions. While this does not account for a month-by-month comparison, it still serves as a high-level quantitative comparison. As shown in **Table 5-10**, the emissions from the Laurel Ridge study are generally higher (ranging from 1% to 8%) than the AIMS data, with the exception being Homer City. This result suggests that the data from the Laurel Ridge database is reasonable and generally aligns with the state-reported data (and is conservative). A copy of the 1990 and 1991 AIMS reports are included in **Attachment G**.

The last column in **Table 5-10** illustrates the annual tons of SO_2 emitted by each facility in the Laurel Ridge study for calendar year 2024. With the implementation of control systems, lower sulfur coal, and utilization, emissions are sharply lower than in the early 1990s. Note that Homer City was decommissioned in July 2023, which is why there are no longer any SO_2 emissions from that facility.

Table 5-10: Total SO_2 Emissions from Laurel Ridge Study Compared to AIMS Reports

Facility (Units)	SO_2 (tons) Laurel Ridge	SO_2 (tons) AIMS Reports			% Difference	2024 CAMPD SO_2 (tons)
	AUG90-JUL91	1990	1991	Est. AUG90-JUL91[(a)]		
Seward (U12, U14, & U15)	18,389.9	16,083.0	17,575.1	16,953.4	+8%	6,462
Conemaugh (U1 & U2)	188,052.6	188,201.4	186,332.4	187,111.2	+1%	1,508
Keystone (U1 & U2)	142,557.1	134,848.5	135,732.3	135,364.1	+5%	7,322
Homer City (U1 – U3)	106,043.8	108,566.7	105,252.2	106,633.2	-1%	0[(b)]

(a) Five-twelfths (5/12) of 1990 plus seven-twelfths (7/12) of 1991. This assumes 5 months in 1990 (aligning with August to December) and 7 months in 1991 (January to July). Since the AIMS does not take into account for the specific month of operations, this can explain the difference between it and the Laurel Ridge data.

(b) Decommissioned on July 1, 2023

5.7 Background Concentration

Ambient air quality data are used to represent the contribution to total ambient air pollutant concentrations from non-modeled sources. The network of monitors along Laurel Ridge would not only measure concentrations from the four (4) major SO_2 sources (Conemaugh, Seward, Homer City, and Keystone), but also those that would have been more distant and/or significantly smaller in magnitude. The modeled concentrations are based solely on the four (4) major SO_2 sources and therefore an ambient background needs to be added in order to conduct an unbiased model to monitor evaluation.

Upon review of Table 3-6 in the 2003 TRC report, an ambient background value of 26.2 $\mu g/m^3$ was computed. As shown in **Table 5-11**, this background value represents an average concentration (values shaded in blue) when the winds were toward the northeast, southwest, and northwest (not placing the monitors downwind of the key SO_2 sources).

Table 5-11: Background SO_2 Concentrations by Flow Vector Quadrant and Meteorological Condition

bin #	Flow Vector Quadrant[1]	Stability[2]	Wind Speed (m/s)	Average SO^2 (ug/m3)	Number of Monitor-hours Used	Number of Times Minimum Was Used
1	northeast	stable	0-3	34.2	3,725	0
2	northeast	stable	>3	49.6	8,718	0
3	northeast	neutral	0-3	47.5	508	0
4	northeast	neutral	3-8	45.3	4,355	0
5	northeast	neutral	>8	29.0	3,338	0
6	northeast	unstable	0-3	65.1	2,462	0
7	northeast	unstable	>3	40.8	8,256	0
8	southeast	stable	0-3	25.9	234	119
9	southeast	stable	>3	19.5	476	218
10	southeast	neutral	0-3	28.4	66	34
11	southeast	neutral	3-8	23.0	1,009	566
12	southeast	neutral	>8	20.3	475	176
13	southeast	unstable	0-3	38.5	272	139
14	southeast	unstable	>3	24.7	1,087	468
15	southwest	stable	0-3	26.4	975	0
16	southwest	stable	>3	12.1	795	0
17	southwest	neutral	0-3	20.7	198	0
18	southwest	neutral	3-8	10.0	643	0
19	southwest	neutral	>8	10.7	68	0
20	southwest	unstable	0-3	28.8	1,004	0
21	southwest	unstable	>3	8.1	676	0
22	northwest	stable	0-3	28.0	2,672	0
23	northwest	stable	>3	9.4	2,588	0
24	northwest	neutral	0-3	24.4	574	0
25	northwest	neutral	3-8	10.7	1,232	0
26	northwest	neutral	>8	7.1	263	0
27	northwest	unstable	0-3	32.8	1,881	0
28	northwest	unstable	>3	9.5	2,148	0
Average of Flow Quadrants Upwind of Modeled Sources (northeast, southwest, and northwest)				**26.2**	N/A	N/A

Source: Table 3-6, TRC 2003[39]

[1] Flow vector quadrant is the 90° sector that the winds are blowing towards. For example, northeast is for winds blowing from the monitor between 0° and 90°.

2 Based upon Pasquill-Gifford (P-G) stability classes. Refer to page 24 of the TRC 2003 report.

[39] TRC, 2003. Final Report. AERMOD Modeling Analyses for SO2 NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania. TRC. March, 2003.

6. Model Evaluation Approach and Performance Metrics

6.1 Model Evaluation Approach

As discussed in Section 5, hourly SO_2 emissions and meteorology for the one-year period (August 1990 – July 1991) from the Laurel Ridge study was used to generate modeled concentrations at the receptors situated at the four (4) monitors (Baldwin Creek, Powdermill Run, Terry's Run, and Sugar Run). An ambient background value of 26.2 µg/m3 was added to each predicted concentration (refer to Section 5.7). Two separate AERMOD runs were executed; (1) using default, regulatory options, and (2) using the alpha LOW_WIND option to set the minimum sigma-v to 0.5 m/s.

An important component of any model evaluation is to ensure that the emissions supplied to the model are concurrent with the monitoring data. Therefore, prior to conducting the performance metrics, described in 6.2 below, each hour of the dataset was reviewed to determine if it met the following criteria. For each unit, an hour is deemed "valid" if the load data indicated it was operating, and coal sulfur content data were available to calculate the hourly SO_2 emission rate (per above, SO_2 CEMs were utilized at Homer City). For hours in which it was determined that unit was operating, but the sulfur content data was missing, that hour was classified as "missing" and no emission rate was calculated. To be a valid hour to be used as part of the model evaluation, an hour would need to be classified as "valid" for each hour of the dataset, each of the six (6) units[40] across Conemaugh, Seward, and Keystone. **Table 6-1** summarizes valid and missing hours on a unit-specific basis and collectively across all six (6) units. On a unit-specific basis, at least 96% of the total study hours contain valid emissions data when a unit was operating. The hours when emissions data were missing don't necessarily occur in the same hour for every unit. Collectively, the total number of hours when all units were operating and had valid emissions was found to be 7,714 hours (88% of the original study period). As a reminder, the load data from the Laurel Ridge study for Seward Units 12 and 14 was a combined value. Therefore, if either or both units were operating, the hour was considered valid. Since the Homer City units (1 through 3) utilized CEMS, this data was not required to undergo this screening process.

The separation of valid and missing hours for model-to-monitor comparison was conducted via a post-processing method. Only the modeled and monitored concentrations for the hours deemed "valid" were carried through to the statistical performance evaluation.

Table 6-1: Summary of Valid and Missing Hours by Unit

Unit	CON 1	CON 2	KEY 1	KEY 2	SEW 12&14	SEW 15	All Units
Valid hours	8690	8515	8670	8641	8460	8449	**7714**
% Valid hours	99%	97%	99%	99%	97%	96%	88%
Missing hours[1]	70	245	90	119	300	311	1046

[1] Missing hours represent unit online (load > 0) with no sulfur data available

6.2 Performance Metrics Used for Performance Evaluation

The 7,714 1-hour predicted concentrations, from both model runs (regulatory model with defaults and alternative model options), and the corresponding observed concentrations at each of the four (4) Laurel Ridge monitors were obtained. A list of the performance measures used in the model evaluation is provided below.

1) 99th percentile design concentration (predicted and observed) at each monitor, and also considering all monitors;
2) Quantile-Quantile (Q-Q) of the ranked hourly SO_2 predicted and observed concentrations across all four (4) monitors; and
3) Screening and statistical tests and their statistical measures (Robust Highest Concentrations (RHCs), fractional bias, Composite Performance Measure (CPM), and Model Comparison Measure

[40] Six units include Conemaugh Unit 1 and Unit 2, Keystone Unit 1 and Unit 2, Seward Stack 4 (Unit 12 and Unit 14), and Seward Stack 5 (Unit 15). If either Seward Unit 12 or 14 was operating or both, then it was deemed valid.

(MCM)), described in EPA's Protocol for Determining the Best Performing Model (EPA-454/R-92-025)[41].

A software package, developed by Sigma Research Corporation and Sonoma Technology, referred to as the Model Evaluation Method (MEM), designed to evaluate model performance by implementing the statistical analysis procedures contained in EPA's Protocol for Determining the Best Performing Model was used to assist in the performance measure calculations. A discussion is provided below on what is available and how the results were evaluated.

This report also includes an analysis (see Section 7.3) of the Laurel Ridge study emissions and monitoring data with the use of a second meteorological datasets from Ash Site #1 (September 2015 through August 2016). This supplemental analysis is designed to demonstrate that the Ash Site #1 meteorological dataset still yields improved performance with the alternative model, while still being conservative relative to the monitoring data and model results using the 1990-1991 Ash Valley meteorological data. As previously discussed in Section 3, the purpose of this analysis is to demonstrate that the alternative model will still result in improved model performance compared to the regulatory model with the CDD meteorological dataset (2015-2016 Ash Site #1) that includes both measured sigma-theta and sigma-w parameters.

6.3 Model Evaluation Methodology (MEM)

The MEM operates in three (3) stages: Screen, Boot, and Combine. Each of these stages have their own individual input files (*.INP) that are accepted by the MEM. The MEM software was used to calculate statistics for the top 25 ranked modeled and observed concentrations. As a quality control step, the average, RHC, standard deviation, and fractional bias of the top 25 concentrations were independently computed and compared to the output from the MEM. The statistics that are computed based upon the MEM's random number generator (i.e., for the bootstrapping technique) were not independently evaluated due to the dependence on a random number generator.

6.3.1 Screen Stage

The first stage in MEM is the Screen Stage. There are five components to the screen input file: Job Control Pathway (JB), Observation Pathway (OB), Model Pathway (MO), Statistics Pathway (ST), and Output Pathway (OU). The job control pathway contains the keywords that provide the overall control of the model run. This pathway includes a Title, the processing option (in the first stage this was Screen), a run or not switch, and an error output declaration. The next pathway, OB, contains information about the monitor and the format of the input data set for observed hourly concentrations. The MO pathway is the model input pathway which processes the modeled hourly concentrations. Statistical analysis is conducted in the ST pathway, ST, where in our case we based the RHC calculations on the top 25 concentrations and conducted the statistics on those data points. Lastly, the OU pathway simply states the file name and location of the output data file. All stages also produce a (*.tst) file which is the compilation and statistic result output.

The purpose of the Screen Stage is to identify models that fail to perform at a minimum operation level (e.g., AFB exceeds 0.67, which means that the model RHC prediction is not within a factor of 2 of the observed RHC).

6.3.2 Boot Stage

After the Screen stage has finished, MEM evaluates the Boot input files. The Boot stage is where bootstrapping[42] statistics are run and model statistics are conducted for comparison of individual and model-to-model performance. Just like the Screen input file, the JB, OB, and MO, pathways are the same with the exception of the procedure operation option being Boot in the JB pathway.

One new pathway is included within the Boot stage, that being the Diagnostic Pathway (DI). The DI pathway contains keywords to read in the relevant observed meteorological data. The meteorological data is used to enhance the model

[41] EPA, 1992. Protocol for Determining the Best Performing Model. EPA-454/R-92-025. September 1992. Available at: https://www.epa.gov/sites/default/files/2020-10/documents/model_eval_protocol.pdf
[42] Bootstrap is a resampling technique where the desired performance measure is recalculated for a dataset. The data is partitioned into 3-day blocks within each season (i.e., spring, summer, fall, winter).

evaluation statistics by categorizing the data set hours into wind speed and stability classes. This stage calculates the statistics (RHC and FB) grouped on each defined class.

The MEM computes the RHC using the top 26 predicted and observed concentrations, as shown below.

$$RHC = X(N) + [X_{ave} - X(N)] \times \ln[\frac{3N-1}{2}]$$ (Equation 1)

where:

N = a user-specified sample size for the top concentrations (typically 25), plus 1;
X_{ave} = average of the N-1 (typically 25) largest values; and
X(N) = N^{th} largest value.

In general, the RHC calculations are performed on the entire dataset being evaluated. The fractional bias (see Equation 2 below) has been selected as the basic measure of performance in the MEM when comparing observed and predicted RHC values. Values for the fractional bias range between -2 and +2 (model over-prediction for negative values and over-prediction for positive values). Fractional biases that are equal to -0.67 are equivalent to model RHC over-predictions by a factor of two, while a fractional bias of +0.67 is equivalent to a model under-prediction by a factor of two. The absolute fractional bias (AFB) statistic (equation 2), which is the absolute value of the fractional bias (FB), is computed for each of the models for each evaluation monitor.

$$AFB = |FB| = |2 \times [\frac{(Observed-Predicted)}{(Observed+Predicted)}]|$$ (Equation 2)

where:

Observed = calculated RHC from observed concentrations
Predicted = calculated RHC from modeled concentrations

The DI pathway needs a file location and the format of the data set. The data used for this pathway is the 10-m wind speed and PG stability class. Classifications of meteorological conditions are conducted under the DICLASS keyword. For our evaluation, the following meteorological classes shown in **Table 6-2** were used.

Table 6-2: Diagnostic Meteorological Classes Tested in MEM

Diagnostic Class	Wind Speed	Stability Class
1	Low wind (0-4 m/s)	Unstable (1-3)
2	Low wind (0-4 m/s)	Unstable/Neutral (3-4)
3	Low wind (0-4 m/s)	Neutral/Stable (4-6)
4	High wind (> 4 m/s)	Unstable (1-3)
5	High wind (> 4 m/s)	Unstable/Neutral (3-4)
6	High wind (> 4 m/s)	Neutral/Stable (4-6)
Diagnostic classes and associated wind speed and stability classes taken from example provided in “User’s Guide for the Model Evaluation Methodology (MEM) System for Comparing Model Performance”, Version 1.0.		

Another parameter in the Boot ST pathway is the resample parameter. The resample parameter defines which “members” within the data set are defined as resample groups, and how the data is divided for resampling. The parameters “Resample Piece”, “Resample Blkrange”, and “Resample Number”, denote how MEM shifts the sequenced data to reflect seasonal groupings (defined in Blkrange). In our modeling, we used four seasons, as recommended by the MEM user guide; the seasons were December – February for winter, March – May for spring, June – August for summer, and September – November for autumn. Lastly, the “Composite” pathway allows for weighting of the diagnostic and operational components when averaging the ABF, we used the weight of 1 for operational and 1 for diagnostic, based upon guidance from EPA[43]. The last pathway within the Boot stage is the OU pathway which declares the name of the output file (*.mcm).

In addition to the RHC and FB, another statistical measure is calculated, referred to as the Composite Performance Measure (CPM). The CPM is a weighted linear combination of the individual FB in an attempt to quantify the uncertainty in the AFB calculations. The uncertainty can be used to determine whether performances of selected models are significantly different for the specific monitor being evaluated. The confidence interval calculated using the bootstrap method includes results for both the 90% and 95% levels; 90% has been used by EPA in past evaluations (see, for example slides 14 and 15 in the presentation at EPA’s 11th Modeling Conference (August 12, 2015) at https://www3.epa.gov/ttn/scram/11thmodconf/presentations/1-5_Proposed_Updates_AERMOD_System.pdf).

The formula for the CPM is shown in equation 3.

$$CPM = \frac{1}{3}\overline{(AFB)_{r,s}} + \frac{2}{3}\left[\frac{(AFB)_1}{2}\right] \qquad \text{(Equation 3)}$$

where:

$(AFB)_{r,s}$ = Absolute Fractional Bias for diagnostic condition r at station s; and

$(AFB)_1$ = Absolute Fractional Bias for 1-hour averages

As described in EPA’s Protocol for Determining the Best Performing Model (EPA, 1992), the smaller the CPM, the better overall performance of that model. A positive value indicates the alternative model is performing better, whereas a negative means the default model is performing better. If the CPM values for our evaluation result in a lower, yet positive value then it can be concluded that the alternative model performs better than the default for this statistical measure.

6.3.3 Combine Stage

After the CPM is computed for each candidate model, the MEM calculates the difference in two models’ CPM results; the result is the “Model Comparison Measure”, or MCM. The MCM is conducted in the final stage within MEM, referred to as the Combine stage. This stage only contains a JB and a CS pathway. The CS pathway groups individual model results together for comparison to generate the MCM. This final result is an overall statement of whether the models being compared have significantly different performance. A negative combined MCM (CMCM) value implies that the default model is performing better, while a positive value indicates the alternative model is performing better. A significant determination depends upon whether or not the confidence interval overlaps zero. If it overlaps zero, then the results are not statistically different. If there is no overlap, then there is a statistically significant difference at that confidence interval.

6.4 Stability Class Determination for MEM Diagnostic Calculations

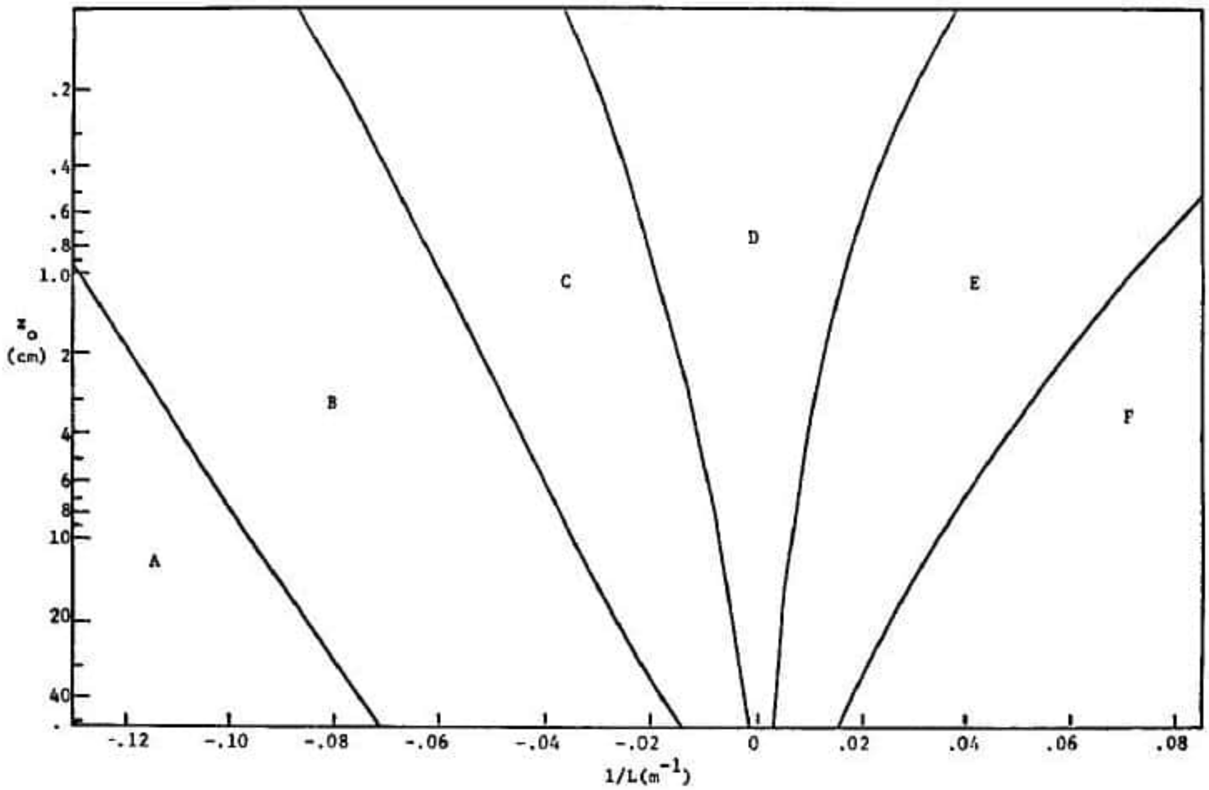
In order for the MEM to conduct the diagnostic statistics, which look at how the model performs under certain conditions, wind speed and stability class inputs are required. The Ash Valley meteorological tower data that was processed through AERMET (see Section 5.3) was used to obtain these inputs. The Pasquill-Gifford (PG) stability classes needed for the MEM diagnostic tests were calculated using the AERMET SURFACE file output; specifically with the hourly Monin-Obukhov length and the surface roughness length.

The PG stability classes were calculated according to the classic Golder (1972) algorithm that establishes a relation between the Monin-Obukhov length and surface roughness length (see **Figure 6-1**)[44]. To create this relationship, we evaluated two points on each quasi-straight line in **Figure 6-2** at z0 = .01 meters and z0 = 0.5 meters and created a best fit line. **Figure 6-2** shows the good fit between these lines and the curves from Golder’s paper. Stability values ranging from 1 to 6 were calculated for every hour of the dataset.

[43] Email correspondence from James Thurman (EPA) to Bob Paine (AECOM) on June 13, 2025.

[44] Golder, D: 1972, ‘Relations Among Stability Parameters in the Surface Layer’, Boundary-Layer Meteorology. **3**, 47-58. We found that the LTOPG curves correspond to a region in the middle of the stability classes shown in Figure 1 rather than the edges of the stability class areas.

Figure 6-1: Golder (1972) Stability Class as a Function of Surface Roughness Length and Monin-Obukhov Length



The fitted equations for PG stability class boundaries that we determined are:

Stability A:B = $10^{\left(\frac{x+0.05937}{0.035315}\right)}$ (brown line in Figure B-13)

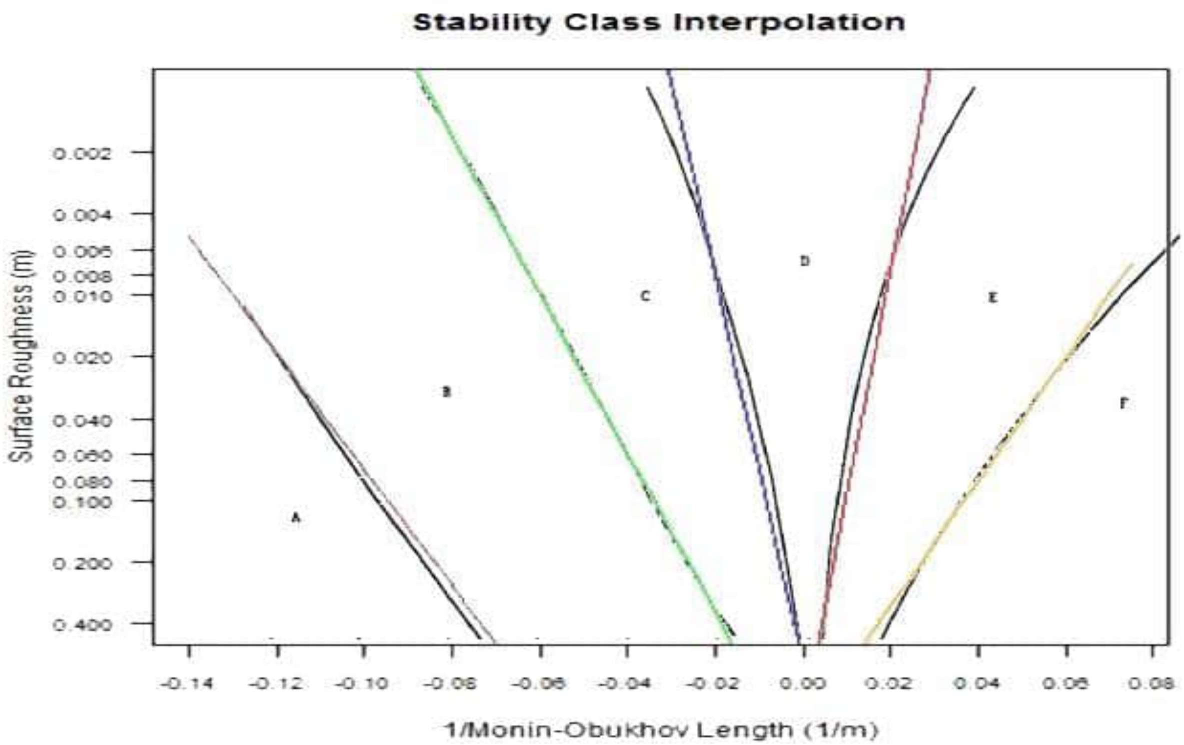
Stability B:C = $10^{\left(\frac{x+0.0082}{0.02589}\right)}$ (green line)

Stability C:D = $10^{\left(\frac{x-0.002189}{0.01059}\right)}$ (blue line)

Stability D:E = $10^{\left(\frac{x-0.000754}{-0.00912}\right)}$ (red line)

Stability E:F = $10^{\left(\frac{x-0.004079}{-0.03296}\right)}$ (yellow line)

Figure 6-2: Best fit lines between stability class regions defined by Golder (1972)



7. Modeling Results of Alternative Model Performance Evaluation

7.1 Peak and Design Concentrations and Quantile-Quantile Plots

The observed and predicted peak and design (99th percentile (4th highest)) concentrations (with background concentration included) for the two AERMOD model options (default and LOW_WIND) are tabulated in **Table 7-1** and **Table 7-2**, respectively. An ideal unbiased model would produce values of the predicted-to-observed ratio between 0.9 and 1.1 (accounting for a 10% uncertainty in the observed SO_2 concentrations due to EPA-allowed tolerances[45]). For the model evaluation case with default options, AERMOD over-predicts the peak and design concentration for the datasets (all four monitors) with value of 2.13 and 1.47, respectively. The alternative model, using a minimum sigma-v of 0.5 m/s, reduces these predicted-to-observed ratios to 1.86 and 1.39 for the peak and design concentrations, respectively. For the individual monitoring sites, the range of predicted-to-observed ratios are between 1.31 and 2.19 (default) and 1.31 and 1.92 (alternative LOW_WIND). The more distant monitors (Baldwin Creek and Powdermill Run) relative to Conemaugh and Seward are not affected by the LOW_WIND adjustment due to the sigma-v already being above 0.5 m/s. These monitors do experience slight improvement in the predicted-to-observed ratios for the design concentrations, but the more significant improvement is at the closer monitors of Sugar Run and Terrys Run to Conemaugh and Seward, as shown in **Table 7-2**.

Figure 7-1 shows the Q-Q plot (unpaired in time and space) for all the monitors with the observed concentrations on the x-axis and the modeled concentrations on the y-axis. For both the default and alternative runs, the Q-Q plot shows that they are above the 1-to-1 line, indicating the modeled results are conservative. The refinement of the increased minimum sigma-v for the alternative model does appear to provide substantial relief to the magnitude of the overprediction exhibited by the default model. Quantifying this improvement in the alternative model's performance is discussed in Section 7.2 through the use of statistical measures.

Figure 7-2 presents Q-Q plots for each monitor (paired in space; unpaired in time).

Table 7-1: Observed and Predicted Peak Concentration

Model Option	Monitor	Peak SO_2 Concentrations ($\mu g/m^3$)		Ratio Predicted to Observed
		Predicted	Observed	
Default (Sigma V=0.2 m/s)	All 4 Monitors	2086.40	979.90	2.13
LOW_WIND (Sigma V=0.5 m/s)	All 4 Monitors	1823.88	979.90	1.86
Default (Sigma V=0.2 m/s)	Baldwin Creek	1151.55	877.70	1.31
LOW_WIND (Sigma V=0.5 m/s)	Baldwin Creek	1150.32	877.70	1.31
Default (Sigma V=0.2 m/s)	Powdermill Run	1153.8	807.0	1.43
LOW_WIND (Sigma V=0.5 m/s)	Powdermill Run	1152.5	807.0	1.43
Default (Sigma V=0.2 m/s)	Sugar Run	1809.6	979.9	1.85
LOW_WIND (Sigma V=0.5 m/s)	Sugar Run	1642.8	979.9	1.68
Default (Sigma V=0.2 m/s)	Terrys Run	2086.4	951.1	2.19
LOW_WIND (Sigma V=0.5 m/s)	Terrys Run	1823.9	951.1	1.92

Notes: m/s = meters per second; $\mu g/m^3$ = micrograms per cubic meter.

[45] *Quality* Assurance Handbook for Air Pollution Measurement Systems, Volume II, Ambient Air Quality Monitoring Program, 2013, available at http://www.epa.gov/ttnamti1/files/ambient/pm25/qa/QA-Handbook-Vol-II.pdf. (Table 10-3 and Appendix D, page 13).

Table 7-2: Observed and Predicted Design Concentration

Model Option	Monitor	SO_2 Design Concentrations (µg/m³)		Ratio Predicted to Observed
		Predicted	Observed	
Default (Sigma V=0.2 m/s)	All 4 Monitors	1213.88	827.90	1.47
LOW_WIND (Sigma V=0.5 m/s)	All 4 Monitors	1150.32	827.90	1.39
Default (Sigma V=0.2 m/s)	Baldwin Creek	951.50	592.10	1.61
LOW_WIND (Sigma V=0.5 m/s)	Baldwin Creek	840.16	592.10	1.42
Default (Sigma V=0.2 m/s)	Powdermill Run	834.7	497.8	1.68
LOW_WIND (Sigma V=0.5 m/s)	Powdermill Run	813.3	497.8	1.63
Default (Sigma V=0.2 m/s)	Sugar Run	987.6	775.5	1.27
LOW_WIND (Sigma V=0.5 m/s)	Sugar Run	780.0	775.5	1.01
Default (Sigma V=0.2 m/s)	Terrys Run	786.4	699.5	1.12
LOW_WIND (Sigma V=0.5 m/s)	Terrys Run	681.3	699.5	0.97

Notes: m/s = meters per second; µg/m³ = micrograms per cubic meter.

Figure 7-1: Quantile-Quantile Plot for Combine Monitors (Baldwin Creek, Powerdermill Run, Sugar Run, and Terrys Run)

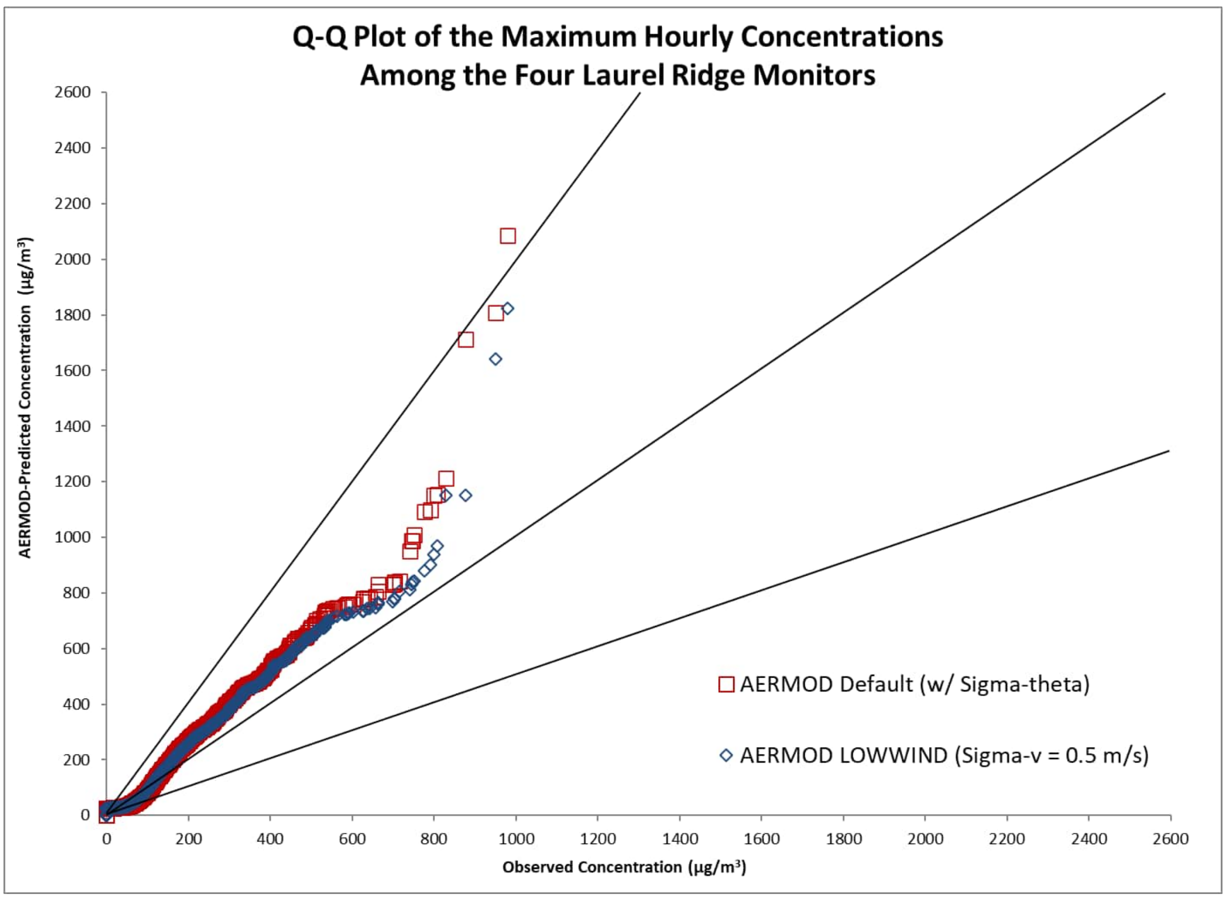
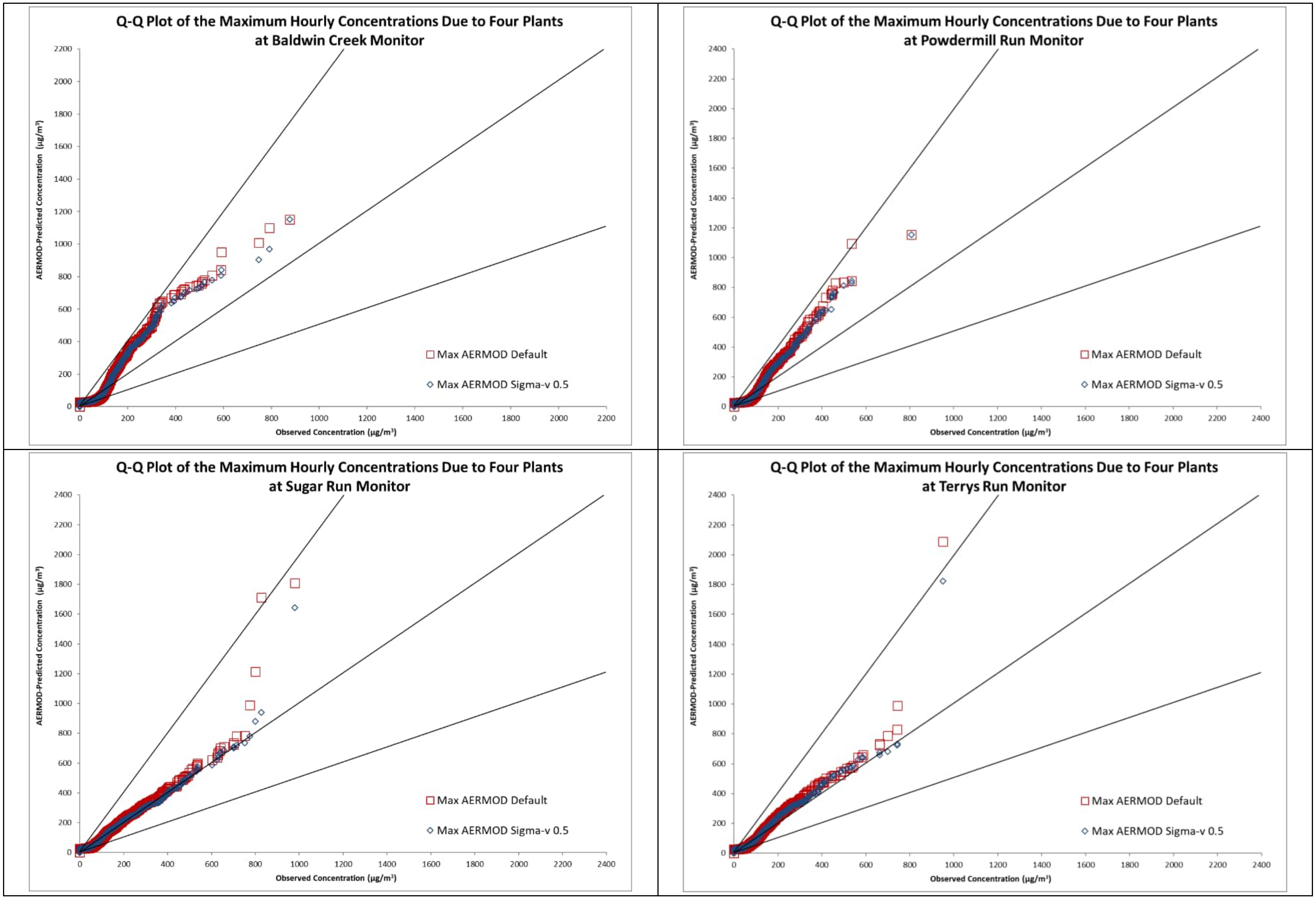


Figure 7-2: Quantile-Quantile Plots for Each Laurel Ridge Monitor Site



7.2 Model Evaluation Methodology Results

7.2.1 Screen Stage Results

The first step consists of a screening test to determine if a selected model meets minimum standards for operational performance. The fractional bias that are equal to -0.67 are equivalent to under-predictions by a factor-of-two, while values that are equal to 0.67 are equivalent to over-predictions by a factor-of-two. Since neither under-predictions nor over-predictions are desirable, these calculations are simplified by determining the absolute fractional bias (AFB). If the AFB is consistently greater than 0.67 for any model, that model should be considered for exclusion from further evaluation due to its limited credibility for refined regulatory analysis. The 25 highest concentrations are ranked for the observed data and the modeled data, and the average and standard deviations are computed. Fractional bias and absolute fractional bias (FB and AFB) of each model are computed, and models that have AFB's that are 0.67 or less are marked with an "X". These are the models that produce averages and standard deviations that are within a factor of two of the corresponding observed data. The results of the screen runs are presented below for Baldwin Creek, Powdermill Run, Sugar Run, and Terrys Run monitors, respectively, in **Figure 7-3** through **Figure 7-6**.

As a quality check of the calculations produced by the MEM for the screening stage, the AFBs for the average and standard deviation were performed outside of the software. The comparison of the independent check and MEM output for each monitor is summarized in **Table 7-3**. The results of the independent calculations verify the values for AFB are correct from the MEM. The spreadsheet used to perform these quality check calculations is included in the electronic model archive.

The overall results of the screening test show that the default model did not pass the screening test for two monitors (Sugar Run and Terrys Run) and passed for the other two monitors (Baldwin Creek and Powdermill Run). The alternative LOW_WIND model passed the screening test at all four monitors. For Sugar Run and Terrys Run, the AFB of the standard deviation was greater than a factor of 2 (> 0.67), but it was below this threshold for the AFB of the average concentrations. This could be considered a marginal result since it was only one of the two AFBs for the default model at these two sites that did not pass. The results from the screening test at the Sugar Run and Terrys Runs sites may also suggest that the default model is not as well suited compared to the alternative model and that more comprehensive statistical test are warranted.

Table 7-3: Quality Check of Screening Statistics (units of µg/m^3)

Monitor	Statistic	MEM Output			Independent Calculation Check		
		Obs	Default	LOWWIND	Obs	Default	LOWWIND
Baldwin Creek	Average	481.65	763.38	727.80	481.65	763.38	727.80
	FB	--	-0.45	-0.41	--	-0.45	-0.41
	AFB	--	0.45	0.41	--	0.45	0.41
	St. Dev	143.89	141.65	128.49	143.89	141.65	128.49
	FB	--	0.02	0.11	--	0.02	0.11
	AFB	--	0.02	0.11	--	0.02	0.11
Powdermill Run	Average	424.34	709.31	670.42	424.34	709.31	670.42
	FB	--	-0.50	-0.45	--	-0.50	-0.45
	AFB	--	0.50	0.45	--	0.50	0.45
	St. Dev	96.95	153.46	140.12	96.95	153.46	140.12
	FB	--	-0.45	-0.36	--	-0.45	-0.36
	AFB	--	0.45	0.36	--	0.45	0.36
Sugar Run	Average	631.74	758.63	677.54	631.74	758.63	677.54
	FB	--	-0.18	-0.07	--	-0.18	-0.07
	AFB	--	0.18	0.07	--	0.18	0.07
	St. Dev	124.86	332.83	227.97	124.86	332.83	227.97
	FB	--	-0.91	-0.58	--	-0.91	-0.58
	AFB	--	0.91	0.58	--	0.91	0.58
Terrys Run	Average	545.17	659.46	623.70	545.17	659.46	623.70
	FB	--	-0.19	-0.13	--	-0.19	-0.13
	AFB	--	0.19	0.13	--	0.19	0.13
	St. Dev	132.42	316.99	257.37	132.42	316.99	257.37
	FB	--	-0.82	-0.64	--	-0.82	-0.64
	AFB	--	0.82	0.64	--	0.82	0.64

Notes: Obs = Observations (i.e., measured data); Default = Default model run; LOWWIND = Alternative model using LOW_WIND option with minimum sigma-v of 0.5 meters per second); FB = fractional bias; St. Dev = Standard Deviation; AFB = absolute fraction bias.

Figure 7-3: Screen Results for Baldwin Creek Monitor

SCREENING TEST RESULTS

Run

Rank	Obs	DFAULT	LOWWIN
1	877.70	1151.55	1150.32
2	791.20	1099.44	969.99
3	746.70	1008.74	902.90
4	592.10	951.50	840.16
5	589.50	840.16	806.18
6	552.80	806.18	779.57
7	521.40	779.57	769.22
8	510.90	769.22	746.80
9	508.30	756.62	744.92
10	495.20	746.80	728.66
11	487.30	744.92	723.87
12	458.50	737.06	716.19
13	437.50	723.87	698.99
14	432.30	719.60	691.46
15	424.40	708.42	678.97
16	421.80	691.46	675.26
17	395.60	689.72	669.15
18	393.00	686.12	647.05
19	382.50	669.15	637.58
20	345.80	647.05	631.56
21	340.60	640.80	612.19
22	340.60	637.58	610.80
23	332.70	636.98	602.88
24	332.70	629.73	582.42
25	330.10	612.19	577.83
AVG:	481.65	763.38	727.80
FB:		-0.45	-0.41
AFB:		0.45	0.41
St.Dev	143.89	141.65	128.49
FB:		0.02	0.11
AFB:		0.02	0.11
		X	X

The AERMOD default model is referred to as "DFAULT", and the one with the Sigma-v = 0.5 m/s, is referred to as "LOWWIN". For Baldwin Creek monitor, both models show AFB less than 0.67, thus passing the screening test.

Figure 7-4: Screen Results for Powdermill Run Monitor

SCREENING TEST RESULTS

Run

Rank	Obs	DFAULT	LOWWIN
1	807.00	1153.83	1152.49
2	534.50	1093.02	844.20
3	534.50	844.20	830.04
4	497.80	834.73	813.32
5	461.10	830.04	766.29
6	448.00	780.29	759.12
7	445.40	759.52	744.66
8	445.40	759.12	733.93
9	442.80	759.12	731.47
10	442.80	749.42	653.46
11	416.60	731.47	644.95
12	403.50	676.08	642.16
13	393.00	642.16	637.85
14	390.40	637.85	628.33
15	387.80	637.09	612.18
16	385.10	628.33	609.62
17	385.10	614.68	607.12
18	374.70	612.18	589.48
19	372.00	603.45	585.33
20	361.60	589.48	570.20
21	343.20	585.33	540.97
22	338.00	570.20	522.60
23	335.40	567.28	520.43
24	332.70	540.97	510.98
25	330.10	533.02	509.23
AVG:	424.34	709.31	670.42
FB:		-0.50	-0.45
AFB:		0.50	0.45
St.Dev	96.95	153.46	140.12
FB:		-0.45	-0.36
AFB:		0.45	0.36
		X	X

The AERMOD default model is referred to as “DFAULT”, and the one with the Sigma-v = 0.5 m/s, is referred to as “LOWWIN”. For the Powdermill Run monitor, both models show AFB less than 0.67, thus passing the screening test.

Figure 7-5: Screen Results for Sugar Run Monitor

SCREENING TEST RESULTS

Run

Rank	Obs	DFAULT	LOWWIN
1	979.90	1809.56	1642.84
2	827.90	1713.20	939.71
3	799.10	1213.88	880.51
4	775.50	987.62	780.01
5	751.90	782.59	734.40
6	715.30	780.01	722.35
7	702.20	734.40	709.73
8	702.20	724.44	702.32
9	657.60	709.73	687.68
10	641.90	702.32	672.98
11	636.70	681.86	665.57
12	628.80	665.57	656.54
13	628.80	656.54	638.41
14	626.20	638.41	620.18
15	602.60	620.18	587.32
16	537.10	599.73	576.63
17	534.50	589.09	565.69
18	534.50	585.57	556.62
19	531.90	576.63	543.31
20	513.50	565.69	535.08
21	508.30	556.62	515.04
22	497.80	535.08	514.08
23	492.60	515.04	507.38
24	484.70	514.08	493.06
25	482.10	507.96	491.07
AVG:	631.74	758.63	677.54
FB:		-0.18	-0.07
AFB:		0.18	0.07
St.Dev	124.86	332.83	227.97
FB:		-0.91	-0.58
AFB:		0.91	0.58

X

The AERMOD default model is referred to as "DFAULT", and the one with the Sigma-v = 0.5 m/s, is referred to as "LOWWIN". For the Sugar Run monitor, the default model has a AFB greater than 0.67 (more than a factor of two over-prediction based on the standard deviation, but less than a factor of two for the average concentration), so it marginally does not pass the MEM screening test for this monitor. The LOWWIND option does pass the screening test for this monitor for both the average and standard deviation.

Figure 7-6: Screen Results for Terrys Run Monitor

SCREENING TEST RESULTS

Run

Rank	Obs	DFAULT	LOWWIN
1	951.10	2086.40	1823.88
2	744.10	987.93	733.38
3	741.50	829.63	724.79
4	699.50	786.40	681.25
5	662.90	733.38	676.53
6	662.90	724.79	657.68
7	586.90	657.68	642.28
8	581.60	644.14	640.73
9	563.30	642.28	626.00
10	542.30	585.85	585.85
11	537.10	577.16	577.16
12	529.20	573.33	573.33
13	513.50	566.51	566.51
14	500.40	549.14	557.19
15	487.30	545.59	549.14
16	484.70	525.59	545.59
17	458.50	521.50	525.59
18	453.30	519.54	519.54
19	445.40	515.02	515.02
20	440.20	505.19	505.19
21	419.20	501.68	482.26
22	408.70	482.26	476.60
23	408.70	476.60	474.33
24	406.10	474.64	472.73
25	400.90	474.33	459.99
AVG:	545.17	659.46	623.70
FB:		-0.19	-0.13
AFB:		0.19	0.13
St.Dev	132.42	316.99	257.37
FB:		-0.82	-0.64
AFB:		0.82	0.64

X

The AERMOD default model is referred to as "DFAULT", and the one with the Sigma-v = 0.5 m/s, is referred to as "LOWWIN". For the Terrys Run monitor, the default model has a AFB greater than 0.67 (more than a factor of two over-prediction based on the standard deviation, but less than a factor of two for the average concentration), so it marginally does not pass the MEM screening test for this monitor. The LOWWIND option does pass the screening test for this monitor for both the average and standard deviation.

7.2.2 Boot Stage Results

Table 7-4 provides a summary of the RHC results for the two models and four monitors being evaluated, as well as across all four monitors (i.e., entire dataset). The RHC is a smoothed estimate of the highest concentrations and generally based on the 25 highest concentrations. In all cases, both models overpredict the RHC, but the alternative model is closer to observations, thus reducing the overprediction bias. The ratio of the RHC for the default model over all monitors in the database is 1.56, compared to 1.23 for the alternative (LOW_WIND) model. This is a reduction of approximately 21% from the default to the alternative. In all cases (each monitor and across all monitors) the ratio of the RHC for the default and alternative remains above 1.0, meaning the model has a tendency to overpredict relative to observed concentrations. The percent reduction from the default to the alternative model at each monitor ranges from 3% to 17%.

Table 7-4: Summary of RHCs

Model Option	Monitor	Robust Highest Concentration (μg/m^3)	Ratio Modeled to Observed
Observed	Over All Monitors	1111.76	-
Default (minimum sigma-v=0.2 m/s)	Over All Monitors	1737.66	1.56
LOW_WIND (minimum sigma-v=0.5 m/s)	Over All Monitors	1371.73	1.23
Observed	Baldwin Creek	897.13	-
Default (minimum sigma-v=0.2 m/s)	Baldwin Creek	1165.11	1.30
LOW_WIND (minimum sigma-v=0.5 m/s)	Baldwin Creek	1130.21	1.26
Observed	Powdermill Run	674.14	-
Default (minimum sigma-v=0.2 m/s)	Powdermill Run	1204.23	1.79
LOW_WIND (minimum sigma-v=0.5 m/s)	Powdermill Run	1106.00	1.64
Observed	Sugar Run	1042.45	-
Default (minimum sigma-v=0.2 m/s)	Sugar Run	1424.62	1.37
LOW_WIND (minimum sigma-v=0.5 m/s)	Sugar Run	1183.56	1.14
Observed	Terrys Run	927.59	-
Default (minimum sigma-v=0.2 m/s)	Terrys Run	1154.43	1.24
LOW_WIND (minimum sigma-v=0.5 m/s)	Terrys Run	1058.03	1.14

Table 7-5 provides a summary of the CPM for the two models for each of the four monitors being evaluated. The CPM is a weighted linear combination of the individual fractional bias components. The CPM can range from 0 zero up to a value of 2, and preferred performance is for a CPM is below 0.67, according to EPA Protocol for Determining the Best Performing Model. The CPMs for the default model range from 0.352 to 0.669. The CPMs for the alternative model range from 0.320 to 0.604. For each monitor, the CPM from the alternative model is lower than the CPM, thus indicating that the alternative model statistically performs better for this metric. Furthermore, the CPM is below the preferred performance threshold of 0.67 for both the default and alternative (although the default CPM for Powdermill Run is very close).

The results of the CPM and 90% confidence interval are shown graphically in **Figure 7-7** through **Figure 7-10** for the four monitors. For all monitors, the alternative model option (LOW_WIND) has a better CPM result.

Table 7-5: Composite Performance Measure (CPM) Results

Model Option	Monitor	CPM	+/- 90% Confidence Interval
Default (minimum sigma-v=0.2 m/s)	Baldwin Creek	0.481	0.173
LOW_WIND (minimum sigma-v=0.5 m/s)	Baldwin Creek	0.449	0.165
Default (minimum sigma-v=0.2 m/s)	Powdermill Run	0.669	0.157
LOW_WIND (minimum sigma-v=0.5 m/s)	Powdermill Run	0.604	0.154
Default (minimum sigma-v=0.2 m/s)	Sugar Run	0.442	0.171
LOW_WIND (minimum sigma-v=0.5 m/s)	Sugar Run	0.342	0.131
Default (minimum sigma-v=0.2 m/s)	Terrys Run	0.352	0.199
LOW_WIND (minimum sigma-v=0.5 m/s)	Terrys Run	0.320	0.153
Note: smaller value of CPM indicates "better" performance; the LOW_WIND option consistently has a lower CPM value.			

Figure 7-7: Composite Performance Measure and 90% C.I. Results at Baldwin Creek Monitor

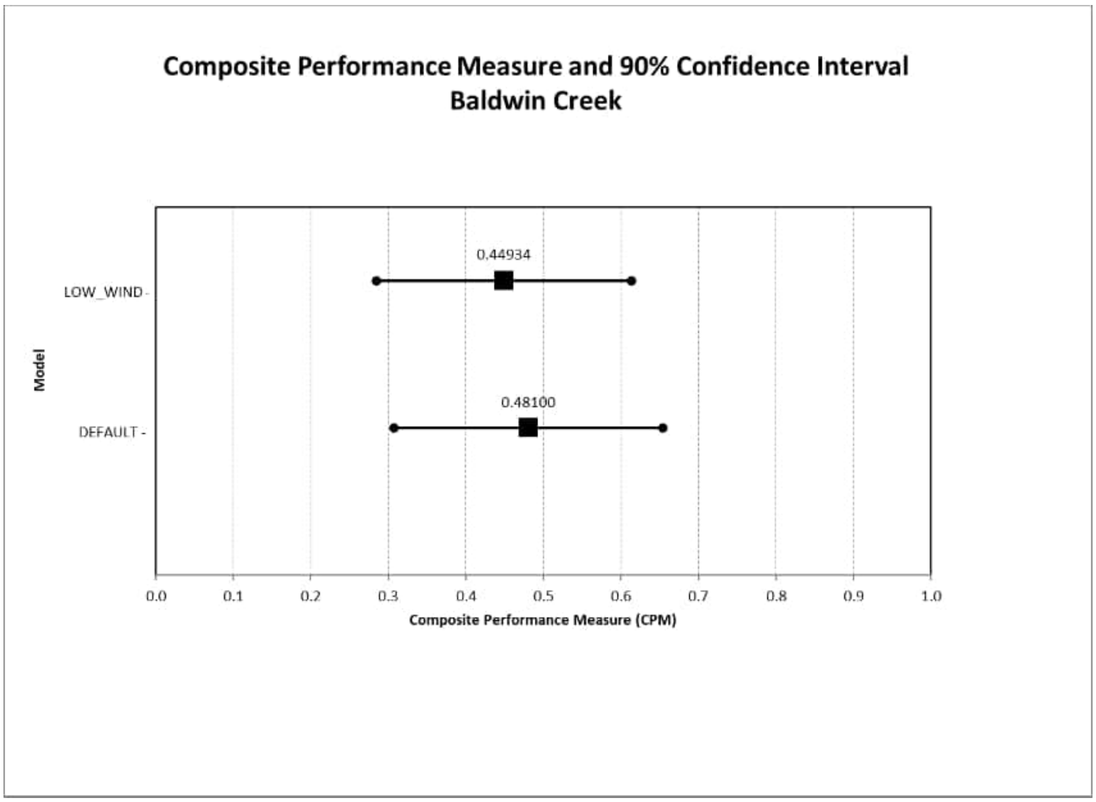


Figure 7-8: Composite Performance Measure and 90% C.I. Results at Powdermill Run Monitor

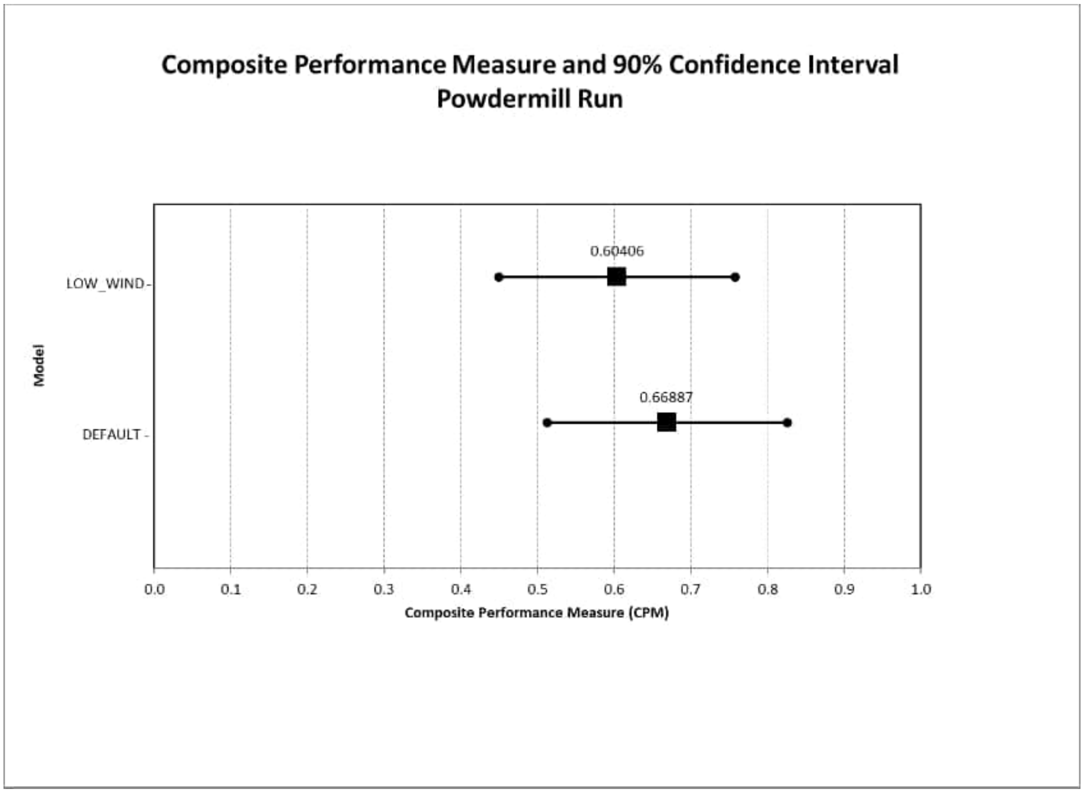


Figure 7-9: Composite Performance Measure and 90% C.I. Results at Sugar Run Monitor

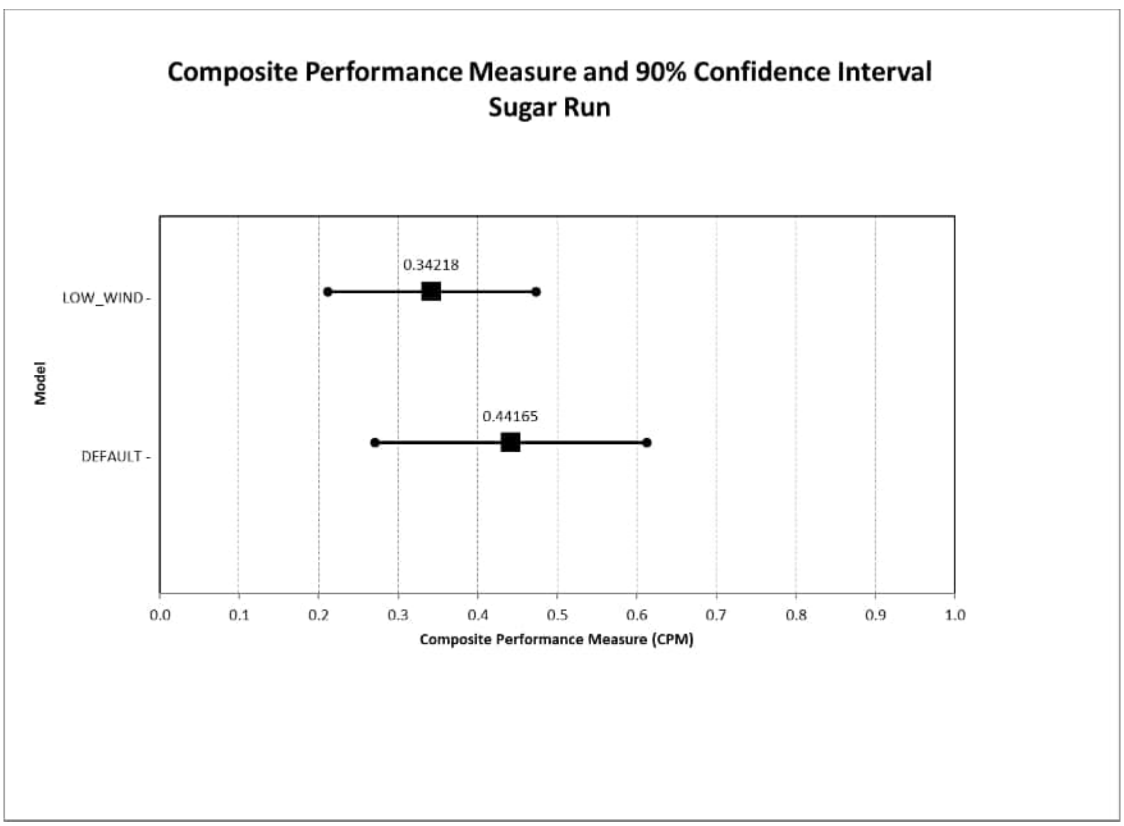
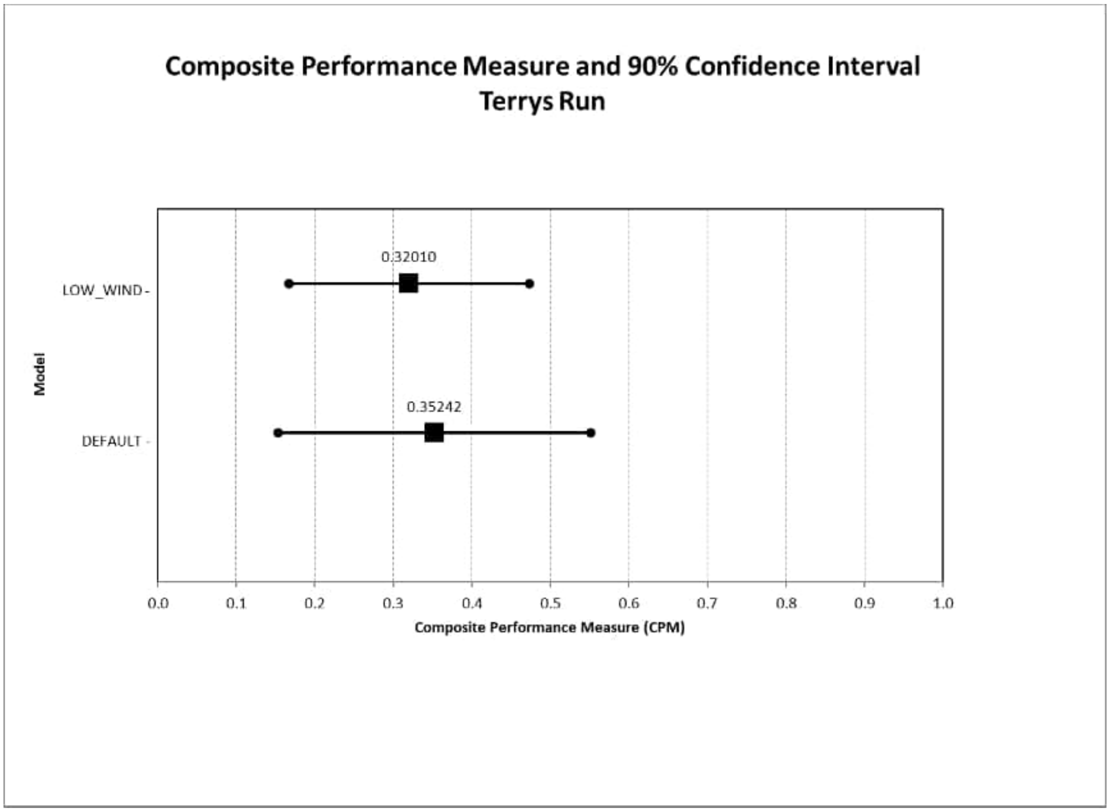


Figure 7-10: Composite Performance Measure and 90% C.I. Results at Terrys Run Monitor



7.2.3 Combined Stage Results

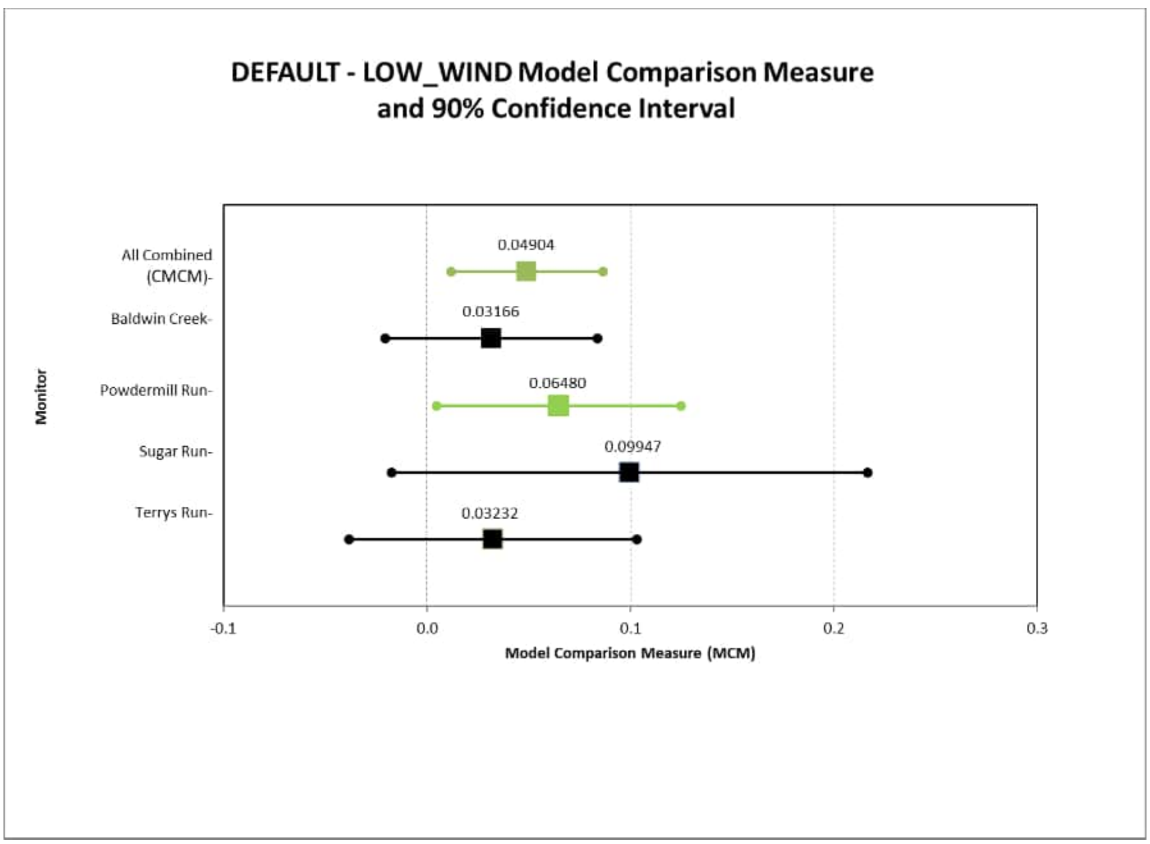
The results of the MCM is shown in **Table 7-6**. The MCM result for each monitor is approximately equal to the default model's CPM value minus the alternative model's CPM value. A positive result for the MCM indicates that the alternative model (LOW_WIND) has a better performance than the default AERMOD model, and a negative result indicates that performance of the default model is better. The MCM values are positive for all four monitors, indicating consistently better performance by the alternative model. For the overall combined model comparison measure (CMCM), the alternative model performance meets the criteria of being statistically significantly improved over the default model within a 90% confidence interval, as the range of the confidence interval does not cross zero. This is shown graphically in **Figure 7-11**. Note that even at the more stringent 95% confidence interval, the range of the CMCM still does not cross zero and therefore it still remains statistically significant. For the individual monitors, the Powdermill Run site also meets the criteria of being statistically significantly for the alternative model.

Table 7-6: Model Comparison Measure Results

Monitor	MCM	+/-90% Confidence Interval[1]	+/-95% Confidence Interval[2]
All Combined (CMCM)	0.0490	0.0373	0.0445
Baldwin Creek	0.0317	0.0522	0.0622
Powdermill Run	0.0648	0.0601	0.0716
Sugar Run	0.0995	0.1169	0.1393
Terrys Run	0.0323	0.0708	0.0843

Note: if MCM confidence interval spans zero, performance differences are not statistically significant
[1] Computed by applying the ratio of 90% confidence interval (standard deviation of 1.645) to 95% confidence interval (standard deviation of 1.96) to the 95% confidence interval value.
[2] Computed by MEM software.

Figure 7-11: Model Comparison Measure and 90% Confidence Interval



Notes: Green-shaded plots indicate that it meets the criteria for being a "statistically significant" difference between the models.

7.3 Supplemental Evaluation Using the Ash Site #1 Meteorological Data

A second set of model runs of the Laurel Ridge study was conducted, but the meteorological dataset was replaced with that of the September 2015 through August 2016 Ash Site #1. This allows for a comparison of the modeled concentrations at the Laurel Ridge monitors for the following:

- Use of the Ash Site #1 meteorological data still yields improved model performance with the alternative model compared to the default while still being conservative to the monitored concentrations, and
- The modeled concentrations are generally higher with the Ash Site #1 meteorological dataset versus the Ash Valley meteorological dataset.

Figure 7-12 shows the Q-Q plot of the maximum hourly concentrations among the four Laurel Ridge monitors for the default model runs using either the 1990-1991 Ash Valley meteorology or the 2015-2016 Ash Site #1 meteorology. For the default model runs, the run utilizing the 2015-2016 Ash Site #1 meteorology yields higher concentrations (above approximately 800 µg/m^3) and then slightly higher to equal concentrations (below approximately 800 µg/m^3). The same behavior is observed for the alternative model runs using the two meteorological datasets in **Figure 7-13**. For both the default and alternative model runs, the use of the Ash Site #1 meteorology not only produces concentrations that are more conservative than the monitored data, but is also more conservative than the corresponding runs using the 1990-1991 Ash Valley meteorology. **Figure 7-14** illustrates through this Q-Q plot that a similar improvement in the model by reducing the concentrations on the top end of the distribution with the use of the alternative model minimum sigma-v adjustment versus the default when using the 2015-2016 Ash Site #1 meteorology.

Figure 7-12: Q-Q Plot of Laurel Ridge Dataset Using Ash Valley vs. Ash Site #1 Meteorological Data – Default Model Runs

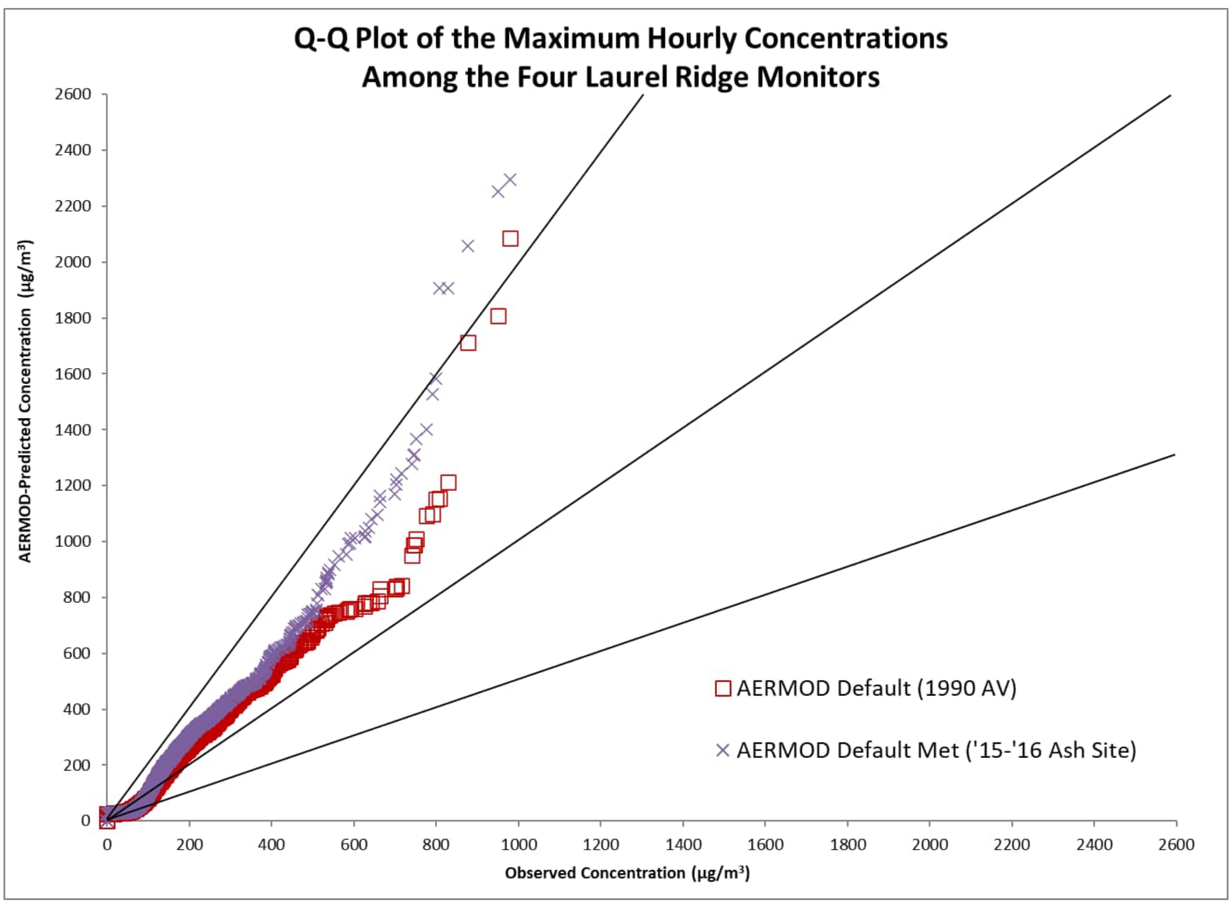


Figure 7-13: Q-Q Plot of Laurel Ridge Dataset Using Ash Valley vs. Ash Site #1 Meteorological Data – Alternative Model Runs

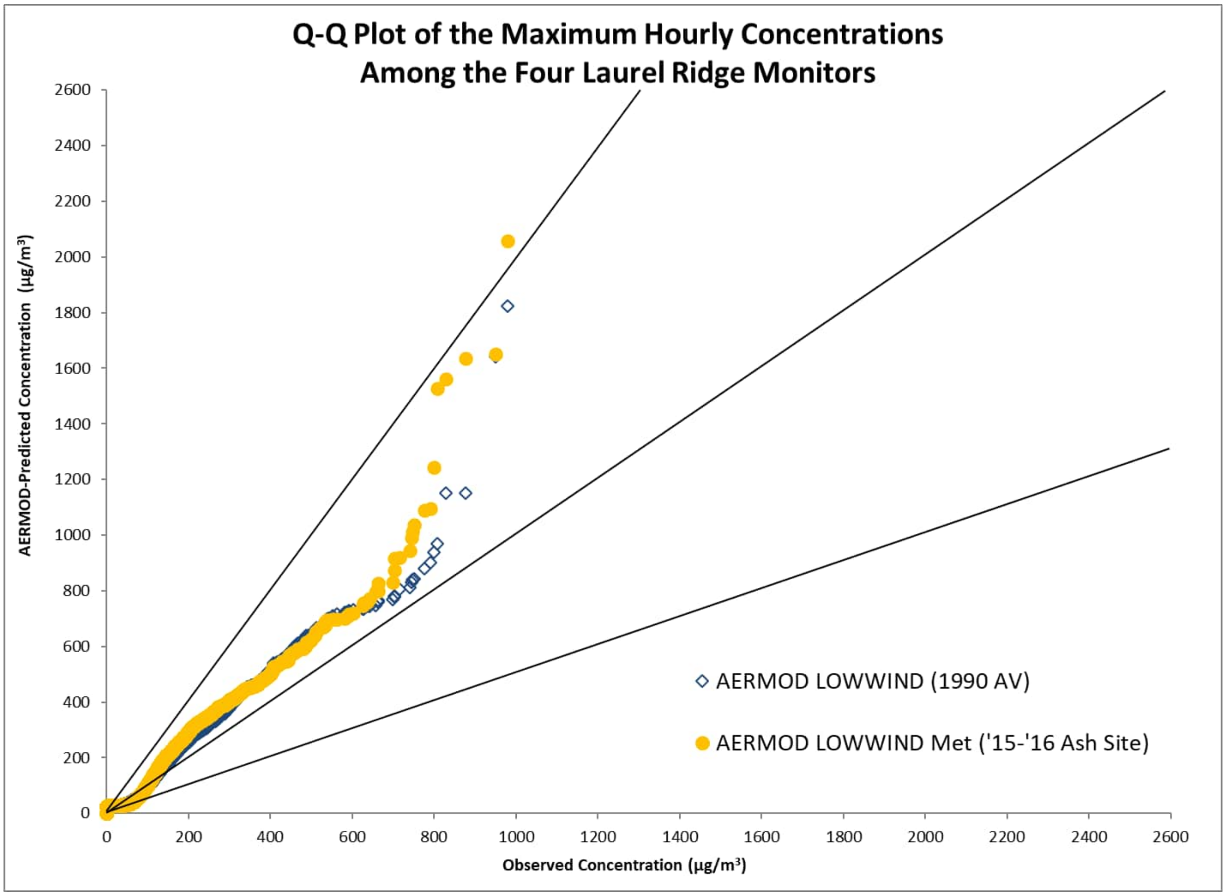
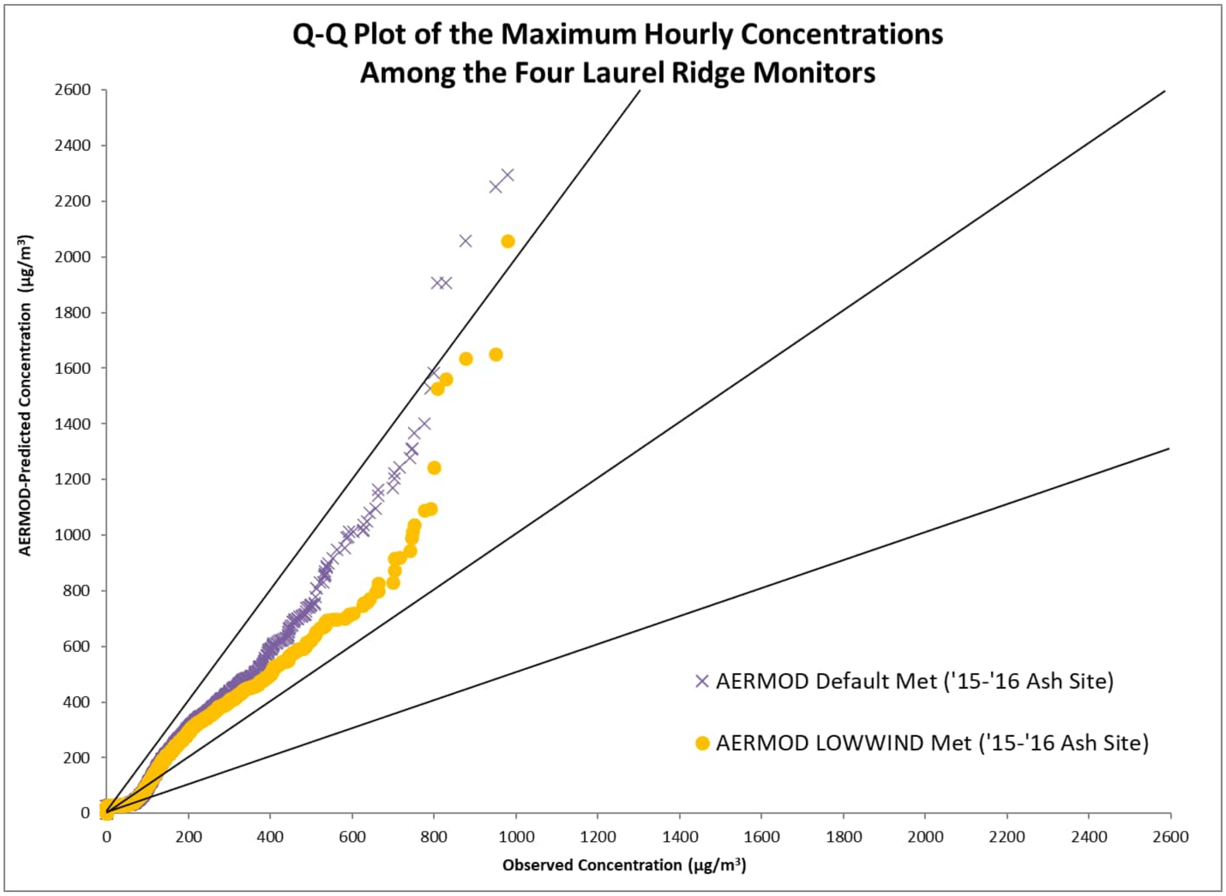


Figure 7-14: Q-Q Plot of Laurel Ridge Dataset Using Ash Site #1 Meteorological Data – Default vs. Alternative Model Runs



8. Summary of Results and Requirements Fulfilled by the Laurel Ridge Study for Justification of an Alternative Model

8.1 Summary of Results

A comprehensive and qualitative analysis was conducted to evaluate the performance of an alternative model compared to the default, regulatory model for a historical field database in an area of complex terrain in western Pennsylvania. The study, referred to as Laurel Ridge, consisted of a 1-year field study (August 1, 1990 through July 31, 1991) that included the collection of SO_2 emissions, meteorological and monitoring data. The key sources of SO_2 emissions were from power plant facilities in Indiana and Armstrong counties of Pennsylvania. The model evaluation focused on monitors, located to the southeast of the SO_2 sources, on Laurel Ridge. The orientation of the complex terrain associated with the ridge relative to the SO_2 emission sources introduced unique challenges to dispersion modeling for this site-specific area. Dispersion modeling was conducted with EPA's preferred near-field model, AERMOD. Based on the results presented in Section 7, the model using default, regulatory options yields significant overprediction bias relative to the observed concentrations along the ridge. As demonstrated in this model performance evaluation report, adjusting the model to account for enhanced wind meandering improves the performance of the model. This adjustment, supported by peer-reviewed paper (discussed in Section 2), established a minimum value of sigma-v to be 0.5 m/s (compared to the default minimum value of 0.2 m/s).

The performance evaluation of the alternative model (using minimum sigma-v of 0.5 m/s) showed through visual graphics (Q-Q plots) and several statistical measures (RHC, FB, CPM, MCM, CMCM) that the alternative model consistently outperformed the default model. The alternative model was found to reduce the overprediction bias of the default model, while remaining conservative relative to the observed concentrations.

The report also demonstrated that the proposed Ash Site #1 meteorological dataset also results in a similar level of improvement with the use of the alternative model compared to the default. The use of the Ash Site #1 meteorological also yields conservative modeled concentrations to the Ash Valley meteorological dataset. This was a key element of the analysis as the Ash Site #1 meteorology is the proposed dataset to be used for a CDD modeling demonstration that overlaps with the area that the Laurel Ridge study covers.

8.2 Fulfilling the Requirements for an Alternative Model

Appendix W Section 3.2.2(e) prescribes the conditions that need to be addressed for approval of an alternative model. The following list goes through each element of the requirements needed to fulfill Section 3.2.2(e) of Appendix W and how the information in this report satisfies it.

1) <u>The model or technique has received a scientific peer review.</u>

   EPA has acknowledged model performance issues during low wind conditions in complex terrain (EPA 2021). Introduced in AERMOD version 12345, LOWWIND1 and LOWWIND2 non-default options were added by EPA to address concerns regarding model performance under low wind speed conditions. LOWWIND1 and LOWWIND2 increased the minimum sigma-v value from 0.2 m/s (default) to 0.5 m/s and 0.3 m/s, respectively. Both were hardcoded values that the user could not modify. LOWWIND3 was later introduced in AERMOD version 15151 that also increased the minimum sigma-v to 0.3 m/s but included the use of the non-default FASTALL approach. In AERMOD 18181, a new LOW_WIND keyword option replaced the former LOWWIND1, LOWWIND2, and LOWWIND3 options. The LOW_WIND option, which is a non-default alpha option in AERMOD 24142, allows the user to specify values for minimum sigma-v, minimum horizontal wind speed, and maximum meander fraction. The LOW_WIND technique, specifically where the minimum sigma-v is increased, has been evaluated using AERMOD in complex terrain in peer-reviewed journal articles (see Attachment A -- Hanna 1983; Hanna 1990).

2) <u>The model or technique can be demonstrated to be applicable to the problem on a theoretical basis</u>.

   The evaluation described in the modeling report used a non-guideline, alpha low wind option (LOW_WIND) that EPA itself proposed (in a similar form as "LOWWIND3" that was proposed by EPA in 2015 for inclusion in Appendix W, as a guideline option). Plume meander can also be greatly affected by vertical shear, terrain induced eddies, and flow perpendicular to significant terrain features. A parameter that is used in the computation of the horizontal plume spreading in AERMOD (which accounts for meandering in low wind conditions) is the above-mentioned standard deviation of the crosswind component, sigma-v (σ_v), which can be parameterized as being proportional to the friction velocity, u* (Smedman, 1988; Mahrt, 1998). These investigators found that there was a minimum, non-zero value of σ_v that can be attributed to wind meandering over the course of a given hour. Hanna[11] found that the hourly-averaged σ_v has a non-zero minimum value of about 0.5 m/s as the wind speed approaches zero. Chowdhury et al. (2016) noted, based upon research conducted by Hanna (1983) and Etling (1990) that a minimum σ_v of 0.5 m/s is justified as a part of the formulation for the advanced puff model SCICHEM.

Besides the technical issues about meander in stable conditions discussed above, the proposed LOW_WIND option has the effect of introducing more meander into the plume centerline concentration that results from complex terrain and wind shear effects that are characteristics of the perpendicular flow across the Conemaugh River Valley and into Laurel Ridge. As discussed in Section 2, the site-specific challenges in properly accounting for the magnitude of horizontal plume meander can be more appropriately addressed using the LOW_WIND option with an increased minimum sigma-v value and is consistent with the findings from the peer-reviewed journal article (Hanna 1990 – see Attachment A).

3) The databases which are necessary to perform the analysis are available and adequate.

The relevance of the 1990-1991 field study to the current modeling application was discussed in Section 4. A rigorous and exhaustive review of the data was performed to identify valid hours for use in a model evaluation demonstration. This review resulted in a total of 7,714 hours of the original 8,760 hours when emissions for all sources in operation had emissions, meteorological data and monitoring data available. This process is consistent with the standards that other modeling database that EPA uses to evaluate AERMOD on.

4) Appropriate performance evaluations of the model or technique are available.

These evaluations need to show that the model or technique is not inappropriately biased for regulatory application. Specifically, EPA prefers that a statistical performance evaluation is conducted using measured air quality data and the result of that evaluation indicates that the alternative model performs better for the given application than a comparable model in Attachment A of Appendix W (default AERMOD). This modeling report describes, in detail, how a site-specific performance evaluation using ambient monitoring data in the area of the Seward and Conemaugh stations along Laurel Ridge was performed. The set of performance metrics that were used are consistent with other site-specific alternative model requests that have received EPA-approval. The suite of performance metrics used for this alternative model demonstration included the following:

- Peak and 99th percentile design concentration (predicted-to-observed) ratios at each monitor and across all four monitors,
- Quantile-Quantile (Q-Q) plots of the ranked hourly SO_2 predicted and observed hourly concentrations across all four monitor and at each monitor, and
- Statistical performance measures from EPA's Protocol for Determining the Best Performing Model (including the Robust Highest Concentration (RHC), fractional bias (FB) of the Top 25 concentrations, the Composite Performance Measure (CPM). Model Comparison Measure (MCM), and Composite Model Comparison Measure (CMCM)).

As discussed in Section 7, the performance evaluation of the alternative model (using minimum sigma-v of 0.5 m/s) showed through visual graphics (Q-Q plots) and the statistical measures (RHC, FB, CPM, MCM, CMCM) that the alternative model consistently outperformed the default model. The alternative model was found to reduce the overprediction bias of the default model, while remaining conservative relative to the observed concentrations.

The report also demonstrated that the proposed Ash Site #1 meteorological dataset also results in a similar level of improvement with the use of the alternative model compared to the default. The use of the Ash Site #1 meteorological also yields conservative modeled concentrations to the Ash Valley meteorological dataset. This was a key element of the analysis as the Ash Site #1 meteorology is the proposed dataset to be used for a CDD modeling demonstration that overlaps with the area that the Laurel Ridge study covers.

5) Modeling procedures that were established have been followed.

This modeling report provides the modeling procedures for the application of AERMOD using the LOW_WIND with a minimum sigma-v of 0.5 m/s for receptors being modeled with the on-site meteorological data. The modeling procedures were approved by EPA on September 30, 2025 and are consistent with those described in Appendix W.

Attachment A

Hanna, 1983: Lateral Turbulence Intensity and Plume Meandering During Stable Conditions

Hanna, 1990: Lateral Dispersion in Light-Wind Stable Conditions Paper

Lateral Turbulence Intensity and Plume Meandering During Stable Conditions

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(Manuscript received 27 December 1982, in final form 19 March 1983)

ABSTRACT

There is much evidence in the literature for the presence of mesoscale lateral meanders in the stable nighttime boundary layer. These meanders result in relatively high lateral turbulence intensities and diffusion rates when averaged over an hour. Anemometer data from 17 overnight experiments at Cinder Cone Butte in Idaho are analyzed to show that the dominant period of the mesoscale meanders is about two hours. Lidar cross-sections of tracer plumes from these same experiments show that the hourly average σ_y is often dominated by meandering. Since meandering is not always observed for given meteorological conditions, it is suggested that nighttime diffusion cannot be accurately predicted without using onsite observations of wind fluctuations. In case no turbulence data are available, an empirical formula is suggested that predicts the hourly average lateral turbulence intensity as a function of wind speed and hour-to-hour variation in wind direction.

1. Introduction

Similarity theory is adequate for estimating turbulence and diffusion during unstable and neutral conditions in the planetary boundary layer. It is also satisfactory for the vertical component of turbulence during stable conditions, since vertical turbulence levels approach zero as stability increases. In these conditions, turbulent energy components σ_v^2 and σ_w^2 are functions of u_* or w_*, z/L, and z_i/L. The parameters σ_v and σ_w are the standard deviations of the lateral and vertical components of turbulent velocity, u_* the friction velocity, L the Monin–Obukhov length, z_i is mixing depth, z is elevation, and w_* the convective scaling velocity [$w_* = (gQ_0z_i/T)^{1/3}$]. The parameter Q_0 is the surface heat flux. Similarity theory does not apply to the lateral component σ_v^2 during stable conditions, when mesoscale eddies or lateral meandering may possibly dominate the measured value (Pasquill, 1974). Several examples of observations of meandering are reviewed in Section 2, providing background for these conclusions and illustrating how the lateral turbulence intensity σ_v/u is a function of wind speed and hour-to-hour variations in wind direction during light-wind stable conditions. This functional dependence is not accounted for by EPA regulatory models but is suggested in some NRC regulatory models (Nuclear Regulatory Commission Regulatory Guide 1.145).

In Section 3 evidence is given of increased lateral turbulence and diffusion due to mesoscale eddies with period 1 to 4 hours at Cinder Cone Butte, Idaho. The first field experiment of EPA's Complex Terrain Model Development (CTMD) program took place in 1980 at Cinder Cone Butte (CCB) (Lavery *et al.*, 1982). This is a multi-year program with the purpose of development of diffusion models for regulatory application in complex terrain. The CCB is an isolated 100 m symmetrical hill located on a flat plain in the Snake River Basin. The field study included ten flow visualization (oil–fog) experiments and 18 multi-hour tracer gas experiments conducted during stable flow conditions. Supporting meteorological, photographic and lidar data were acquired. Because the principal 150 m meteorological tower was sited in a location outside the zone perturbed by CCB during easterly and west-northwesterly stable winds and because the oil–fog and tracer gas release location (via a mobile crane) was typically 1 km upwind of CCB, the tower and source data do not reflect the butte's perturbation and can be analyzed as if they were taken over flat terrain. Considerable lateral meandering of the plume was often observed during light-wind stable conditions. In this study, time series analysis techniques are used to estimate the time scales of these mesoscale fluctuations. Energy spectra and autocorrelograms are used as a basis for estimation of time scales. Lidar cross-sections of the plume upwind of the butte also illustrate the meandering of the plume centroid and its influence on hourly averaged plume spread. Finally, the 136 hours of data are used to verify an empirical formula that permits the hourly average lateral turbulence intensity to be estimated from hourly average wind speed and direction records.

2. Background

Current models of atmospheric diffusion at short distances in the boundary layer are generally satisfactory for nearly-neutral stabilities. The parameters of the Gaussian plume model, which is used for most regulatory applications, are best defined for those conditions. Furthermore, other diffusion models, such as similarity theory and K theory models, are most dependable in the neutral limit, where the Monin–Obukhov length L does not enter the problem. Studies of the unstable boundary layer (Deardorff, 1974) suggest that diffusion under unstable conditions is determined by the convective velocity scale w_* and the mixing depth z_i. However, on the stable side, boundary layer parameters and diffusion are well-determined only for slightly stable conditions when there is sufficient mechanical turbulence generated to assure that the atmosphere is well-mixed (critical Richardson number less than about one). Vertical turbulence and diffusion rates are small, and as a consequence of the three-dimensional nature of small scale turbulence, diffusion due to small scale eddies in all three components is reduced. However, two-dimensional mesoscale horizontal eddies are not suppressed by vertical stability forces and are produced by gravity waves, terrain interactions with the flow, mesoscale rolls and cell patterns in the synoptic flow or surface inhomogeneities. Their effect on plumes is usually recognized as a slow meandering of the plume; i.e., the instantaneous plume may be thin but over a time period of an hour or more it may meander over a wide angle.

Pasquill (1974) briefly reviews the variation of the standard deviation of wind direction fluctuations σ_θ during stable conditions, where σ_θ is related to the lateral turbulence intensity $i_y = \sigma_v/u$, by the formula,

$$\tan\sigma_\theta = \sigma_v/u = i_y. \quad (1)$$

This parameter is important for calculating diffusion because it is used in the following relation for σ_y (Pasquill, 1976):

$$\sigma_y = i_y x F_y(x),$$
$$(i_y = \sigma_\theta \quad \text{for small } \sigma_\theta) \quad (2)$$

where σ_y is the standard deviation of the lateral concentration distribution in the plume, and $F_y(x)$ a dimensionless function that is close to unity at distances less than 1 km from the source and drops to about 0.5 to 0.8 at a distance of 10 km. Pasquill presents data observed by Smith and Abbott (1961), which are reproduced here as Fig. 1, illustrating that σ_θ increases as winds become light at night (i.e., as stability increases). The best fit line through these data suggest that at that particular measurement site (Porton, England) during stable conditions, σ_v is relatively insensitive to both wind speed and stability (in fact σ_v retains a value of about 0.3 m s^{-1} for all wind speeds during stable conditions).

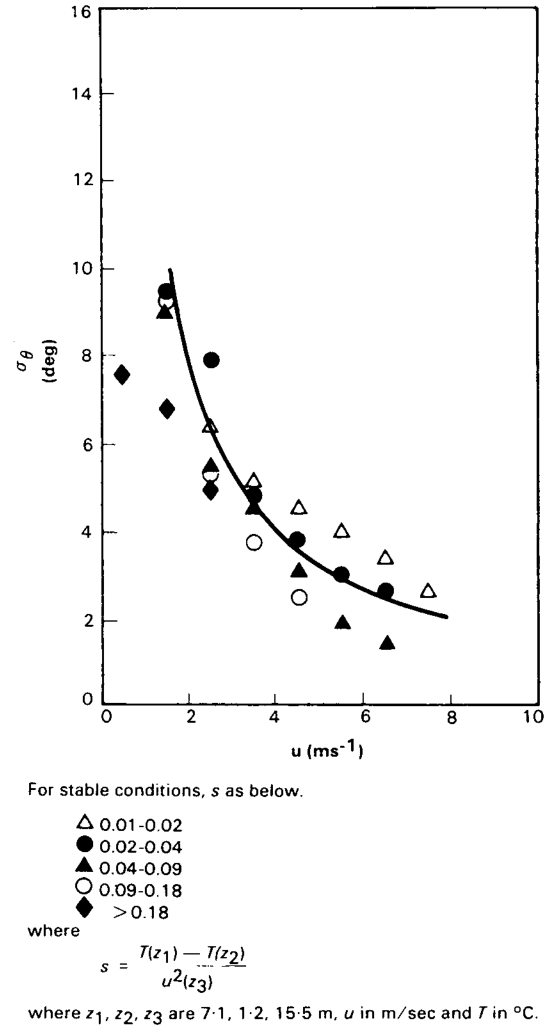

FIG. 1. Wind direction fluctuation as a function of wind speed and stability observations (from Smith and Abbott 1961) at a height of 16 m over open grassland, Porton.

Similar results were obtained from a complex terrain site in California by Hanna (1981a) during nighttime conditions, who found that a constant value of σ_v ($\approx\sigma_\theta u$) of about 1 m s^{-1} is most appropriate for this site, independent of wind speed. It seems reasonable that the larger value of σ_v in California is due to lateral eddies induced by the terrain (measurement heights were not much different—16 m in England and 10 m in California). The analysis further illustrated the large variability in σ_θ at low wind speeds for σ_θ was found to vary between 20 and 100° at a wind speed of 1 m s^{-1}.

An another example Schacher *et al.* (1982) found that σ_θ was relatively large and variable during stable conditions for an overwater diffusion experiment performed off the California coast. A constant value of

σ_v of about 0.5 m s^{-1} is appropriate for these data. They attributed their observations of large σ_θ to local mesoscale eddies caused by sea breeze interactions with the coastal mountains or flow around the channel islands, but Lemone (1978) states that "the importance of the mesoscale over the ocean emphasizes the tendency of the atmosphere to introduce these scales even without forcing from an irregular lower boundary." Mesoscale eddies or meandering can occur anywhere in the earth's planetary boundary layer, no matter how flat and uniform the surface.

Standard Environmental Protection Agency regulatory guidance (e.g., as summarized by Gifford 1976) still supports the use of Pasquill–Gifford stability classes determined from winds, cloud cover, and radiation. The Nuclear Regulatory Commission sometimes permits the determination of stability class from σ_θ by means of the following monotonic relationship between Pasquill stability class and σ_θ:

Pasquill class	A	B	C	D	E	F
σ_θ (deg)	≥22.5	17.5–22.5	12.5–17.5	7.5–12.5	3.8–7.5	<3.8

This is a conservative approach, for we see from the data reported by Pasquill (1974), Hanna (1981a) and Schacher *et al.* (1982) that σ_θ is only occasionally observed to be small during stable condition (classes E or F), and usually σ_θ is much larger. The EPA and NRC do allow in special circumstances the use of observed values of σ_θ to estimate σ_y from a method such as that in Eq. (1), but special permission is required for each application. The Nuclear Regulatory Commission (NRC, 1979) has recognized this inconsistency between the Pasquill class and the σ_θ's given in the above table, and has sponsored a series of tracer experiments during light-wind, stable conditions (e.g., Sagendorf and Dickson, 1974; VanderHoven, 1976). Sagendorf and Dickson report observations of hourly average σ_θ from 12 to 72° for wind speeds ranging from 0.8 to 1.9 m s^{-1}. The information in these experiments as well as several other field experiments was condensed into a set of tentative empirical correction factors for σ_y for lateral meander suggested in NRC Regulatory Guide 1.145 (see Figure 2). According to these procedures σ_y would be calculated using standard Pasquill–Gifford–Turner techniques and then multiplied by the factor M which is as high as 6.0 for stability class G and wind speeds less than 2 m s^{-1}. The NRC stresses that this guidance is preliminary and needs testing.

Kristensen *et al.* (1981) developed a mathematical model for stable diffusion based on Taylor's statistical theory, where it is required that the time scale of the meandering eddies be known. They used meteorological data from Riso, Denmark, and the small island of Sprogo to show that, as a rule, meandering is present in a strongly stable atmosphere with low wind speeds. Values of σ_y for an averaging time of three hours at a downwind distance of 20 km were calculated from their theory using Riso data with the result that σ_y is seen to be largest for strongly stable conditions with light wind speeds. The "best fit" line from their calculations is given by the formula,

$$\sigma_y = 5400u^{-0.8},$$
$$(\sigma_y \text{ in m at } x = 20 \text{ km}, \quad u \text{ in m s}^{-1}). \quad (3)$$

All the evidence in the report by Kristensen *et al.* and the other papers reviewed above suggests that i_y, σ_θ, and σ_y are often large during light-wind, stable conditions. In the remainder of this paper, we provide further evidence for this effect from a diffusion experiment at Cinder Cone Butte, Idaho, analyze the spectral characteristics of the lateral mesoscale eddies or meanders that produce this effect, and suggest a simple empirical formula for stable i_y.

3. Time series analysis of wind speed data at Cinder Cone Butte

The purpose of the EPA-sponsored field study at Cinder Cone Butte was to aid in the development of a diffusion model for plume impaction on elevated terrain. Experiments took place on several nights during October 1980, and tracer releases were from ele-

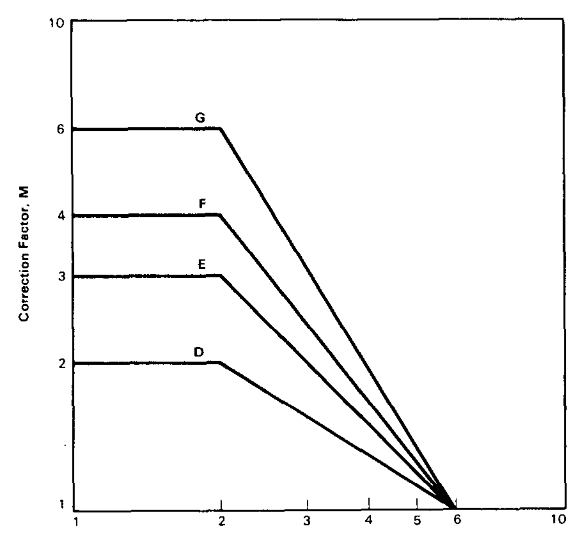

FIG. 2. Correction factors for Pasquill-Gifford σ_y values due to meander, based on a figure in NRC Regulatory Guide 1.145. The letters G, F, E, D denote the stability class based on $\Delta T/\Delta z$.

vations varying from ~20 to ~80 m. Wind speed data were obtained from three-component propeller anemometers at the 40 or 80 m levels on a 150 m tower. Since the butte is a relatively small hill on an otherwise flat plain, the measurements upwind of the butte can be treated as if they are representative of flow over a flat surface. These wind observations confirm the findings at other sites reported in Section 2. The 8 h wind records are characterized by slow fluctuations in wind speed and direction. Meanders or mesoscale fluctuations are evident on strip charts of wind velocity and suggest time periods on the order of 10 min to several hours. Some of the CCB experiments exhibit exceptional variability in wind speed and direction. For example, a time series of the 5 min average u-component wind speed from the 40 m level of the 150 m tower for Experiment 207 from 0000 to 0800 LST 25 October 1980 is plotted in Fig. 3. Eddies with periods of 30 min to 2 h are apparent on this figure. In a few of the 8 h experiments at CCB the wind direction went completely around the compass during the period.

Energy spectra of the wind speed during stable nighttime conditions were calculated for seventeen CCB experiments of eight-hour duration. A standard Fast Fourier Transform (FFT) computer code was applied to the u and v components of the wind speed for each experiment. A linear trend was removed from each time series, since a trend will show up in the spectrum as a great deal of energy at the lowest frequency point. Also the beginning and end of the time series were smoothed to prevent unrealistic behavior of the spectrum at high frequencies (Rayment, 1970; Cooley and Tukey, 1965). Autocorrelograms and spectra were plotted for each experiment. The autocorrelogram and energy spectrum for the data in Fig. 3 are given in Figs. 4 and 5. The autocorrelogram indicates strong cyclic behavior, reaching a minimum of −0.65 at a time lag of 50 min and a secondary maximum of 0.40 at a time lag of about 120 min. The spectrum is seen to contain the most energy in the frequency range from about 0.2 to 1 cycles per hour.

A summary of the time series analysis of 17 of the CCB experiments is given in Table 1. Wind observations at the 40 m level of the 150 m tower were used if available; otherwise, the winds at the 80 m level were used. The time period T_{max} at which maximum turbulent energy occurs is estimated by two procedures:

• Autocorrelogram method: $T_{max} = 5T(e^{-1})$, where $T(e^{-1})$ is the time lag when the autocorrelogram first drops to e^{-1} or 0.37. The time period T_{max} of the turbulent fluctuation associated with $T(e^{-1})$ is obtained by multiplying by 5. The factor 5 comes from cal-

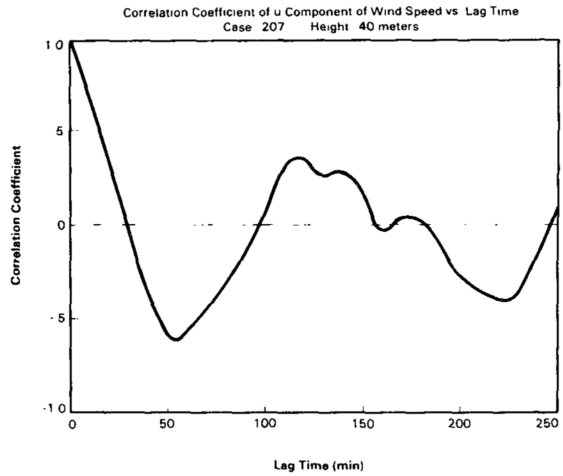

FIG. 4. Autocorrelogram for data in Fig. 3.

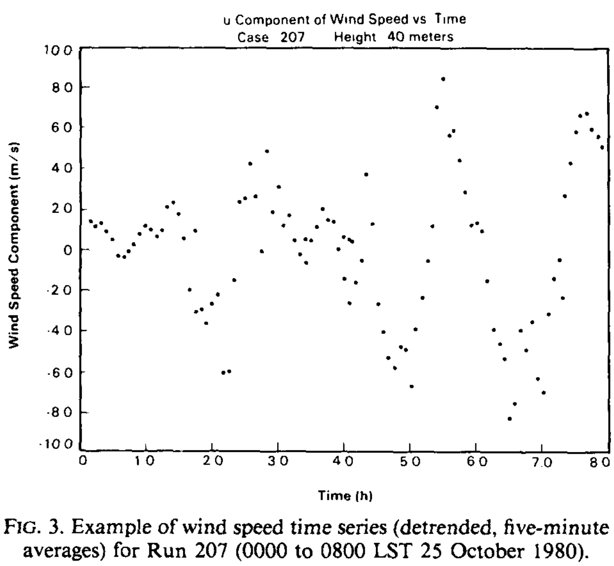

FIG. 3. Example of wind speed time series (detrended, five-minute averages) for Run 207 (0000 to 0800 LST 25 October 1980).

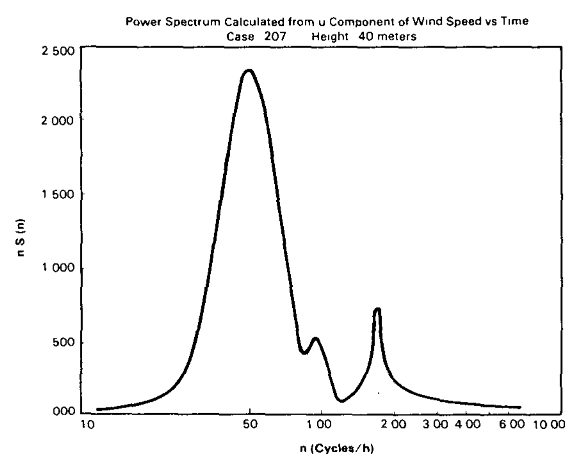

FIG. 5. Power spectrum for data in Fig. 3.

TABLE 1. Time scales as estimated by the spectral and autocorrelogram techniques for 34 CCB time series.

			Time scale (min)	
Run	Wind component	Height (m)	from spectrum	from autocorrelogram
201	u	40	100	80
201	v	40	120	110
202	u	40	86	85
202	v	40	120	140
203	u	40	50	100
203	v	40	120	125
204	u	40	67	100
204	v	40	55	100
205	u	80	200	175
205	v	80	120	115
206	u	80	120	85
206	v	80	150	160
207	u	40	100	85
207	v	40	150	125
208	u	40	120	135
208	v	40	120	135
209	u	40	120	85
209	v	40	55	50
210	u	80	200	175
210	v	80	100	50
211	u	80	100	110
211	v	80	120	150
213	u	40	120	140
213	v	40	240	200
214	u	40	240	275
214	v	40	120	100
215	u	40	210	110
215	v	40	240	250
216	u	40	—	250
216	v	40	240	200
217	u	40	240	100
217	v	40	86	125
218	u	40	240	150
218	v	40	240	175
	Median		120 min	125 min
	Range		50–240 min	50–275 min

culating the spectrum for a sinusoidal fluctuation (Hanna, 1981b).

• Spectral method: T_{max} is the period associated with maximum $nS(n)$, where n is frequency and S is energy density in units of $m^2 s^{-2}$ per unit frequency.

The T_{max} values determined by the autocorrelogram and spectral methods agree within about ±50%. The median T_{max} equals ~2 h with a range from 50 min to 275 min for the CCB cases. Thus the time series analyses suggest time scales of about one to four hours for the lateral mesoscale meanders at CCB.

The CCB data also reveal a dependence of lateral turbulence intensity $i_y = \sigma_v u^{-1}$ on wind speed similar to that exhibited by the data in Fig. 1. Hourly average i_y and u are plotted in Fig. 6, illustrating that i_y is small and well-behaved for high wind speeds but is large and scattered for low wind speeds. These data suggest that hourly average σ_v is equal to ~0.50 m s^{-1} during average nighttime conditions over the Snake River Plain in Idaho. The magnitude of σ_v here is midway between that observed over flat grassland in England and mountainous terrain in California.

The information in Figs. 3 through 5 can be used to develop an empirical formula for average hourly lateral turbulence intensity i_y that is based on hourly wind speed and direction data. We see in Figs. 3 and 5 that there is often much mesoscale energy at time scales greater than the one-hour averaging time for meteorological variables at CCB, but also that there are fluctuations at time scales less than one hour. It is reasonable to break up average hourly i_y into two independent components—a component i_{y1} accounting for eddies with time scales greater than one hour and a component i_{y2} accounting for eddies with time scales less than one hour:

$$i_y^2 = i_{y1}^2 + i_{y2}^2. \tag{4}$$

We assume that the large-scale component i_{y1} is caused entirely by changes in mean wind direction from hour-to-hour:

$$i_{y1} = \tan[0.145(|\Delta WD_-| + |\Delta WD_+|)], \tag{5}$$

if ΔWD_- and ΔWD_+ are the same sign, or

$$i_{y1} = \tan[0.145\ \mathrm{MAX}(|\Delta WD_-|, |\Delta WD_+|)], \tag{6}$$

if ΔWD_- and ΔWD_+ are different sign, where

ΔWD_- = wind direction (degrees) at hour of interest minus wind direction at previous hour

ΔWD_+ = wind direction (degrees) at next hour minus wind direction at hour of interest.

In this equation wind direction is in degrees and it is assumed that the standard deviation of a uniform

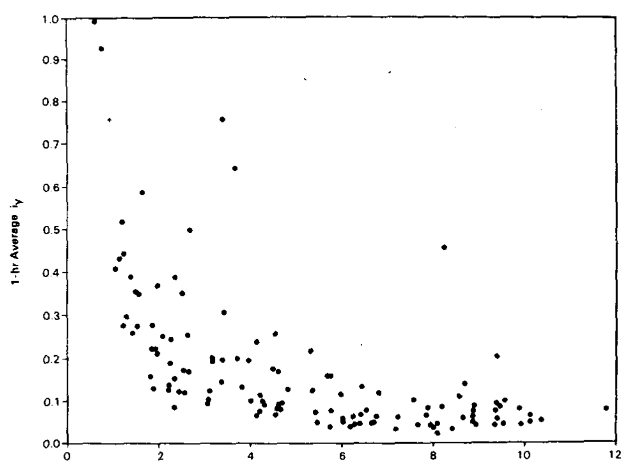

FIG. 6. Average hourly lateral turbulence intensity i_y as a function of wind speed u from Cinder Cone Butte experiment. Most data are from the 40 m tower level; on a few occasions when the 40 m data are not available, the 80 m level is substituted.

distribution equals 0.29 times the width of the distribution. Even if there is no small scale turbulence, a change in wind direction of 40° over a two-hour period centered on the hour of interest will result in an i_y of 0.10.

The small scale component i_{y2} is assumed to be given by the formula:

$$i_{y2} = \sigma_{v2}u^{-1} = (0.5 \text{ m s}^{-1})u^{-1}, \qquad (7)$$

where u is the hourly averaged wind speed in m s^{-1} and $\sigma_{v2} = 0.5$ m s^{-1} is a site-specific constant. This formula is consistent with the data in Figs. 1 and 5, implying that σ_{v2} is nearly constant during stable conditions at any site. We have looked at data from several other sites and find that σ_{v2} ranges from about 0.3 to 1.0 m s^{-1}, depending on local effects such as topography, synoptic conditions, and coastal influences. Predictions of average hourly i_y made using Eq. (4) are compared with observations of i_y at the 10 m level of the CCB tower in Fig. 7, showing that the predictions are fairly good on the average, and that 94% of the observations are within a factor of two of the predictions. The underprediction of the highest six observed i_y values is probably caused by our smoothing procedure for hour-to-hour wind direction changes. If all the wind direction change occurred during a short period, the i_{y1} value calculated by Eq. (5) or (6) would be a factor of two low.

4. Observations of lateral dispersion

Lidar observations of the plume upwind of the Butte were used to estimate cross-wind diffusion, as

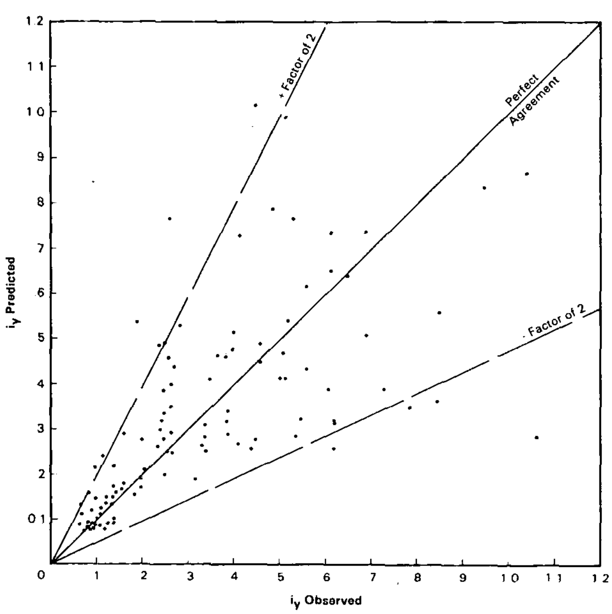

FIG. 7. Observed hourly lateral turbulence intensity at the 10 m level plotted versus predicted hourly lateral turbulent intensity from Eq. (4).

indicated by σ_y, the standard deviation of the lateral concentration distribution. Lidar data were available from less than half the experiments included in Table 1. Nearly instantaneous plume observations σ_{yi} were obtained from individual lidar cross-sections and the total hourly σ_y was estimated by taking the sum of the squares of the instantaneous values and the plume centroid displacements:

$$\sigma_y^2 = \sum_{i=1}^{n} \sigma_{yi}^2 n^{-1} + \sum_{i=1}^{n} (y_{ci} - \bar{y}_c)^2 n^{-1}. \qquad (8)$$

The first and last terms can be thought of as σ_{yt}^2 and σ_{yc}^2, or the contribution to total σ_y due to small-scale turbulence and plume centroid position fluctuations, respectively. The parameter y_c is the centroid position, and n is the number of lidar cross-sections at the particular downwind distance during that hour (usually $n \sim 10$). The contribution to σ_y from lateral displacement of centroids or meandering is greater than the individual scan contribution in about 50% of the cases analyzed. In 20% of the cases, the meander component exceeds the individual scan component by a factor of 5–10. High values of σ_y/σ_{yt} are sometimes observed for all wind speeds less than about 6 m s^{-1} and are never observed for wind speeds greater than 6 m s^{-1}.

If we assume that $F_y(x)$ equals unity at small distances in Eq. (2), then observed lidar σ_y's upwind of the hill should approximate $i_y x$, where i_y is obtained for the source height by linear interpolation from adjacent tower levels. In Fig. 8, the hourly averaged σ_y's are plotted versus $i_y x$ for 13 separate experiment hours. Each hourly σ_y is made up of contributions from individual lidar scans and from the lateral displacement of observed plume centroids [as given in Eq. (8)]. Figure 8 shows that the line $\sigma_y = i_y x$ passes through the middle of the data set, but that the data from individual hours can be as much as a factor of 3 different from this line. The curves for individual hours generally have slopes close to unity. Many factors could contribute to the scatter on the figure, including small sample size, unrepresentative tower i_y, lidar resolution and accuracy, and poor wind instrument response during light and variable winds.

5. Implications of results for diffusion calculations

The presence of mesoscale lateral eddies with periods of about two hours during stable conditions has been confirmed by analysis of 17 overnight experiments at CCB. When averaging times for meteorological and concentration data are one hour, about one-half to one full cycle can be expected to be captured during periods when these mesoscale eddies are present. It is possible that the winds will continually decrease or increase during the 1 h period, or decrease for the first 30 min and increase for the last 30 min of the period, depending on the portion of the sinusoidal wind cycle

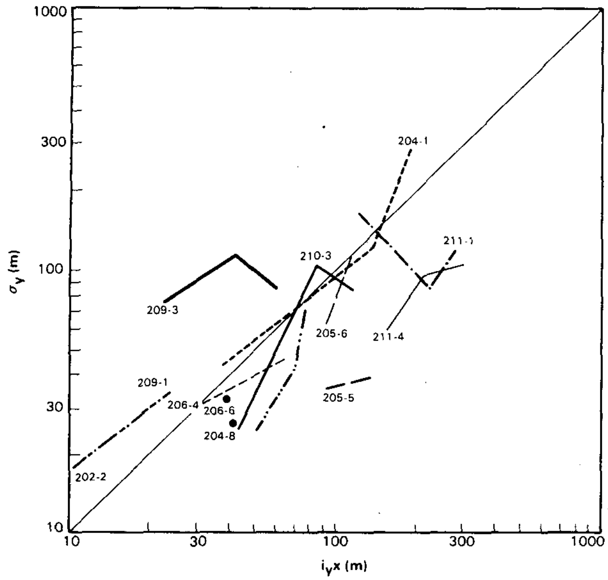

FIG. 8. Observed hourly σ_y plotted as a function of $i_y x$ for selected experiment hours.

that is captured (see Fig. 3). This mesoscale energy thus appears as a trend or a slow meander during a 1-hour period rather than as a turbulent fluctuation. Because these time scales are comparable to the averaging periods of interest, the effects of mesoscale meander must be accounted for explicitly. It is best to use observations of σ_θ, i_y, or the actual hourly probability distributions of wind direction (rather than some conjectured distribution) to model hourly average plume transport and impacts. If the distribution of wind direction is clearly non-Gaussian, then it is important that the actual distribution be used in place of the Gaussian shape in a diffusion model. Kristensen *et al.* (1981) suggest that if the dispersion by meandering is not taken into account, estimates of mean concentrations can easily be a factor of 4–6 too high. If no fluctuation data are available, then an empirical formula [Eq. (4)] can be used to estimate hourly average i_y from hourly records of mean wind speed and direction.

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Lateral Dispersion in Light-Wind Stable Conditions (*) (**).

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Summary. — At downwind distances of 400 m or less, the angular standard deviation, $\sigma_{\theta c}$, of the lateral distribution of pollutants released from a point source over a given time period is shown to equal the standard deviation, σ_θ, of the wind direction fluctuations observed over the same time period. Data taken during light wind, stable conditions at two field sites (Idaho Falls, ID, and Oak Ridge, TN) are used in this analysis. This relation is most reliable if the pollutant concentration distribution is observed on a circle at constant distance from the source (*i.e.*, on a polar coordinate system).

PACS 92.60 – Meteorology.

1. – Introduction.

As the wind speed decreases, the hourly averaged standard deviation, σ_θ, of the wind direction increases. This phenomenon is common knowledge among weather observers and forecasters, who use the terminology «light and variable winds». Because lateral dispersion, σ_y, is directly proportional to σ_θ, it is important to account for this «meandering» effect in plume dispersion models. Mitchell and Timbre [1] and Van der Hoven [2] suggest empirical formulae that account for the increased σ_y in light-wind, stable conditions, and Hanna [3] and Hanna *et al.* [4] expand these methods for use in applied dispersion models. However, there are very few available data bases that can be used for further model development and testing.

This paper describes an analysis of some stable light-wind field data collected by the U.S. Nuclear Regulatory Commission (NRC) in Idaho and Tennessee [2, 5, 6]. These data were also reviewed and summarized by Draxler [7]. The NRC was concerned specifically with the fact that hourly-averaged plumes had been observed to be much wider than plumes predicted by the Pasquill-Gifford-Turner procedures during very stable conditions. Each field experiment consisted of 11 one-hour tracer tests, with concentrations observed at monitors located on circles with radii 100 m, 200 m, and 400 m. The Idaho site was flat with a median observed wind speed of 1.21 m/s and the

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(**) To speed up publication, proofs were not sent to the author and were supervised by the Scientific Committee.

Tennessee site was moderately hilly with a median observed wind speed of 0.31 m/s. The low wind speeds in Tennessee could be resolved only with laser anemometers. The following conclusions related to lateral dispersion are presented in the final reports for these two studies.

Best agreement with observed concentrations is given by models that use meandering enhancement at low wind speed (*e.g.*, the Idaho National Engineering Laboratory (INEL) empirical lateral dispersion curves, a «split-σ» approach, or observed lateral turbulence, σ_θ).

When the plume covers 90° or more of a monitoring arc, a polar coordinate system rather than a rectilinear system should be used to calculate dispersion.

Hanna *et al.* [4] proposed a simple formula for σ_θ that accounted for the plume meandering discussed in the first conclusion. In a subsequent report, they generalized their model so that it employed the polar coordinate system mentioned in the second conclusion. A comparison of the σ_y formula predictions with the Idaho Falls observations is given below.

2. – Formulae for σ_y in light-wind stable conditions.

The data collected by the Idaho Falls scientists provide an excellent opportunity for testing the formulae suggested by Hanna *et al.* [4]:

$$\sigma_y = i_y x (1 + 0.0001x)^{-1/2}, \tag{1}$$

where i_y is the lateral turbulence intensity, σ_v/u, which equals σ_θ (in rad) for small i_y or σ_θ. In general, $\sigma_\theta = \mathrm{arc\,tg}\; i_y$. Observations of i_y may be used in eq. (1), or it may be parameterized through the formula

$$i_y = (0.5\,\mathrm{m/s})/u, \tag{2}$$

which assumes that the hourly-averaged σ_v maintains a value of about 0.5 m/s even as the wind speed approaches zero. This empirical result is based on observations from many sites, including data from experiments over water and over complex terrain [4]. These experiments suggest that the $\sigma_v \sim 0.5$ m/s relation is valid over all types of terrain and that the larger values of i_y or σ_θ observed over complex terrain are actually due to lower wind speeds over that type of terrain. However, it should be pointed out that when σ_v is plotted *vs.* u at any site, the σ_v values typically exhibit a scatter of about ± 0.3 m/s about the $\sigma_v \sim 0.5$ m/s relation.

Equations (1) and (2) are based in the rectilinear system, with σ_y and σ_v assumed to be perpendicular to the direction of the mean plume axis. They are valid as long as the small angle approximation, $\theta \simeq \mathrm{tg}\,\theta$ is valid, where θ is in rad. As θ increases beyond about 0.5 rad (28°), this approximation has an error of more than 10%. Consequently, when σ_y/x or i_y are greater than about 0.5 rad, it is better to rewrite the equations in their more general form, valid on a polar coordinate system:

$$\sigma_{\theta c} = \sigma_\theta (1 + 0.0001x)^{-1/2}, \tag{3}$$

$$\sigma_\theta = \mathrm{arc\,tg}\,((0.5\,\mathrm{m/s})/u), \tag{4}$$

where x is the radial distance from the source, $\sigma_{\theta c}$ is the standard deviation (in rad) of the concentration distribution observed on an arc along a circle around the source, and σ_θ is the standard deviation (in rad) of the wind direction observations [8]. Both $\sigma_{\theta c}$ and σ_θ have a maximum of 1.83 rad (105°), which is the standard deviation of a uniform distribution around the circle.

3. – Description of tracer data and meteorological data.

The Sagendorf and Dickson [5] and Wilson *et al.* [6] reports contain data from the Idaho Falls and Oak Ridge experiments, respectively. These reports do not give values of the angular standard deviation of the concentration distribution, $\sigma_{\theta c}$, but do provide tables containing all of the concentration data for each monitor. We used these data to calculate $\sigma_{\theta c}$ for all 22 runs at the 100 m arc. The observations used in this analysis are presented in table I, which includes the wind speed, u, the standard

TABLE I. – *Listing of data from the Oak Ridge* (OR) *and Idaho Falls* (IF) *Sites.*

Test	u(m/s)	σ_θ(rad)	Stability class (from dT/dz)	$\sigma_{\theta c}$(rad)
OR1	0.49	not observed	E	0.65
OR2	0.42	at Oak Ridge	F	0.80
OR3	0.31		D	0.69
OR4	0.15		E	1.12
OR5	0.26		E	1.15
OR6	0.23		E	1.45
OR7	0.32		E	1.00
OR8	0.34		E	1.57
OR9	0.23		E	0.77
OR10	0.75		D	0.44
OR11	0.29		E	1.23
IF4	1.21	0.21	G	0.20
IFS	0.88	0.50	G	0.50
IF6	1.29	0.20	D	0.18
IF7	0.90	0.39	G	0.36
IF8	0.75	1.26	E	0.99
IF9	0.80	0.31	E	0.21
IF10	1.66	0.38	G	0.58
IF11	1.92	0.66	G	0.67
IF12	1.08	1.06	F	0.42
IF12	1.61	0.21	G	0.38
IF14	1.47	0.33	G	0.32

deviation of wind direction fluctuations, σ_θ, the stability class, and the standard deviation of the concentration distribution, $\sigma_{\theta c}$. The stability class is not used in our analysis, but is included in case other researchers wish to analyze these data from another viewpoint. Since the square-root term in eq. (3) is 0.995 for x equal to 100 m, it can be ignored and the following simple approximation to eq. (3) can be tested with these data:

$$\sigma_{\theta c} = \sigma_\theta . \tag{5}$$

At the Idaho Falls site, the standard deviation of the wind direction fluctuations, σ_θ, was observed by fast-response wind instruments on a tower. At the Oak Ridge site, the wind speed was so light (median wind speed of 0.31 m/s) that it would not move conventional wind instruments. Consequently no σ_θ data are available at that site. Orthogonal sets of laser instruments with 350 m path lengths were used to determine the mean wind at Oak Ridge. The observed $\sigma_{\theta c}$ was therefore compared with observed σ_θ only at the Idaho Falls site. The observed $\sigma_{\theta c}$ was compared with parameterized σ_θ (*i.e.*, $\sigma_\theta = \mathrm{arc\,tg}\,((0.5\ \mathrm{m/s})/u)$) at both sites.

4. – Comparisons of model predictions with observations.

Figure 1 compares the $\sigma_{\theta c}$ and σ_θ observations from the Idaho Falls site, showing good agreement for most of the data points. Six of the eleven σ_θ observations are within $\pm 10\%$ of the $\sigma_{\theta c}$ observations, and the median σ_θ and $\sigma_{\theta c}$ also agree within $\pm 10\%$. It can be concluded that, for observed σ_θ in the range from 0.2 to 1.25 rad (11.5° to 72°), the formula $\sigma_{\theta c} = \sigma_\theta$ is quite accurate.

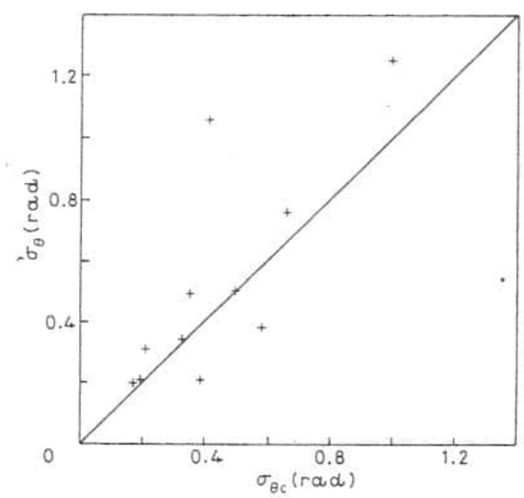

Fig. 1. – Idaho Falls observations of $\sigma_{\theta c}$ from concentration observations on 100 m arc, compared with observations of σ_θ from wind instruments.

Figure 2 contains the comparison of observed $\sigma_{\theta c}$ with parameterized σ_θ (from eq. (3)) for both the Idaho Falls and Oak Ridge sites. The cloud of points from Idaho Falls is located at lower values of σ_θ than the cloud of points from Oak Ridge, due to the difference in wind speeds at the two sites. The observed concentrations were distributed all around the monitoring circle during several runs in Oak Ridge, where the wind speeds were very low. Thus this is as severe a test of the formula as one is likely to find. It is seen that there is little bias on the figure, with better than $\pm 1\%$

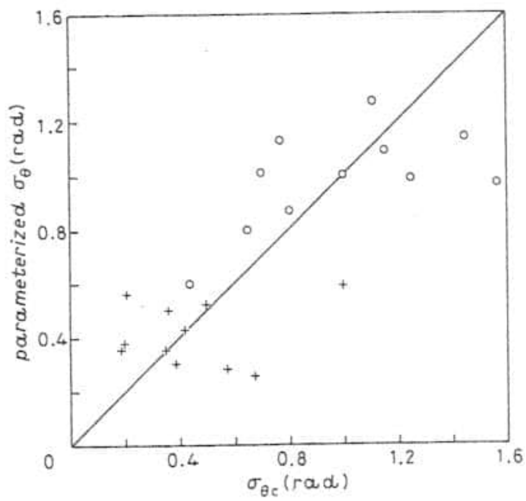

Fig. 2. – Idaho Falls (+) and Oak Ridge (○) observations of $\sigma_{\theta c}$ compared with parameterized $\sigma_\theta = (\mathrm{tg}^{-1}((0.5\,\mathrm{m/s})/u))$ based on wind speed observations.

agreement in the medians at each site. Considering all the points, there are 7 of the 22 that agree within ± 20%, and 17 of the 22 that agree within ± 50%. Even though the correlation of σ_θ with $\sigma_{\theta c}$ is relatively low at each site, the correlation is much better when the data from both sites are plotted together. Thus the parameterization of σ_θ is acceptable.

It is concluded that eqs. (3) and (4), suggested by Hanna *et al.* [4] and DiCristofaro and Hanna [8] for lateral diffusion during stable, light-wind conditions, produce quite good agreement with independent field data. The data suggest that the observed $\sigma_{\theta c}$ is within ± 50% of the predicted value about 70% of the time. Of course, the assumption of a Gaussian distribution breaks down as σ_θ increases beyond about 60°, since there is pollutant material at all points of the compass. In this case, Sagendorf and Dickson [5] show that a probability distribution function (p.d.f.) model is desirable, where the p.d.f. of the angular distribution of concentrations is assumed to be equivalent to the p.d.f. of the angular distribution of wind direction observations. However, this method requires more detailed processing of the wind direction data, and does not significantly improve the predictions of maximum concentrations on the arc.

* * *

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Proceedings of the

EURASAP Meeting and GNFAO/CNR Workshop on Atmospheric Dispersion in Low Windspeeds and Foggy Conditions

Torino, September 5-7, 1989

edited by

D. Anfossi and A. Longhetto

Attachment B

Sullivan County Alternative Model Approval Letter

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

JUN 0 1 2015

Mr. Barry R. Stephens
Director
Division of Air Pollution Control
Tennessee Department of Environment and Conservation
William R. Snodgrass Tennessee Tower
312 Rosa L. Parks Avenue, 15 Floor
Nashville, Tennessee 37243

RE: Approval of Alternative Model Request
Modeling of Sulfur Dioxide Emissions from Eastman Chemical Company
Sullivan County, Tennessee, 2010 Sulfur Dioxide National Ambient Air Quality Standards (NAAQS) Nonattainment Area

Dear Mr. Stephens:

This letter provides our approval of an alternative model for the attainment demonstration required pursuant to Section 172(c) of the Clean Air Act (CAA), for the Nonattainment Area State Implementation Plan (SIP) for the Sullivan County, Tennessee 2010 1-hour sulfur dioxide (SO_2) Nonattainment Area. The attainment demonstration must contain an air quality modeling analysis which demonstrates that the emission limits in the plan will provide for timely attainment of the standard. The U. S. Environmental Protection Agency's guidance memorandum titled: "Guidance for 1-Hour SO_2 Nonattainment Area SIP Submissions," dated April 23, 2014, indicates that the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) is the recommended model for SO_2 attainment demonstration modeling analyses. However, the guidance memo also provides flexibility for consideration for use of alternative models on a case-by-case basis when an adequate demonstration is made that the alternative model performs better than AERMOD for a particular application. An adequate demonstration should meet the criteria provided in Section 3.2.2(d) of the EPA's Guideline on Air Quality Models contained in 40 CFR Part 51, Appendix W.

The Eastman Chemical Company has proposed to use an alternative modeling system, which they have called "EASTMOD," to model the SO_2 emissions from their facility located in the Sullivan County SO_2 Nonattainment Area. Based upon a review of all of the information that has been provided by Eastman since the original proposal in 2014, the EPA is approving portions of the proposed changes to the AERMOD Modeling System that are incorporated into the EASTMOD proposal and not approving other portions of the proposal. We have determined that the following modifications to the regulatory AERMOD modeling system are acceptable for modeling Eastman's SO_2 emissions: use of the beta ADJ_U* option in the meteorological preprocessor, AERMET, and use of the LOWWIND2 beta option in AERMOD (with a 0.4 m/s minimum sigma-v value). We have determined that Eastman's proposal to modify the LOWWIND2 beta option to allow use of split minimum sigma-v values for stable and unstable atmospheric conditions is not acceptable.

The EPA has performed considerable testing of both the beta ADJ_U* option in AERMET and the LOWWIND2 beta option in AERMOD using multiple tracer-studies[1]. Since Eastman has shown that the combination of these beta options has improved model performance for their site-specific case, the EPA believes that these alternative model options are appropriate for Tennessee's SO_2 attainment demonstration SIP modeling. As has been stated in previous technical review comments[2], the EPA continues to have concerns about Eastman's proposal to use split minimum sigma-v values for unstable (0.4 m/s) and stable (0.6 m/s) atmospheric conditions, due in part to the fact that the AERMOD model formulation incorporates a horizontal plume meander component that effectively increases lateral plume spread, especially under low wind stable conditions. As a result of these concerns, the EPA does not believe that the additional information provided by Eastman on March 3, 2015, justifies use of this proposed change to the model.

Based upon the site-specific model performance information provided by Eastman[3], it appears that use of the LOWWIND2 beta option with a single minimum sigma-v value of 0.4 m/s significantly improves model performance for the Ross N. Robinson, Meadowview, Skyland Drive and B-267 monitors when compared to the regulatory default version of AERMOD. We are approving a minimum sigma-v value of 0.4 m/s (versus the current default value of 0.3 m/s associated with the beta LOWWIND2 option) for Eastman specific case due to the complex dispersion environment associated with very low wind speeds and nearby complex terrain. These influences are likely to result in significant vertical wind shear that could contribute to increased lateral plume dispersion.

As indicated in our Technical Review Comments dated September 5, 2014, we have determined that the proposed AERLIFT component of EASTMOD is a source characterization procedure and is not an integral part of the AERMOD Modeling System. Therefore, it is not subject to the Appendix W, Section 3.2.2 alternative model evaluation criteria. We have considered the AERLIFT procedure separately from the modifications proposed to be made to the actual AERMOD Modeling System. In order to fully address the modeling procedures being proposed by Eastman, we are also providing our decisions regarding application of the AERLIFT procedure in this letter. Based upon the entirety of information provided by Eastman regarding AERLIFT, the EPA believes that the AERLIFT procedure is acceptable for use in modeling the five closely-spaced stacks at the B-253 powerhouse, but is not acceptable for the two B-83 stacks.

The additional information provided by Eastman in its March 3, 2015, submittal[3] clearly indicates that use of AERLIFT for the five closely spaced B-253 stacks improves model performance at the Ross N. Robinson, Skyland Drive and Meadowview monitor locations and shows a small improvement for the B-267 monitor location when compared to the no-AERLIFT cases. The studies in the references cited by both the EPA and Eastman in previous correspondence provide supporting information for use of AERLIFT for the five closely-spaced (approx. 15 meters apart) B-253 stacks. Conversely, the use of AERLIFT for the two B-83 stacks that are relatively far apart (approx. 50 meter or 11 stack diameters apart) results in very little change to the model performance at the Ross N. Robinson, Skyland Drive, Meadowview and B-267 monitor locations when compared to the no-AERLIFT cases. As has been pointed out in previous EPA comments[2], the literature appears to be consistent regarding the lack of any

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[1] EPA Webinar dated August 12, 2014 (http://www.epa.gov/ttn/scram/webinar/AERMOD_13350_Update/AERMOD_System_Update_Webinar_01-14-2014_FINAL.pdf)

[2] Email from Rick Gillam (EPA) to Haidar Al-Rawli (TDEC) on November 16, 2015, email from Rick Gillam (EPA) to Stephen Gossett (Eastman) dated February 4, 2015, and email from Scott Davis (EPA) to Barry Stephens (TDEC) on April 13, 2015.

[3] Eastman's Responses to Comments dated October 8, 2014, January 20, 2015, and March 3, 2015.

plume rise enhancement for two stacks spaced far apart like the B-83 stacks. The lack of performance improvement with AERLIFT for the B-83 stacks is consistent with the studies which question plume rise enhancement for two far apart stacks. Therefore, the EPA does not believe it is appropriate to approve the use of AERLIFT for the B-83 stacks. The EPA also notes that the additional information provided by Eastman indicates that the importance of the AERLIFT procedure will be greatly reduced for the future attainment year modeling case, in which the B-253 SO_2 emissions will be mostly eliminated by the fuel switch from coal to natural gas for the B-253 boilers.

In summary, we approve the following modifications to the EPA's regulatory AERMOD modeling system (version 14134) for modeling of SO_2 emissions from the Eastman facility for this site-specific SO_2 attainment demonstration modeling application: use of the beta ADJ_U* option in the meteorological preprocessor, AERMET, and use of the LOWWIND2 beta option in AERMOD (with a 0.4 m/s minimum sigma-v value). This approval is being made pursuant to Section 3.2.2(d) of 40 CFR Part 51, Appendix W, and is only applicable for this specific modeling application. Use of these modifications for other applications of the EPA's regulatory AERMOD modeling system are subject to review and approval on a case-by-case basis. Also, please note that our approval of the use of these alternative model options does not represent any determination or disposition on the actual attainment demonstration modeling that will be used for the Sullivan County SO_2 Nonattainment Area SIP nor does it make any final approvability determinations concerning other components of the attainment demonstration SIP submission. If you have any questions regarding the contents of this letter, please contact Rick Gillam at (404) 562-9049.

Sincerely,

Carol L. Kemker for

Beverly H. Banister
Director
Air, Pesticides and Toxics Management Division

Attachment C

TRC 1993 Model Performance Study for Laurel Ridge

Revised Final Report on the Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge

TRC

TRC Environmental Corporation

REVISED FINAL REPORT ON THE MODEL PERFORMANCE COMPARISON STUDY FOR LAUREL RIDGE AND CHESTNUT RIDGE

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TRC Project No. 8026-R61

January 13, 1993

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EXECUTIVE SUMMARY

A model performance comparison study was conducted to determine the most appropriate dispersion modeling approach for estimating air quality impacts on elevated terrain in the region northwest of Johnstown, PA. This report describes the study, which was designed based on the U.S. Environmental Protection Agency's (EPA) "Interim Procedures for Evaluating Air Quality Models (Revised)", (EPA, 1984) and was conducted in accordance with the "Protocol for Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge", (TRC, 1991).

The modeling protocol was formally approved by the Pennsylvania Department of Environmental Resources (PaDER) and EPA on January 20, 1992. The protocol presented the study design, including the monitoring network; established the basis for judging model performance; and described the intended application of the winning model to estimate air quality impacts and to assess the adequacy of emission limits for specific sources. Relevant portions of the modeling protocol are summarized in this report.

The original version of this report was dated July 10, 1992. However, in late August, a number of minor discrepancies were identified in the stack parameter data (i.e., stack i.d., exit velocity, etc.) for certain Penelec power plants in the Laurel/Chestnut Ridge area. As a result, TRC has repeated the model performance comparison study based on the updated stack parameter data. This revised report describes the model performance comparison results obtained using the updated stack parameter data. All other aspects of the study remain unchanged from those described in the July 10, 1992 version of this report.

The study described in this report involved performance comparisons between the Large Area Power Plant Effluent Study (LAPPES) model and the Rough

Terrain Diffusion Model (RTDM). The study results show that LAPPES is the superior model for determining the air quality impacts of the power plants operated by Penelec in the Laurel Ridge and Chestnut Ridge area. LAPPES outperformed RTDM under all conditions and met the scoring criteria specified in the modeling protocol. Complete details on the model performance comparison procedures and results are provided in this report.

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1.0 INTRODUCTION

The Pennsylvania Electric Company (Penelec) operates four major coal-fired generating facilities in the Laurel Ridge/Chestnut Ridge area of southwestern Pennsylvania. Seward Station, Conemaugh Station, Homer City Station, and Keystone Station are all located within a distance of 25 miles of one another. The air quality impacts of these facilities can overlap, leading to regulatory concerns regarding the attainment and maintenance of National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO_2) in the region. Air quality impacts at high terrain locations are a particular concern.

New allowable SO_2 emission limits must be determined for the Penelec-operated facilities in the Laurel/Chestnut Ridge area because of the 1985 stack height regulations (which affect both the Seward and Homer City Unit 3 stacks) and the 1990 Clean Air Act Amendments (which affect Conemaugh Station). These new SO_2 emission limits must be established by dispersion modeling analyses.

Applicable EPA guidance requires the use of two models to determine air quality impacts in terrain that is defined as "intermediate complex terrain" (i.e., terrain between the stack top and plume height elevations). The applicable guideline models for the Laurel/Chestnut Ridge area are MPTER (EPA, 1980), for terrain elevations below plume height, and RTDM (ERT, 1987), for terrain elevations above stack top. For receptors with elevations between stack top and plume height, EPA requires comparing MPTER and RTDM predictions hour-by-hour and selecting the higher value.

The Large Area Power Plant Effluent Study was carried out in the Laurel Ridge/Chestnut Ridge area between 1967 and 1972. The LAPPES model was originally developed by Penelec for application to this region (Slowik, A.A., J.M. Austin, G.N. Pica, 1977). Penelec would prefer to use the LAPPES dispersion model for terrain above stack top throughout the study region.

Previous studies for other locations have shown that RTDM overpredicted at elevated terrain locations by a factor of two or more, when the EPA-specified model options were used. By contrast, LAPPES has not shown substantial prediction bias in comparisons with observed air quality.

The model performance comparison study was required to obtain PaDER and EPA approval for the use of LAPPES instead of RTDM/MPTER to establish emission limits for the Penelec power plants in the Laurel/Chestnut Ridge area. The criteria for approval to use LAPPES included minimum scoring requirements and a demonstration that LAPPES performs better than RTDM/MPTER, based on comparisons to measured air quality.

As described in the EPA Interim Procedures document and TRC's February 1991 modeling protocol, the required approach for the model comparison study began with the design of the monitoring network, using modeled predictions of the air quality impacts across the region. Initial dispersion modeling for the monitoring network design was performed in 1987, and changes to the then existing monitoring network were proposed. A modeling report and proposed network design were provided to PaDER and EPA Region III for review (TRC, 1987). After several iterations and additional modeling analyses in response to regulatory agency review comments, the final network design was approved in 1990 (letter from J. Slade, PaDER to V. Brisini, Penelec, dated May 4, 1990).

The February 1991 protocol (as approved by PaDER and EPA on January 20, 1992) for evaluating model performance defined 1) procedures to run the models to obtain predictions comparable to measured air quality concentrations; 2) the statistical measures to be used as performance indicators; 3) the calculations to determine each model's performance score; and 4) the criteria for determining the winning model. The protocol also discussed the intended use of the winning model including the choice of model inputs, the sources to be modeled, the derivation and use of representative background air quality concentrations, appropriate receptor arrays, and any required adjustments for underpredictions by the LAPPES model.

This revised report is based on updated stack parameter data provided to TRC by Penelec on September 9, 1992. The report revisions pertain only to the new stack parameter data and the corresponding model performance comparison results. All other aspects of the study remained unchanged from those described in the original July 10, 1992 report.

The results of the model comparison, for both the original and revised stack parameter data, can be summarized as follows:

- LAPPES, by all measures, is the model which best simulates the air quality impacts at elevated terrain from Penelec-owned and operated sources in the Laurel/Chestnut Ridge region.
- LAPPES outperformed RTDM under all conditions in the study and met the scoring criteria specified in the modeling protocol to be selected as the winning model.
- The LAPPES model showed no bias toward underprediction of the measured SO_2 concentrations for the 3-hour and 24-hour averaging periods.
- RTDM did not estimate air quality impacts accurately in elevated terrain for the physical circumstances modeled in this study, and scored poorly in the model performance evaluation.

Section 2 of this report addresses background issues and the project history. The database used for the model comparison study is described in Section 3. The statistical measures used to evaluate model performance are explained in Section 4. The revised model performance comparison results are contained in Section 5, while the study conclusions and references are provided in Sections 6 and 7, respectively.

2.0 STUDY DESIGN

This section provides the foundation for the design of the model performance evaluation study. It includes a discussion of the regulatory setting, a description of the source and source environment, a technical description of the reference and proposed models, a summary of the preliminary modeling performed to design the monitoring network, and a discussion of other technical issues pertaining to the intended use of the winning model.

2.1 Regulatory Setting

The primary regulatory issue pertaining to this study concerns the impact of SO_2 emissions from Penelec-operated sources on air quality at elevated terrain locations north and west of Johnstown, Pennsylvania. The dispersion models RTDM and MPTER predict frequent violations of the short-term NAAQS for SO_2 at current allowable emissions rates. For over 11 years, Penelec has operated an extensive network of ambient SO_2 monitors, which measure peak concentrations substantially lower than those predicted by RTDM and MPTER on high terrain.

The regulatory status of the study region is further complicated by the fact that stacks at two Penelec-operated facilities are subject to Good Engineering Practice (GEP) stack height limitations, and both have actual stack heights in excess of "GEP formula" height (see Section 2.2). Beginning in 1995, at least one Penelec-operated facility (Conemaugh) will also be subject to Phase I of the Acid Rain provisions of the 1990 Clean Air Act, which impose restrictions on annual SO_2 emissions.

2.2 Sources and Source Environment

The Penelec-operated sources and regional terrain are illustrated in Figure 2-1. Dispersion modeling has consistently indicated that peak

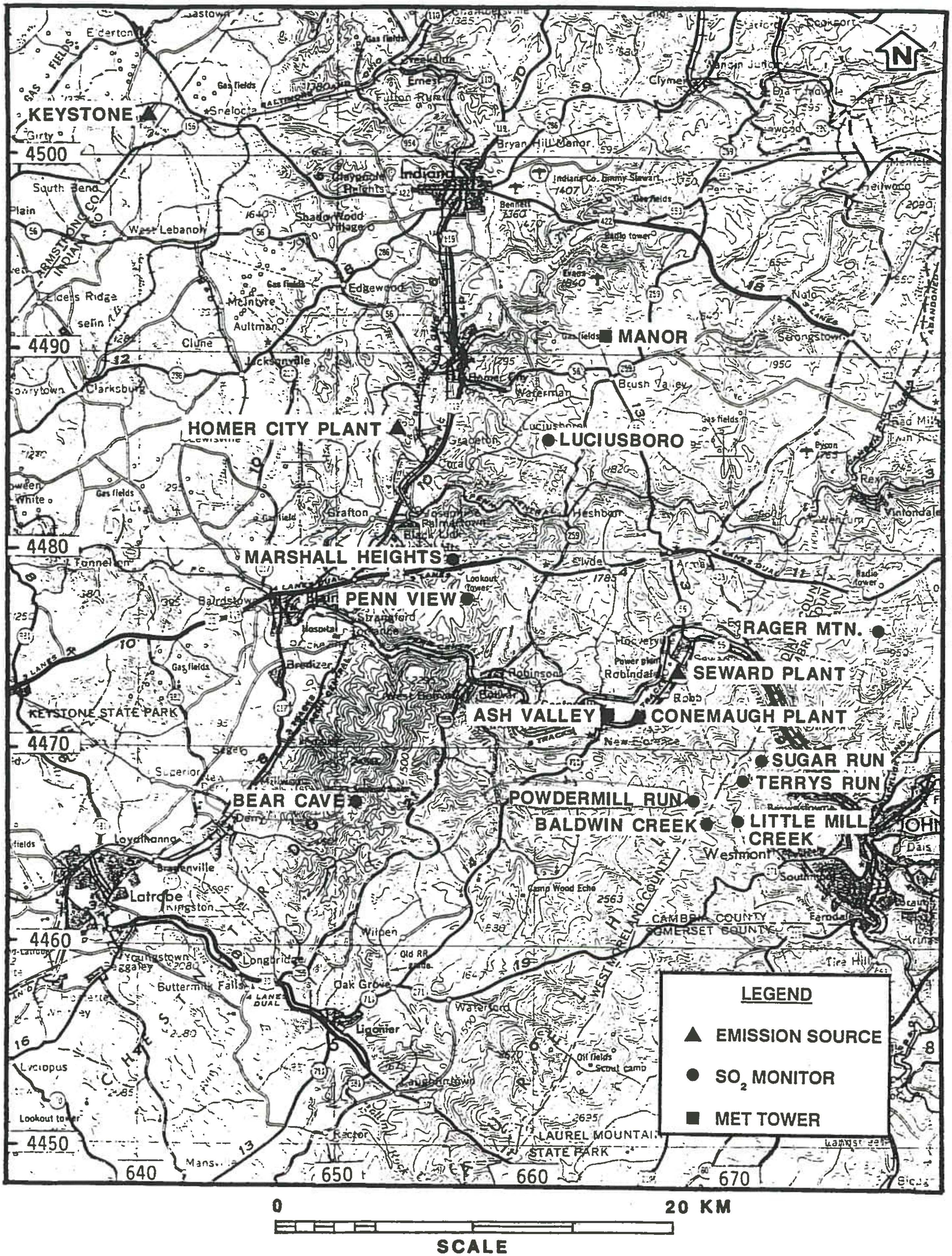


FIGURE 2-1. STUDY REGION AND MONITORING SITES

short-term SO_2 concentrations are expected on the elevated terrain portions of Laurel Ridge and Chestnut Ridge, which are oriented north-northeast to south-southwest. The Conemaugh and Seward Generating Stations are located between the ridges, while Homer City and Keystone are located northwest of both ridges.

The Pennsylvania State Implementation Plan (SIP) SO_2 emission limitations expressed as pounds per million British thermal units (lbs/MMBtu) for major fossil fuel-fired boilers follow:

Averaging Period	Allowable lbs SO_2 per MMBtu Heat Input
Thirty-day running average not to be exceeded at any time	3.7
Daily average not to be exceeded more than 2 days in any running 30-day period	4.0
Daily average maximum not to be exceeded at any time	4.8

Source characteristics and maximum allowable emission rates are summarized in Tables 2-1 and 2-2.

Stack heights for these sources range from 182.9 m (600 feet) for Seward to 370.6 m (1,216 feet) for Homer City Unit 3. Most of the stacks were constructed prior to 1970 and are not subject to GEP stack height limitations. The exceptions are Homer City Unit 3 and Seward. For Homer City Unit 3, the GEP stack height was determined to be 260 m (853 feet), based on the results of a fluid modeling study to assess downwash due to cooling towers. The Seward stack was built after 1970 and exceeds GEP formula height based on building dimensions. A fluid modeling study for Seward determined that the existing 182.9 m (600 feet) stack height is required to avoid excessive concentrations due to terrain-induced downwash effects.

TABLE 2-1

FIXED STACK PARAMETERS COMPILED FOR THE
LAUREL/CHESTNUT RIDGE DISPERSION MODELING ANALYSIS

Source	UTM Coordinates (KM) East	UTM Coordinates (KM) North	Stack Height	Stack Diameter	Stack Base Elevation (ft)
Conemaugh Unit 1	664.58	4472.00	304.8 m (1,000 ft)	8.3 m (27.2 ft)	1,088.5*
Conemaugh Unit 2	664.58	4472.00	304.8 m (1,000 ft)	8.3 m (27.2 ft)	1,088.5*
Homer City Unit 1	652.77	4486.11	243.8 m* (800 ft)	7.3 m (24.0 ft)	1,200
Homer City Unit 2	652.77	4486.11	243.8 m* (800 ft)	7.3 m (24.0 ft)	1,200
Homer City Unit 3	652.77	4486.11	370.6 m* (1,216 ft)	6.9 m (22.6 ft)	1,200
Keystone Unit 1	640.18	4502.15	243.8 m (800 ft)	8.3 m* (27.2 ft)	1,012*
Keystone Unit 2	640.18	4502.15	243.8 m (800 ft)	8.3 m* (27.2 ft)	1,012*
Seward Units 4 and 5	666.81	4474.68	182.9 m (600 ft)	5.3 m (17.4 ft)	1,085*

* Revised data provided by Penelec on 9/9/92.

TABLE 2-2

MAXIMUM CAPACITY (100%) EMISSION RATES AND STACK PARAMETERS COMPILED FOR THE LAUREL/CHESTNUT RIDGE DISPERSION MODELING ANALYSIS

Source	SO_2 Emission Factor Limit (lb/MMBtu)	Generator Capacity* (MW)	Heat Input* (MMBtu/MWh)	SO_2 Emission Rate*	Exit Velocity*	Exit Temperature*
Conemaugh Unit 1	4.8	893	8.82	4763.5 g/s (37,806 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Conemaugh Unit 2	4.8	893	8.82	4763.5 g/s (37,806 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Homer City Unit 1	4.8	662	9.02	3611.3 g/s (28,662 lb/hr)	30.0 m/s (98.4 ft/s)	440°K (333°F)
Homer City Unit 2	4.8	650	9.01	3541.9 g/s (28,111 lb/hr)	30.0 m/s (98.4 ft/s)	440°K (333°F)
Homer City Unit 3	1.2	682	9.20	948.7 g/s (7,529 lb/hr)	30.7 m/s (100.7 ft/s)	440°K (333°F)
Keystone Unit 1	4.8	893	8.97	4844.5 g/s (38,449 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Keystone Unit 2	4.8	893	8.97	4844.5 g/s (38,449 lb/hr)	29.0 m/s (95.1 ft/s)	430°K (315°F)
Seward Units 4 and 5	4.8	214	10.36	1340.8 g/s (10,642 lb/hr)	23.3 m/s (76.4 ft/s)	418°K (293°F)

* Revised data provided by Penelec on 9/9/92.

2.3 Description of Models

The alternative model used in the model comparison study was LAPPES. EPA has designated as the reference model a combination of RTDM and MPTER. For each source, MPTER was used for all receptors below stack top. Above stack top, either RTDM or MPTER applied, depending upon which model predicts higher concentrations. These models are described below.

2.3.1 LAPPES (Proposed Model)

The LAPPES model is named for the Large Area Power Plant Effluent Study carried out in western Pennsylvania between 1967 and 1972. LAPPES is a non-guideline model that was developed for use in complex terrain areas. The LAPPES model was originally tested in the Chestnut Ridge area of Pennsylvania, where it was demonstrated to outperform EPA's Complex I model. LAPPES has subsequently been used in other ridge and valley terrain settings. The version of LAPPES proposed for this study is a modified version of the Complex II computer code.

Distinguishing features of the LAPPES model include:

- Empirical dispersion coefficients based on Pasquill and Gifford.
- For unstable conditions, Class A stability shifted to Class B.
- Enhanced horizontal plume spread under stable conditions to account for plume meander.
- Plume rise calculated as a function of downwind distance using Briggs plume rise equations.
- Enhanced initial plume growth due to buoyancy-induced dispersion.
- Plume height adjusted as a function of stability class and underlying terrain height.

Perhaps the most important feature is the algorithm to adjust the effective plume height in response to terrain higher than stack height. The plume height is gradually reduced to a certain minimum height as it passes over elevated terrain. The minimum height is one-half the unadjusted plume height for non-stable conditions and 35 percent of the unadjusted plume height for stable conditions. This allows the simulated plume to respond to the flow effects caused by the terrain.

Dispersion Coefficients - The LAPPES model employs the standard Gaussian plume formulation with full ground reflection. Vertical dispersion coefficients are unmodified Pasquill-Gifford (P-G) coefficients as calculated by MPTER. Horizontal coefficients are also unmodified P-G values for unstable and neutral conditions. For stable conditions, σ_y is enhanced by:

$$\sigma_y = \sigma_y (P\text{-}G)/(0.4 * u_E{}^{.3})$$

where:

σ_y (P-G) = Pasquill-Gifford σ_y

$u_E = u - 0.5$

u = wind speed at stack top (m/s)

If $u < 1$ m/s, $u_E = .5$ m/s

If $u > 9$ m/s, $u_E = 8.5$ m/s

This σ_y enhancement for plume meander represents an empirical adjustment of P-G values, based on plume behavior observed during the LAPPES experiments. Under stable conditions, the P-G σ_y values are increased by a factor ranging from 1.32 to 3.08, depending upon the wind speed.

Stability Class A was not considered appropriate for tall stack sources by the developers of LAPPES (A.A. Slowik, J.M. Austin, G.N. Pica, 1977), based on empirical observations of plume behavior. Hours with stability Class A input are therefore modeled by LAPPES using P-G dispersion curves for Class B stability.

Plume Rise - Plume rise is calculated using the BEH072 subroutine from models in the EPA Users Network for Applied Modeling of Air Pollutants (UNAMAP), modified to include a factor of 2.6 (instead of 2.4) under stable conditions.

Plume Height Adjustment - Under unstable and neutral conditions, LAPPES employs a plume height adjustment factor of 0.5, as Complex I and RTDM do. With this adjustment, the effective plume height, H_E, between plume centerline and ground level is given by:

$$H_E = h + \Delta H - 0.5z, \quad z \leq h + \Delta H$$

$$H_E = 0.5\ (h + \Delta H), \quad z > h + \Delta H$$

where:

z = terrain elevation above stack base

h = stack height

ΔH = plume rise

For stable conditions, the effective plume height is given by:

$$H_E = h + \Delta H - z, \quad z \leq (h + \Delta H)/1.7$$

$$h + \Delta H - 0.65z, \quad \frac{(h + \Delta H)}{1.7} < z \leq (h + \Delta H)$$

$$0.35\ (h + \Delta H), \quad z > h + \Delta H$$

For low terrain elevations, this treatment corresponds to full terrain subtraction. As the terrain elevation increases, the effective plume height reaches the minimum approach distance and then remains constant.

2.3.2 RTDM (Reference Model)

The RTDM formulation is fully described in the document User's Guide to the Rough Terrain Diffusion Model (RTDM) Rev. 3.2 (ERT, July 1987).

RTDM version 3.2 is a sequential version of the ERT Rough Terrain Diffusion Model, and is based upon the case-study model, RTDM.WC, submitted to EPA in August 1980. The model can be used in flat or complex terrain, but it has features specifically designed for simulating plume dispersion in complex terrain.

The "default" version of RTDM is recommended by EPA as a third-level screening model for complex terrain applications using on-site meteorological data. Specific default features employed by RTDM in estimating ground-level concentrations are listed below:

- Reflection of plume mass from the ground is limited by the second law of thermodynamics, so that the maximum concentrations cannot increase with distance downwind. (This feature is termed "partial ground reflection.")
- In stable conditions, a critical height (H_{crit}) is computed from the wind speed, the terrain height and the strength of the inversion. Plumes below this height are allowed to impinge on the terrain.
- The effects of buoyant entrainment can be accounted for in calculating plume size.
- Transitional plume rise may be employed in model computations until the downwind distance to equilibrium plume height is reached by the plume.
- During neutral and unstable conditions or above H_{crit} in stable conditions, a "half-height" correction simulates the effect of terrain-induced plume modifications on ground-level concentrations.
- Decrease in plume rise due to stack-tip downwash can be accounted for.
- Uniform crosswind concentration distribution over a 22.5 degree sector is assumed.
- Different wind speeds are used for calculating plume rise and dilution. For plume rise, the wind speed at stack top is used. Plume dilution is estimated using the wind speed at plume height.
- Vertical dispersion is based on ASME dispersion coefficients.

When the "partial ground reflection" option is employed in RTDM, the concentration at a receptor point depends upon the travel path of the plume (the upwind concentrations) as well as the location of the receptor itself. This is a feature found in few Gaussian models, and it requires the RTDM user to supply detailed terrain information in each of 36 directions (at 10° intervals). The required terrain data consist of downwind distances to successive contour heights (at constant height intervals) starting below stack top elevation and ending at the highest point along each direction within the study region.

2.3.3 MPTER (Reference Model)

The MPTER model is intended for multi-source applications in rural areas with flat or moderate terrain (up to stack height). MPTER is a standard Gaussian model and employs the Pasquill-Gifford dispersion coefficients for both horizontal and vertical dispersion. In the regulatory mode, MPTER includes the following features:

- Final plume rise (distance-independent) based on Brigg's equations.
- Enhanced initial plume growth due to buoyancy-induced dispersion.
- Stack-tip downwash.
- Full terrain subtraction for all stabilities. No terrain above stack top.

For complex terrain applications, MPTER is recommended by EPA only for terrain below stack top. For receptors with actual elevation above stack top, an elevation equal to stack top is used with MPTER.

2.4 Monitoring Network Design

The design of a site-specific model evaluation requires a preliminary analysis of the sources and the dispersive setting of the sources in order to site monitors which will adequately characterize the situation and provide representative source-receptor relationships. Since the regulatory models are generally concerned with predicting maximum impacts, monitor placement should attempt to reflect areas of expected concentration maxima. To anticipate areas of maximum concentrations in order to correctly place monitors, TRC conducted preliminary modeling for Penelec utilizing RTDM/MPTER and LAPPES in 1987.

In 1987, Penelec's Laurel/Chestnut Ridge monitoring network contained 15 SO_2 sampling sites and the preliminary modeling was performed using meteorological measurements collected from April 15, 1981 through April 14, 1982 at a 70-foot meteorological tower located at Penn View (see Figure 2-1). Additional details on the preliminary modeling, including the modeling approach, sources, receptors, meteorological data, and results, are provided in TRC's February 1991 modeling protocol.

The preliminary modeling in 1987 produced the following information about the models and the predicted concentration fields near the Penelec sources:

- Peak concentration predictions by RTDM/MPTER at the existing Laurel Ridge monitors were higher than peak predictions by LAPPES by a factor of 2 to 3.
- Predictions by LAPPES at the existing monitoring locations were generally representative of the highest predictions at any receptors.
- Peak predictions by RTDM/MPTER for Laurel Ridge occurred at receptors northwest of the existing monitors, at lower terrain elevations and closer to Conemaugh and Seward Stations. A new monitoring site, Powdermill Run, was added to represent these locations (see Figure 2-1).

- The nonattainment region on Laurel Ridge predicted by RTDM/MPTER extended northeast beyond the Rager Mountain monitor and southwest at least 10 km beyond Baldwin Creek.

- A second nonattainment region was predicted by RTDM/MPTER on Chestnut Ridge, south of the Conemaugh River. A new monitoring site, Bear Cave, was added to represent this region (see Figure 2-1).

The following changes were also made to Penelec's Laurel/Chestnut Ridge monitoring network as a result of the 1987 monitoring network design study:

- The 70-foot meteorological tower at Penn View was replaced by two new meteorological towers located at Ash Valley and Manor (see Figure 2-1).

- The existing Laurel Ridge SO_2 monitor was replaced by the Sugar Run SO_2 monitor when it was discovered that the data recorded at the Laurel Ridge site were subject to interference from a nearby radio transmission tower.

- Seven non-essential SO_2 monitors were decommissioned (Creekside, Parkwood, Brush Valley, Ramsey Run, Armagh, Gas Center, West Fairfield), since data collected at these sites were not needed for the model performance evaluation study.

The SO_2 monitoring sites selected in the 1987 preliminary analysis have now been modeled as discrete receptors using Ash Valley and Manor meteorological data to obtain paired predicted and observed SO_2 concentration data for this model performance comparison study.

2.5 Intended Model Application

Following completion of the 1987 preliminary analysis, three important technical issues were raised by EPA Region III regarding the study design and the intended application of the winning model. The first issue (see Section 1.0), concerned the requirement to compare and merge hourly prediction files by source and receptor for the RTDM/MPTER "reference model" combination. This procedure, wherein maximum hourly concentrations are selected, was used for the RTDM/MPTER portion of the model performance comparison.

Second, the model comparison study objectives were clarified, to indicate that LAPPES would be tested against RTDM/MPTER for elevated terrain locations, and that the study results would only apply for elevated terrain. Therefore, in the future when modeling is performed to determine emission limits, LAPPES (the best performing model) will be used to predict impacts only for receptors above stack top elevation. (Penelec could have undertaken an additional model comparison effort to test LAPPES versus MPTER on lower terrain, but elected not to pursue this option.)

The third issue concerned the applicability of the study results to Seward Generating Station, with its shorter stack. Results from the preliminary analysis indicated that peak short-term impacts from Seward are predicted by RTDM/MPTER at receptors with terrain elevations on Laurel Ridge substantially lower than the locations of maximum combined impacts. (Combined impacts were dominated by predictions for Conemaugh Generating Station.) Specifically, peak short-term impacts from Seward alone were predicted on Laurel Ridge at elevations between 2,000 and 2,250 feet, while peak combined impacts were generally predicted at elevations of 2,500 feet and above. At these higher elevations, the impacts of Seward predicted by RTDM/MPTER were roughly half of the peak values predicted at lower elevations.

From a regulatory perspective, monitoring stations representative of peak predictions by RTDM/MPTER for Seward would be needed in order to demonstrate that LAPPES performs better than RTDM for Seward Station. Candidate monitor locations were judged to be inaccessible, particularly during winter, and are remote from any existing source of electric power. Penelec, after investigating the feasibility and costs associated with installing and operating monitors in such locations, elected not to pursue this supplementary monitoring as part of the present study. Therefore, when modeling is performed to determine future emission limits, RTDM/MPTER will be used to estimate the Seward Station's impacts.

3.0 DATABASE FOR MODEL PERFORMANCE COMPARISON

The preliminary analysis served to identify locations where peak concentrations were predicted by each model. The study design analysis also identified the need for on-site meteorological measurements consistent with current regulatory guidance. The procedures used and decisions made in selecting the monitoring sites are discussed in the February 1991 modeling protocol. The locations of the ten SO_2 monitors and two meteorological towers used for this model comparison study are shown in Figure 2-1. Figure 3-1 provides greater detail of the region surrounding the five Laurel Ridge SO_2 monitoring sites. Site elevations and coordinates for the meteorological towers are provided in Table 3-1, and for the SO_2 monitoring stations in Table 3-2.

The meteorological measurements are described below in Section 3.1, which also explains how model inputs were determined from available measurements. The SO_2 monitoring network is discussed in Section 3.2. A previous reassessment of the adequacy of the network coverage of peak concentration predictions is summarized in Section 3.3. This network coverage analysis, performed for the February 1991 modeling protocol, reflected updated modeling based on one year of meteorological data from the Ash Valley and Manor meteorological towers. Estimation of background concentrations is discussed in Section 3.4. Emission estimates are described in Section 3.5.

3.1 Meteorological Measurements

Two meteorological towers were used to gather on-site measurements to support dispersion modeling (see Figure 2-1). The Ash Valley (AV) meteorological tower is located approximately 3 km northwest of Conemaugh Station, at a base elevation of 1,401 feet. This site was chosen to obtain meteorological measurements representative of transport and dispersion

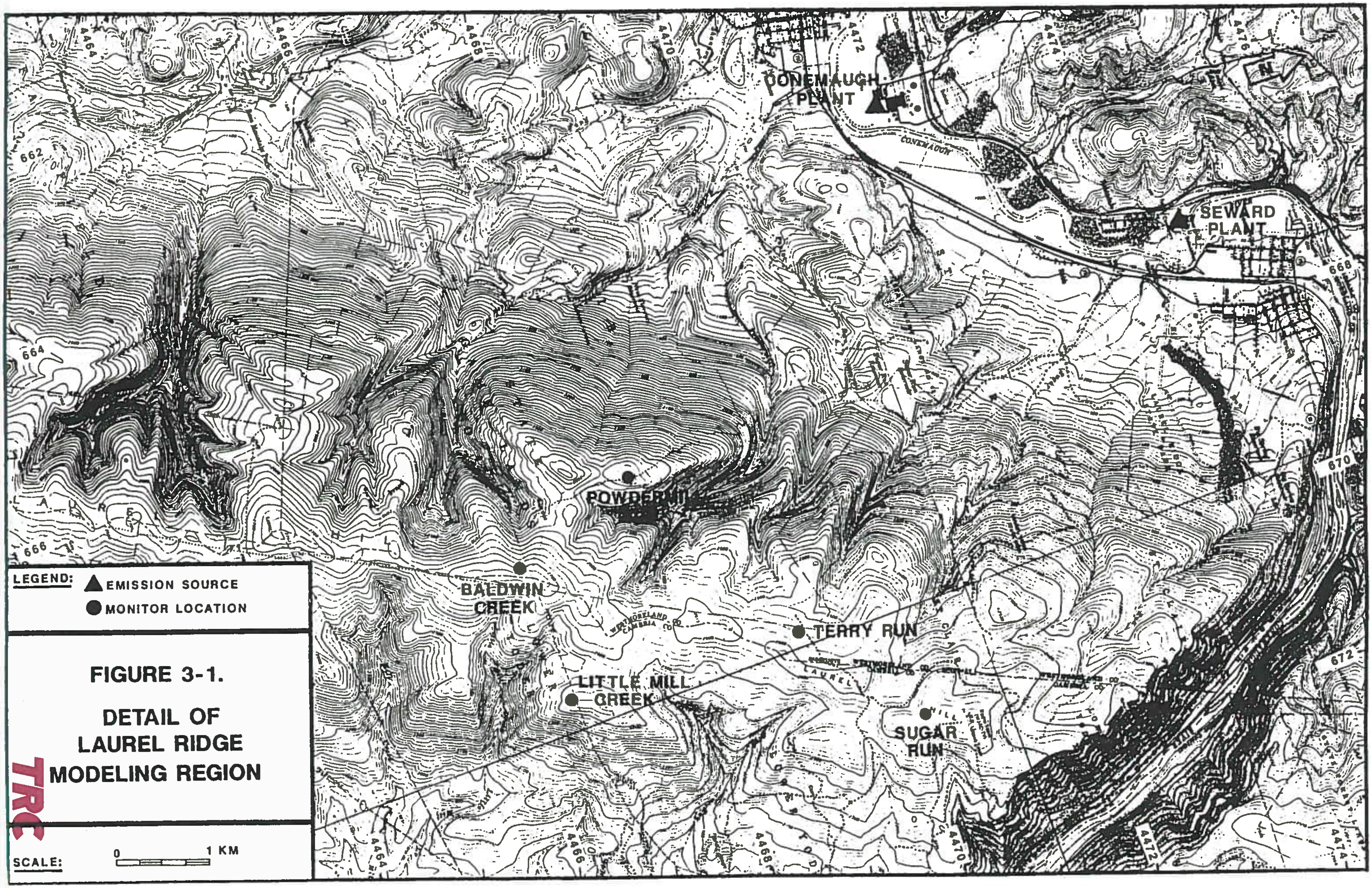


FIGURE 3-1.

DETAIL OF LAUREL RIDGE MODELING REGION

TABLE 3-1

METEOROLOGICAL MONITORING SITES FOR
LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

Location Description	MSL (ft.)	Above Grade (ft.)	Parameters* Monitored
(a) Ash Valley 150 Meter Tower			
Tower UTM – N = 4472558.36 – E = 661721.53			
Tower Base Plate	1401	–	–
Lower Sensor Level	1434	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1565	164 (50 m)	WD, WS
Upper Sensor Level	1695	292 (89 m)	WD, WS
Top Sensor Level	1893	492 (150 m)	WD, WS
(b) Manor 100 Meter Tower			
Tower UTM – N = 4492005.66 – E = 660560.42			
Tower Base Plate	1730	–	–
Lower Sensor Level	1763	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1894	164 (50 m)	WD, WS
Upper Sensor Level	2058	328 (100 m)	WD, WS

* Parameter Identifiers

WD = wind direction
WDST = standard deviation of wind direction (sigma theta)
WS = wind speed
AT = ambient temperature

TABLE 3-2

LOCATIONS OF SO_2 MONITORS FOR
LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

Site Name	UTM (E) (km)	UTM (N) (km)	Elevation (feet)
Marshall Heights	655.755	4479.660	1,880
Penn View	655.970	4477.320	2,030
Rager Mountain	677.490	4477.860	2,480
Bear Cave	650.660	4467.530	2,623
Sugar Run	670.900	4469.900	2,660
Terrys Run	669.910	4469.390	2,580
Little Mill Creek	669.650	4466.700	2,640
Baldwin Creek	668.050	4466.680	2,720
Powdermill Run	667.420	4467.980	2,584
Luciusboro	660.500	4484.760	1,660

conditions for Conemaugh and Seward Stations. Measurements at the 10 m level are intended for determining atmospheric stability class. The "upper" sensor level at 89 m above tower base provides wind speed measurements at Seward stack top elevation. The "top" sensor level at 150 m provides wind direction measurements for estimating plume transport for both Seward and Conemaugh, plus wind speed measurements representative of Conemaugh stack top. The Conemaugh stack top elevation is almost 200 feet higher than tower top. The models adjust the measured wind speeds to account for this difference.

The Manor meteorological tower is located approximately 9 km northeast of Homer City Station, with a base elevation of 1,730 feet. The 10 m sensor level again provides measurements to determine atmospheric stability class. The upper (100 m) sensor level was used for stack top wind speed measurements for both the Homer City and Keystone Stations. Wind directions from this level were used to predict plume transport for Homer City and Keystone.

Meteorological input files were created using measurements from the two on-site meteorological towers at Ash Valley and Manor for the one year study period, from August 1, 1990 through July 31, 1991. Source-specific meteorological files were defined to provide wind speed, wind direction and atmospheric stability values most appropriate for each station, as summarized in Table 3-3.

Table 3-3 also indicates both the substitution hierarchy used to replace missing data and the number of hours used from each monitoring location for each parameter. The table shows the substitution hierarchy in descending order; the top listed monitoring location was the primary data source for each input variable. In cases where only one or two hours were missing, interpolated values were used.

For all of the meteorological parameters (except the Seward Station stack top wind speed), Table 3-3 shows that the primary data source was used for

TABLE 3-3

METEOROLOGICAL DATA SOURCES, SUBSTITUTION HIERARCHY FOR MISSING DATA, AND HOURS OF DATA USED FOR MODELING

	Homer City and Keystone		Conemaugh		Seward	
	Parameter	Number of Hours Used	Parameter	Number of Hours Used	Parameter	Number of Hours Used
Wind Direction	M-100	8,446	AV-top	8,643	AV-top	8,643
	M-50	208	AV-upper	95	AV-upper	95
	AV-top	106	M-100	22	M-100	22
	AV-upper	0	M-50	0	M-50	0
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0
Stack Top Wind Speed	M-100	8,371	AV-top	8,197	AV-upper	7,176
	M-50	282	AV-upper	541	AV-mid	1,562
	AV-top	107	M-100	22	M-100	22
	AV-upper	0	M-50	0	M-50	0
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0
Plume Height Wind Speed	M-100	8,371	AV-top	8,197	AV-top	8,197
	M-50	282	AV-upper	541	AV-upper	541
	AV-top	107	M-100	22	M-100	22
	AV-upper	0	M-50	0	M-50	0
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0
Atmospheric Stability	M-10	8,559	AV-10	8,418	AV-10	8,418
	AV-10	201	M-10	342	M-10	342
	Pitt NWS	0	Pitt NWS	0	Pitt NWS	0

AV = Ash Valley
M = Manor
Pitt NWS = Pittsburg National Weather Service

AV-top = 150 m
AV-upper = 89 m
AV-mid = 50 m

more than 90 percent of the hours in the year, and when data were missing from the primary source, substitution below the secondary level was seldom necessary. Although available, National Weather Service (NWS) data from Greater Pittsburgh Airport were never used.

For stability class, the EPA recommended scheme based on 10 m wind speed, sigma theta and solar angle was used as the primary approach. Sigma theta cutoff values for Manor were adjusted for surface roughness. Based on an analysis of 1989-90 meteorological measurements, a surface roughness length of 2.3 cm was used. No such adjustment was required at Ash Valley. Figures 3-2 and 3-3 provide frequency distributions for the atmospheric stability class values determined for the Ash Valley and Manor monitoring locations, respectively.

3.2 Ambient Sulfur Dioxide Measurements

The SO_2 monitoring network includes ten stations, with six on Laurel Ridge and three on Chestnut Ridge (see Figure 2-1). Luciusboro and two of the Chestnut Ridge Stations, Penn View and Marshall Heights, have relatively low terrain elevations. Neither RTDM/MPTER nor LAPPES has predicted any NAAQS exceedances at these three monitors, nor have any been observed in over eleven years of operation. Their primary function for the model comparison study is to supplement the network for estimating background concentrations.

The new Powdermill Run monitor is the site located closest to Conemaugh Station. Powdermill Run is roughly 1 km west of the ridge top and about 200 feet below the peak elevation. Powdermill Run was sited to represent the primary "hot spot" location predicted by RTDM/MPTER on Laurel Ridge in the 1987 preliminary analysis. Sugar Run, Baldwin Creek, Little Mill Creek and Terrys Run are also located within the portion of Laurel Ridge where both RTDM/MPTER and LAPPES predict the highest short-term average SO_2

Figure 3–2

Stability Class Frequencies for the
Ash Valley Meteorological Data Set

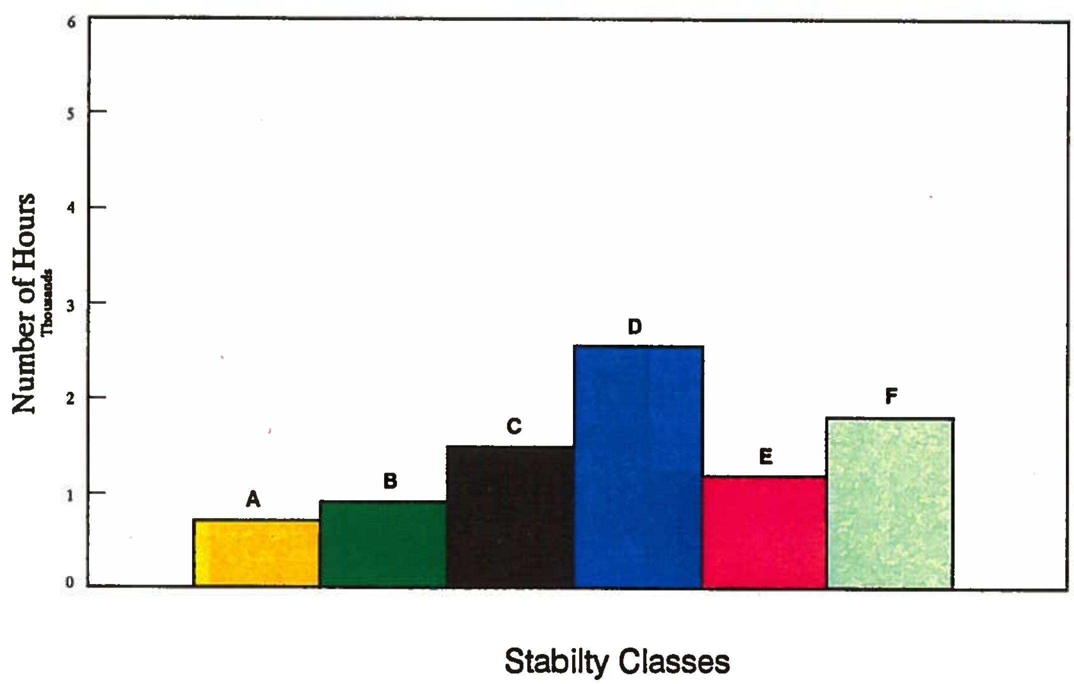
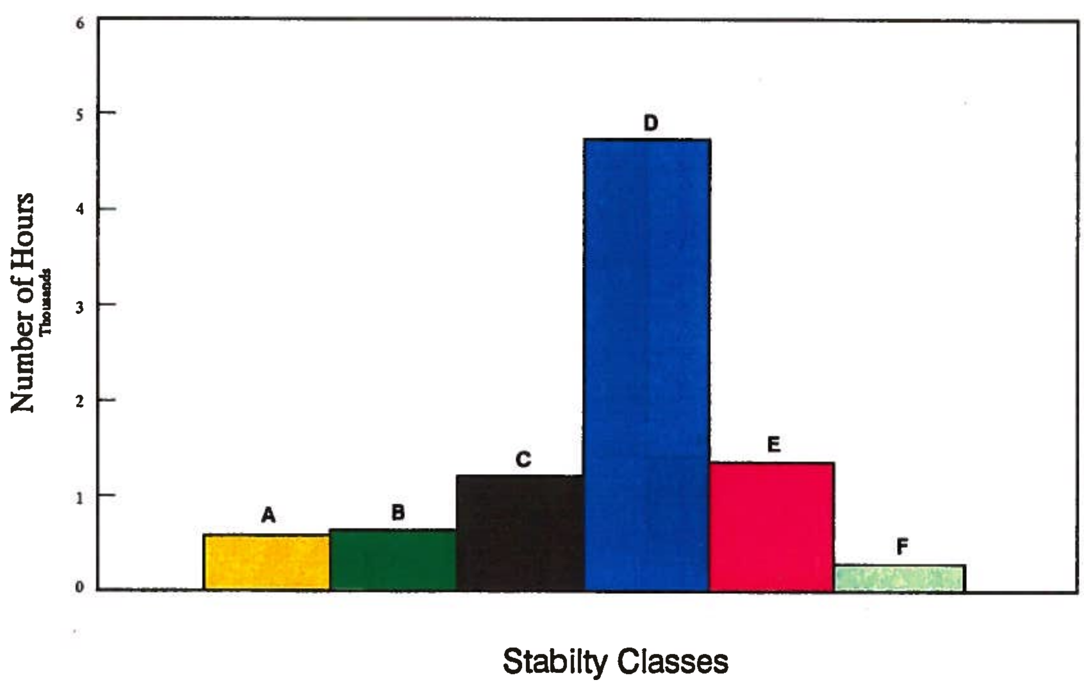


Figure 3–3

Stability Class Frequencies for the Manor Meteorological Data Set



concentrations. The Bear Cave and Rager Mountain monitors are located in other areas where RTDM/MPTER predicted nonattainment; they serve to ensure that the study results are applicable to the larger geographic region where Penelec wishes to use LAPPES in place of RTDM/MPTER.

3.3 Assessment of Network Coverage

The ability of the monitoring network to provide measurements representative of peak predicted concentrations for the study region was thoroughly reevaluated in the February 1991 modeling protocol. The adequacy of the monitoring network was confirmed for various combined applications of the RTDM, MPTER and LAPPES models for all the Penelec-operated SO_2 emission sources. This validation of the monitoring network was performed using September 1988 through August 1989 meteorological data recorded at the Ash Valley and Manor Towers. Peak 3-hour and 24-hour concentrations predicted for an array of 399 receptors were compared to the peak average concentrations predicted at the seven highest-terrain SO_2 monitoring locations (i.e., not including Luciusboro, Penn View and Marshall Heights). The procedure employed was to identify the maximum predicted concentration and receptor location for episodes with peak predicted impacts, and then to identify predictions at monitor locations for the same episodes among the listed high-five predictions.

A summary of the results of the February 1991 modeling analyses performed to reassess the coverage of the SO_2 monitoring network follows:

- The monitoring network provides excellent coverage for the use of RTDM/MPTER and LAPPES/MPTER for both the Laurel Ridge and Chestnut Ridge regions of the study area.
- On Laurel Ridge, the Powder Mill Run and Baldwin Creek monitors provide the best coverage for RTDM/MPTER, while the peak concentrations predicted by LAPPES/MPTER are spread over a wider area.

- On Chestnut Ridge, the coverage provided by the Bear Cave monitor is excellent for the peak concentrations predicted by both RTDM/MPTER and LAPPES/MPTER.

- The monitoring network also provides adequate coverage for the use of RTDM/MPTER for Seward Station combined with LAPPES/MPTER for all the other Penelec sources.

3.4 Background Air Quality

The lowest hourly SO_2 concentration measured by any station in the monitoring network was chosen as the background concentration for each hour. Neither Penelec nor the regulatory agencies are aware of any significant SO_2 emission sources within the study region, except for Penelec-operated sources. Consequently, background estimates should reflect regional-scale contributions from distant source regions, rather than unidentified local contributions.

Table 3-4 provides a summary of the measured SO_2 concentration data obtained from Penelec's Laurel/Chestnut Ridge monitoring network during the period from August 1, 1990 through July 31, 1991. The table shows values for 1) all the available hours of SO_2 data as well as 2) only those hours used to define background SO_2 concentrations. For each monitoring site, the table lists 1) the number of hours where SO_2 data were a) available and b) used to define background, 2) the average SO_2 concentration for a) the available hours and b) the hours used to define background, and 3) the highest 1-hour average SO_2 concentration for a) the available hours and b) the hours used to define background.

Table 3-4 shows that the monitor with the most available hours of SO_2 data was Luciusboro (8676 hours), while the monitor used most often to determine background was ~~Baldwin Creek~~ Luciusboro (~~2016~~ 2044 hours). The table shows that the highest average SO_2 concentration (~~35.6~~ 51.0 µg/m^3) was recorded at Rager Mountain, while ~~Bear Cave~~ Luciusboro recorded the highest average SO_2 concentration (~~81.8~~ 17.4 µg/m^3) based on

TABLE 3–4

SUMMARY OF THE MONITOR NETWORK
SULFUR DIOXIDE CONCENTRATION VALUES
(AUGUST 1,1990 – JULY 31,1991)

Monitor Name	Number of Hours		Average for the		Highest 1–Hour for the	
	Available	Used for Background	Available Hours (µg/m3)	Background Hours (µg/m3)	Available Hours (µg/m3)	Background Hours (µg/m3)
BALDWIN CREEK	8652	2016	18.9	8.49	791	113
BEAR CAVE	8326	1041	20.4	81.8	765	396
LITTLE MILL CREEK	7776	541	18.7	59.4	1040	215
MARSHALL HEIGHTS	8605	1022	21.5	42.9	652	210
PENN VIEW	8586	630	20.3	36.1	550	152
POWDERMILL RUN	8371	745	17.0	26.4	584	181
RAGER MTN.	8395	765	35.6	19.3	841	157
SUGAR RUN	7464	345	26.9	18.4	980	126
TERRYS RUN	8583	565	23.0	18.4	951	115
LUCIUSBORO	8676	1090	19.1	23.6	611	144

TRC

the hours of data used to define background. The highest 1-hour average SO_2 concentration (1040 $\mu g/m^3$) was recorded at Little Mill Creek and the highest 1-hour average background SO_2 concentration (396 $\mu g/m^3$) was recorded at Bear Cave. Table 3-4 shows that all the SO_2 monitoring sites achieved the 80 percent minimum data capture requirement.

The SO_2 concentration data in Table 3-4 show that the highest background SO_2 concentrations were recorded at the Bear Cave, Little Mill Creek and Marshall Heights monitoring sites. Thus, during hours when all the monitors are recording high SO_2 concentrations, i.e., when high background SO_2 concentrations are being transported into the Laurel/Chestnut Ridge area from other regions, these three monitors tend to record the lowest SO_2 concentrations among all the monitors. Based on the locations of the Marshall Heights, Bear Cave, and Little Mill Creek monitors (see Figure 2-1), high background SO_2 concentrations are apparently transported into the Laurel/Chestnut Ridge area when the wind is blowing roughly from the west, southwest and south, respectively.

3.5 Emission Data

Actual hourly SO_2 emissions and exhaust gas parameters for each stack at each generating station were required as model inputs for the model comparison study. Stack temperature, exhaust gas flow and exit velocity are not measured continuously for any stack.

These parameters were calculated from hourly load records, based on the following equations:

$$v_s = v_{100} (L/L_{100})$$
$$T_s = 2T_{50} + (T_{100} - T_{50})\, 2L/L_{100} - T_{100}$$
$$Q = SEL\ (0.126\ g\ hr\ /\ lb\ sec)$$

TRC

where:

v_s = Exit speed, m/sec
T_s = Exit temperature, K
Q = SO_2 emission rate, g/sec
L = Operating load, MW
L_{100} = Operating load at 100% capacity, MW
v_{100} = Exit speed at 100% load, m/sec
T_{100} = Exit temperature at 100% load, K
T_{50} = Exit temperature at 50% load, K
E = Operating Heat Input Rate, 10^6 Btu/MWh
S = Fuel sulfur emission factor, lb $SO_2/10^6$ Btu

Hourly gross operating load data were obtained for each generating unit. Continuous emission monitor data for Homer City were used along with load and heat rate data to calculate mass emission rates for Homer City Units 1, 2, and 3. For all other generating stations, the 24-hour average fuel sampling sulfur content values from the Certified Coal Sampling and Analysis System were used in combination with heat rates and hourly load data to calculate hourly emission rates. The 24-hour average fuel sampling sulfur content values are composites obtained from 48 samples per day, taken twice hourly.

Table 3-5 summarizes the SO_2 emission rates produced by each of the Penelec power plant stacks during the period from August 1, 1990 through July 31, 1991. The table shows the heat input rate, fuel sulfur content and emission rate for each stack. The values shown for the last two parameters are based on the number of valid operating days and hours per year.

3.6 Model Options

Tables 3-6 through 3-9 summarize the regulatory options and related input data used for the RTDM, LAPPES and MPTER model comparison analyses. Table 3-6 contains source-dependent model option data, and Tables 3-7 through 3-9 present the other options used in the RTDM, LAPPES and MPTER models, respectively. All the options were activated in accordance with EPA guidance and the February 1991 modeling protocol. The tables are discussed briefly below.

Table 3–5

Summary of the Penelec Power Plant Sulfur Dioxide Emission Rates (August 1, 1990 – July 31, 1991)

Source Name	Heat Input Rate (MMBtu/MWhr)	Average SO2 Emission Rate	
		from Fuel Sampling (lb/MMBtu)	When Operating (g/s)
Conemaugh Unit 1	8.82	3.30	2975
Conemaugh Unit 2	8.82	3.45	3156
Homer City Unit 1	9.02	2.37	1537
Homer City Unit 2	9.01	2.34	1522
Homer City Unit 3	9.20	1.13	834
Keystone Unit 1	8.97	2.71	2458
Keystone Unit 2	8.97	2.71	2501
Seward Unit 4	10.36	2.55	130
Seward Unit 5	10.36	2.56	458

TRC

Table 3–6

Source Dependent Model Option Data

Power Plant	Anemometer Heights (m)* # 1 (a)	Anemometer Heights (m)* # 2 (b)	PR004 (c)	Wind Speed Profile Exponents (for stability classes 1–6, respectively)					
Conemaugh	245.1	245.1	1	0.18	0.16	0.18	0.26	0.35	0.58
Homer City	261.5	261.5	1	0.06	0.08	0.11	0.22	0.25	0.26
Keystone	318.8	318.8	1	0.06	0.08	0.11	0.22	0.25	0.26
Seward	185.9	246.3	2	0.18	0.16	0.18	0.26	0.35	0.58

* above the stack base elevation
(a) # 1 for RTDM; single anemometer height for LAPPES and MPTER
(b) # 2 for RTDM
(c) dilution wind speed option number for RTDM

TABLE 3-7

RTDM MODEL OPTIONS

Model Parameters:

PR0001: Horizontal Scale is 1000.000 Meters Per User Unit

PR0002: Vertical Scale is .305 Meters Per User Unit

PR0003: Wind Speed Scale is .447 m/sec Per User Unit

PR0004: Anemometer #1 Height Above ZA (Used for Plume Rise) is (see Table 3-6)
If Available, Anemometer #2 Height Above ZA (Used for Plume Dilution) is (see Table 3-6)
Dilution Wind Speed Option is (see Table 3-6) (If 0, One Wind Speed--at Stack Height--is Used for Plume Rise and Dilution
If 1, Wind Speed at Level #1 is Extrapolated to Stack-Top Height for Plume Rise and to Plume Height for Dilution
If 2, Wind Speed at Level #1 is Extrapolated to Stack-Top Height for Plume Rise, and the Speed at Level #2 is Extrapolated to Plume Height for Dilution)
ZA (Height in Meters Above Stack Base Elevation where the Wind Speed Profile is Assumed to Originate) = .000

PR0005: Default Wind Speed Profile Exponents as a Function of Stability Class (1-6, respectively): (see Table 3-6)

PR006: Dispersion Coefficients are Briggs Rural/ASME-1979 (Unless Replaced by On-Site Turbulence Data)

PR009: Partial Plume Penetration of Mixing Lids is Not Being Used

PR010: Buoyancy-Enhanced Plume Dispersion is Used; Parameter Alpha is: 3.162

PR011: Unlimited Mixing Height Used for Stable Condition

PR012: Transitional Plume Rise is Used

PR013: Plume Path Coefficients for Stability Classes 1-6: .500, .500, .500, .500, .500, .500

PR014: Default Vertical Potential Temperature Gradients Used for Stable Plume Rise (Classes 5 & 6): .0200, .0350

PR015: Stack-Tip Downwash is Used

PR016: Y-Component Turbulence Intensity Values are Not Provided; Stability Class is Used to Obtain Sigma-Y.

PR017: Z-Component Turbulence Intensity Values are Not Provided; Stability Class is Used to Obtain Sigma-Z.

PR018: Hourly Vertical Potential Temperature Gradients are Not Provided to Determine Stable Plume Rise; Use Default Values (see PR014)

PR019: Hourly Vertical Potential Temperature Gradients are Not Provided to Determine HCRIT; Use Default Values (see PR014)

PR020: Wind Direction Shear is Not Used in Computation of Sigma-Y.

PR021: Hourly Values of Wind Speed Profile Exponent are Not Provided; Use Defaults (see PR005)

PR022: Partial Reflection Algorithm is Being Used; Keyword Terrain Must be Used to Read in Terrain

PR023: Sector Averaging is Used for All Stabilities
Sector Widths (Deg) for Stabilities 1-6 are: 22.50, 22.50, 22.50, 22.50, 22.50, 22.50

PR024: Hourly Emissions Data are Available and Will Replace the Constant Values Specified in the Stacks Section

PR025: Detailed Information About Each Case will Not Be Printed

TABLE 3-8

LAPPES MODEL OPTIONS

Option	Option List	Option Specification 0 = Ignore Option 1 = Use Option
	Technical Options	
1	Terrain Adjustments	1
2	Do Not Include Stack Downwash Calculations	0
3	Do Not Include Gradual Plume Rise Calculations	0
4	Calculate Initial Plume Size	1
	Input Options	
5	Read Met Data from Cards	0
6	Read Hourly Emissions	1
7	Specify Significant Sources	0
8	Read Radial Distances to Generate Receptors	0
	Printed Output Options	
9	Delete Emissions with Height Table	1
10	Delete Met Data Summary for Average Period	1
11	Delete Hourly Contributions	1
12	Delete Met Data on Hourly Contributions	1
13	Delete Final Plume Rise Calc on Hourly Contributions	1
14	Delete Hourly Summary	1
15	Delete Met Data on Hourly Summary	1
16	Delete Final Plume Rise Calc on Hourly Summary	1
17	Delete Avg-Period Contributions	1
18	Delete Averaging Period Summary	1
19	Delete Avg Concentrations and Hi-5 Tables	0
	Other Control and Output Options	
20	Run is Part of a Segmented Run	0
21	Write Partial Conc to Disk or Tape	0
22	Write Hourly Conc to Disk or Tape	1
23	Write Avg-Period Conc to Disk or Tape	0
24	Punch Avg-Period Conc onto Cards	0
25	Complex Terrain Option	6

Anemometer Height is: (see Table 3-6)
Exponents for Power-Law Wind Increase with Height are: (see Table 3-6)
Terrain Adjustments are: .500, .500, .500, .500, .000, .000
Zmin is: 10.0

TABLE 3-9

MPTER MODEL OPTIONS

Option	Option List	Option Specification 0 = Ignore Option 1 = Use Option
	<u>Technical Options</u>	
1	Terrain Adjustments	1
2	Do Not Include Stack Downwash Calculations	0
3	Do Not Include Gradual Plume Rise Calculations	1
4	Calculate Initial Plume Size	1
	<u>Input Options</u>	
5	Read Met Data from Cards	0
6	Read Hourly Emissions	1
7	Specify Significant Sources	0
8	Read Radial Distances to Generate Receptors	0
	<u>Printed Output Options</u>	
9	Delete Emissions with Height Table	1
10	Delete Met Data Summary for Average Period	1
11	Delete Hourly Contributions	1
12	Delete Met Data on Hourly Contributions	1
13	Delete Final Plume Rise Calc on Hourly Contributions	1
14	Delete Hourly Summary	1
15	Delete Met Data on Hourly Summary	1
16	Delete Final Plume Rise Calc on Hourly Summary	1
17	Delete Avg-Period Contributions	1
18	Delete Averaging Period Summary	1
19	Delete Avg Concentrations and Hi-5 Tables	0
	<u>Other Control and Output Options</u>	
20	Run is Part of a Segmented Run	0
21	Write Partial Conc to Disk or Tape	0
22	Write Hourly Conc to Disk or Tape	1
23	Write Avg-Period Conc to Disk or Tape	0
24	Punch Avg-Period Conc onto Cards	0
	<u>Default Option</u>	
25	Use Default Option	0

Anemometer Height is: (see Table 3-6)
Exponents for Power-Law Wind Increase with Height are: (see Table 3-6)
Terrain Adjustments are: .000, .000, .000, .000, .000, .000

The anemometer heights shown in Table 3-6 are relative to the stack base elevations at each power plant. With RTDM, plume height and plume dilution can be calculated using wind speed data collected at two levels. For Conemaugh, Homer City and Keystone, the plume height and plume dilution wind speeds were extrapolated from meteorological tower top wind speeds only. The Ash Valley 150 meter level data were used for Conemaugh, and the Manor 100 meter level data were used for Homer City and Keystone. For Seward, Ash Valley upper level (89 meter) data were used for stack top wind speed, and Ash Valley tower top level (150 meter) data were used for plume height wind speed.

The wind speed profile exponents in Table 3-6 were derived using the on-site data. The selection of the wind speed profile exponents was the same in all three models. These data were available from analyses performed on the site-specific wind speeds (when scaling factors were derived to implement the meteorological data substitution for the different tower level wind speeds). Sensitivity analyses performed indicated that the use of site-specific exponents in RTDM and LAPPES as opposed to the RTDM regulatory default exponents resulted in marginally higher concentration predictions for both models.

Since LAPPES is a non-regulatory model there is no specific EPA guidance to reference with respect to the model inputs. However, the model options were chosen to follow the approach described in the modeling protocol and the general regulatory specifications for RTDM. The most distinguishing feature of LAPPES is the treatment of terrain (Section 2.3.1). The LAPPES terrain treatment was selected by setting model option number 25 to a value of 6.

The MPTER options selected were standard for typical regulatory applications, and follow those contained in the modeling protocol (Section 2.3.3).

4.0 STATISTICAL PROTOCOL FOR PERFORMANCE COMPARISON

The model evaluation data base included one year of ambient SO_2 air quality measurements from the network of ten monitors sited to measure peak short-term (3-hour and 24-hour average) concentrations. The data base also included predicted hourly concentrations from the reference model (RTDM/MPTER) and LAPPES/MPTER.

The protocol for model comparison defined the procedure which was used to score each model's performance and to select the winning model. The scoring procedures involved three elements: defining the performance measures, i.e., the specific characteristics of the observed and predicted values which were compared; assigning weights to the different performance measures; and specifying the numerical basis for assigning a performance score to each model.

4.1 Objectives

The objective of the Laurel/Chestnut Ridge model comparison study was to select that model which is the best predictor of peak short-term (3-hour and 24-hour average) SO_2 concentrations produced by the combined impacts of Penelec-operated sources at elevated terrain locations.

For regulatory applications, the magnitude of the highest second-highest 3-hour and 24-hour average predicted concentrations is the most critical factor for determining whether ambient standards are satisfied. Accounting for the contributions of individual emission sources to peak concentrations is also important for establishing emission limits. It is therefore desirable to predict the time and location of peak impacts correctly.

In order to estimate correctly how often critical impacts are likely to occur, it is also important for the models to predict peak impacts for appropriate meteorological conditions. Model performance was therefore also assessed as a function of meteorology.

4.2 Performance Measures

The performance measures and associated maximum possible point scores used in the Laurel/Chestnut Ridge model comparison study are summarized in Table 4-1. The magnitudes assigned to the maximum possible scores emphasize model performance for estimating peak short-term concentrations, since the network design analysis indicated that short-term concentrations will be controlling for setting emission limits.

The first performance measure, highest second-highest 3-hour and 24-hour average values, was considered to represent the "design concentration" for the monitoring network. A maximum of 30 out of 135 possible points, with equal weight for 3-hour and 24-hour values was assigned to this performance measure. The predicted design value must be within a factor of two of the observed value for points to be received.

The second set of performance measures involved the second-highest observed and predicted values at each station. Specific measures included the average difference over all stations, and the mean squared error, normalized by the standard deviations of the observed and predicted values. A maximum total of 49 points was available for these measures.

The third set of measures involved comparison of the average of the top N observed and predicted values, with N ranging from 25 for 1-hour averages to 10 for 24-hour averages. N was varied in recognition that the total sample size decreases as averaging time increases. These measures were assigned a maximum total of 21 points.

The fourth and fifth sets of performance measures were related to scientific evaluation. Peak observed and predicted values were compared for subsets based on meteorology, directly parallel to the comparisons in Items 1 and 3. Five subsets were defined by stability and stack top wind speed:

TABLE 4-1

SUMMARY OF SCORING FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

Performance Measure	Possible Score
1. Highest second high values	
3-hour average	15
24-hour average	15
2. Second high by station, paired by location	
a. Average difference (fractional bias)	
1-hour	5
3-hour	15
24-hour	15
b. Mean square error (normalized)	
1-hour	2
3-hour	6
24-hour	6
3. Top N values - fractional bias on average values	
a. 1-hour (N=25)	3
b. 3-hour (N=20)	9
c. 24-hour (N=10)	9
4. Second high by meteorological category (1 hour only - five categories)	
fractional bias - each category	10
5. Top N values by meteorological category (1 hour only - five categories)	
N = one percent of hours in category $10 \leq N \leq 25$	
fractional bias on average values - each category	5
6. All values - paired in time and location (1-hour)	
a. Average difference - fractional bias	7
b. MS error (normalized)	3
7. Annual average (each station)	
a. Highest observed vs. highest predicted (fractional bias)	5
b. Average observed vs. average predicted (fractional bias)	5
Total	135

1. Unstable (Class A, B, C)
2. Neutral, low wind speed (Class D; u $\leq$4 m/s)
3. Neutral, high wind speed (Class D; u >4 m/s)
4. Stable, low wind speed (Class E, F; u $\leq$4 m/s)
5. Stable, high wind speed (Class E, F; u >4 m/s)

Tower-top wind speeds and stability class values from Ash Valley were used to define the meteorological categories. A maximum total of 15 points was included for items 4 and 5. Comparisons were based only on 1-hour averages.

Item 6 involved all values, paired in time and location. Measures included the average difference and mean-squared error. These measures reflect the average bias and scatter associated with hourly predictions and were included primarily for scientific evaluation. A maximum total of 10 points was available for these items.

The final item concerned annual averages. Performance measures included comparison of the maximum annual values and the average difference over all monitors. A maximum total of 10 points was assigned for annual averages.

Overall, 25 points were allocated to peak one-hour values, 45 each to peak 3-hour and 24-hour values, 10 for the average of all values, and 10 for annual averages. Roughly equal weight was given to peak values compared without regard to location and to peak values paired by location.

The winning model will be used to estimate both the magnitude of peak concentrations and the relative contribution of different sources for the purpose of determining future emission limits. Source contributions are closely linked to specific receptor locations.

4.3 Methods for Calculating Point Scores

The calculation methods used for assigning point scores based on model performance are outlined in Table 4-2. For bias, all point scores were based on the absolute fractional bias (AFB). Fractional bias (FB) represents the

TABLE 4-2

PERFORMANCE SCORE CALCULATION METHODS FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY

---

1. Highest second high values - absolute fractional bias (AFB)
   Score = P(1-1.5 AFB), AFB $\leq$ 2/3
   Score = 0 , AFB $>$ 2/3
   Where P = possible score (15 for both the 3-hour and 24-hour averages, as indicated in Table 4-1)

2. Second high by station

   a. Average difference - AFB (same equation as Item 1)

   b. Normalized RMS Error (NRMSE)
      Score = p(1-0.5 NRMSE), NRMSE $\leq$2
      Score = 0 , NRMSE $>$2

3. Top N values - fractional bias on average values
   Score = P (1 - 2.5 AFB), AFB $\leq$ 0.4
   Score = 0 , AFB $>$ 0.4

4. Second high by meteorological category - AFB (same equation as Item 1)

5. Top N values by meteorological category - AFB on average of N values (same equation as Item 3)

6. All values - paired in time and location

   a. Average difference - AFB (same equation as Item 3)

   b. Normalized RMS Error (NRMSE)
      Score = P(1 - 0.5 NRMSE), NRMSE $\leq$ 2
      Score = 0 , NRMSE $>$ 2

7. Annual average

   a. AFB (same equation as Item 3)

   b. AFB (same equation as Item 3)

---

difference between observed and predicted values, normalized by the average of the same observed and predicted values.

$$FB = \frac{(Obs - Pred)}{0.5\ (Obs + Pred)} ,$$

where Obs and Pred represent the observed and predicted values being compared. FB can range in value between -2 and +2. A value of zero for FB represents perfect agreement between observed and predicted values. When observed and predicted values agree within a factor of 2, the FB will range between -2/3 and +2/3. Absolute fractional bias (AFB) represents the absolute value of the fractional bias and ranges between 0 and 2. The AFB gives equal weight to over- and underprediction, based on the ratio of the observed and predicted values.

The root mean-squared error (RMSE) is a measure of the magnitude of the differences between pairs of observed and predicted values. The mean-squared error (MSE) is given by:

$$MSE = \frac{1}{N} \sum_{i} (O_i - P_i)^2$$

where:

O_i, P_i and N are defined above.

The RMSE is simply the square root of the MSE. For performance scoring, the RMSE was normalized by the average observed value.

Performance scoring based on the AFB was similar for items 1, 2a and 4 in Table 4-2. A perfect score would be received when the AFB = 0. Zero score would be received unless observed and predicted values agree within a factor of two. Agreement within a factor of two for peak values is one generally recognized measure of acceptable model performance. The performance score would decrease linearly as the AFB increases from 0 to 2/3. For example, if the highest second-highest predicted and observed 3-hour concentrations for model A are 1000 μg/m^3 and 750 μg/m^3, respectively, then

$$AFB = \frac{|750 - 1000|}{0.5\ (750 + 1000)} = \frac{250.}{875.} = 0.286$$

The score received by model A would then be

$$S = P\ (1 - 1.5\ AFB) = 15\ (1 - .429) = 8.57$$

For items 3, 5, 6a and 7, the scores were also based on the AFB. These measures depend on averages over a number of peak concentrations, rather than single-value comparisons. Averages are subject to less uncertainty than single extreme values. The "acceptable range" of model performance was therefore narrower for these measures. Zero score would be received unless the observed and predicted average values agree within a factor of 1.5 (corresponding to an AFB = 0.40).

For Items 2b and 6b, a perfect score would be received for an RMSE = 0. No score would be received if the RMS error is more than twice as large as the average of the observed values. As the RMSE increases, the model score decreases. For example, if the RMSE is 25 μg/m^3 and the average observed concentration value is 15 μg/m^3, the model score would be

$$S = 3\ (1 - 0.5\ \frac{25}{15}) = 0.50$$

4.4 Selection Criteria

After point scores were calculated for each item, the total performance scores for the reference model and the proposed model were compared. In order to have been selected for future use, the proposed model must have achieved a performance score of at least 30 points and must have scored higher than the reference model.

5.0 MODEL COMPARISON RESULTS

The LAPPES model scored 52.03 points in the revised comparison study and the reference model, RTDM/MPTER, scored 2.73 points. LAPPES therefore achieved the two performance goals of outscoring the reference model and achieving a minimum of 30 points using the protocol scoring scheme. This section discusses the scoring and is organized by performance measure. Tables 5-1 and 5-2 provide a summary of the revised scoring for LAPPES and RTDM/MPTER by performance measure. Appendix A details the statistical calculations and the basis for the scoring.

5.1 Highest Second-High 3-Hour and 24-Hour Averages

This measure accounted for 22 percent of the total possible points in this comparison study and provided LAPPES with 29 percent (15.16) of its total points. LAPPES overpredicted by 41 percent and 38 percent for the 3-hour and 24-hour values, respectively. Both of these are within the factor of two criteria set forth to score any points. RTDM/MPTER overpredicted by 1304 percent and by 716 percent for the 3-hour and 24-hour averages, respectively, and scored zero points.

5.2 Highest Second-High by Station

For the 1-hour averaging period, the highest second-high observed SO_2 concentration of 929 μg/m^3 occurred at the Little Mill Creek receptor (M3). LAPPES predicted a highest second-high value of 1473 μg/m^3 at the same receptor (M3). RTDM/MPTER predicted a highest second-high 1-hour average concentration value of 12074 μg/m^3 at the Powdermill Run (M6) receptor. LAPPES overpredicted by up to a factor of 2.6, while the RTDM/MPTER overpredictions ranged up to a factor of 22.6. On average, LAPPES overpredicted this measure by a factor of 1.6, while RTDM/MPTER overpredicted

TABLE 5-1

SUMMARY OF SCORING FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY
LAPPES MODELING RESULTS

Performance Measure	Score (Actual/Possible)	
1. Highest Second High Values		
3-hour average	7.37	15
24-hour average	7.79	15
2. Second High by Station, Paired by Location		
a. Average Difference (fractional bias)		
1-hour	1.75	5
3-hour	8.29	15
24-hour	7.30	15
b. Mean Square Error (normalized)		
1-hour	1.31	2
3-hour	4.47	6
24-hour	4.61	6
3. Top N Values - Fractional Bias on Average Values		
a. 1-hour (N=25)	0.00	3
b. 3-hour (N=20)	0.00	9
c. 24-hour (N=10)	0.00	9
4. Second High by Meteorological Category (1-hour only - five categories)		
Fractional Bias - Each Category	3.32	10
5. Top N Values by Meteorological Category (1-hour only - five categories)		
N = one percent of hours in category 10 < = N < = 25		
Fractional Bias on Average Values - Each Category	0.57	5
6. All Values Paired in Time and Location (1-hour)		
a. Average Difference - Fractional Bias	0.00	7
b. MS Error (normalized)	0.00	3
7. Annual Average (each station)		
a. Highest Observed vs. Highest Predicted (fractional bias)	3.08	5
b. Average Observed vs. Average Predicted (fractional bias)	2.16	5
Totals	52.03	135

TABLE 5-2

SUMMARY OF SCORING FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY
RTDM MODELING RESULTS

Performance Measure	Score (Actual/Possible)	
1. Highest Second High Values		
3-hour average	0.00	15
24-hour average	0.00	15
2. Second High by Station, Paired by Location		
a. Average Difference (fractional bias)		
1-hour	0.00	5
3-hour	0.00	15
24-hour	0.00	15
b. Mean Square Error (normalized)		
1-hour	0.00	2
3-hour	0.00	6
24-hour	0.00	6
3. Top N Values - Fractional Bias on Average Values		
a. 1-hour (N=25)	0.00	3
b. 3-hour (N=20)	0.00	9
c. 24-hour (N=10)	0.00	9
4. Second High by Meteorological Category (1-hour only - five categories)		
Fractional Bias - Each Category	2.07	10
5. Top N Values by Meteorological Category (1-hour only - five categories)		
N = one percent of hours in category 10 < = N < = 25		
Fractional Bias on Average Values - Each Category	0.66	5
6. All Values Paired in Time and Location (1-hour)		
a. Average Difference - Fractional Bias	0.00	7
b. MS Error (normalized)	0.00	3
7. Annual Average (each station)		
a. Highest Observed vs. Highest Predicted (fractional bias)	0.00	5
b. Average Observed vs. Average Predicted (fractional bias)	0.00	5
Totals	2.73	135

by a factor of 5.4. RTDM/MPTER gained no points on this measure for both fractional bias and MSE, while LAPPES gained 1.75 and 1.31 points for fractional bias and MSE, respectively.

For the 3-hour averaging period, LAPPES predicted a highest second-high value of 740 $\mu g/m^3$ at the Sugar Run monitor (M8). RTDM predicted a highest second-high value of 7383 $\mu g/m^3$ at the Powdermill Run monitor (M6). The highest second-high observed SO_2 concentration value was 464 $\mu g/m^3$ at the Terrys Run monitor site (M9). When the data were paired in this manner, RTDM/MPTER overpredicted the measured concentrations by up to a factor of 22.8 and, on average, by a factor of 5.8. LAPPES scored considerably better, with a maximum overprediction of less than a factor of two and an average overprediction of 1.4. LAPPES scored 8.29 points on the absolute fractional bias portion of this measure and 4.47 points on the MSE portion. This measure provided LAPPES with 12.76 points and 25 percent of its total score. RTDM/MPTER did not receive any points for this measure.

For the 24-hour averaging period, both models overpredicted on average, but this measure showed cases at individual monitors where both LAPPES/MPTER and RTDM/MPTER underpredicted. Both models underpredicted the highest second-high at the Marshall Heights (M4) and Luciusboro (M10) monitors. LAPPES also underpredicted the highest second-high at the Bear Cave (M2) and Penn View (M5) monitors. However, on average, RTDM/MPTER overestimated this measure by a factor of 4.5 and LAPPES overestimated by a factor of only 1.1. The absolute value of the fractional bias was used in the analysis to prevent underprediction and overprediction from compensating for each other in the aggregate statistics, which would result in an artificially higher score. Even with this compensatory effect removed, LAPPES scored 7.30 points on the absolute fractional bias portion and 4.61 points on the MSE portion of this measure. This measure accounted for 23 percent of the LAPPES point total while RTDM/MPTER scored zero.

The Marshall Heights and Luciusboro monitors are located at the lowest terrain elevations of the ten monitors included in the study. The Luciusboro monitor is located below all the Penelec power plant stack top elevations, and the Marshall heights monitor is located below all the stack top elevations except those of Keystone and Seward. Thus, the peak predicted impacts at these two monitors are primarily attributable to those calculated by the MPTER model (see Figure 5-1). Many of the peak predicted impacts at the Penn View monitor are also likely to be attributable to the MPTER model, as the Penn View monitor is also located at a relatively low elevation (i.e., below the stack top elevations of Conemaugh and Homer City 3 and only 30 feet above the stack top elevations of Homer City 1 & 2).

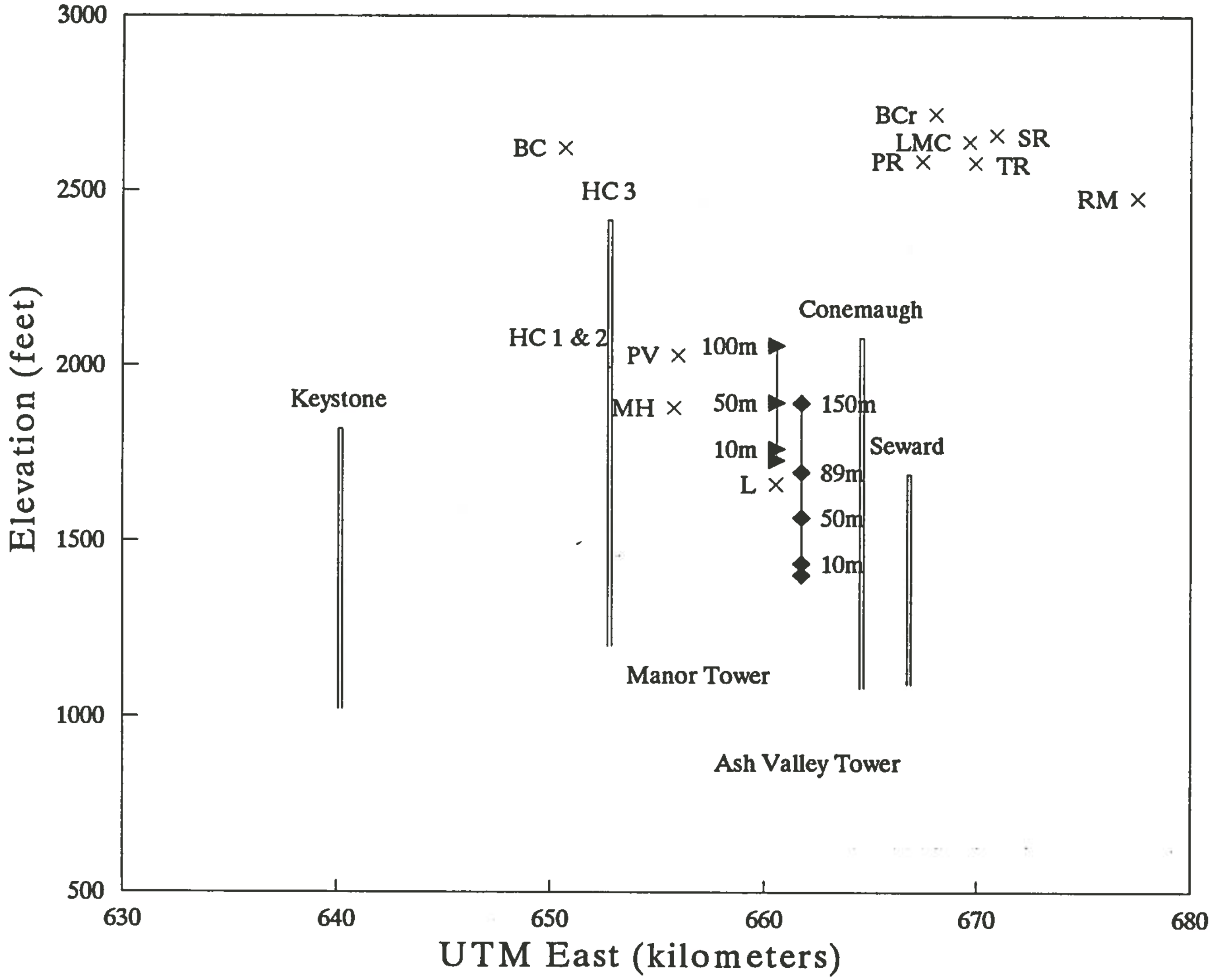
As shown in Figures 5-2 through 5-4, the LAPPES model provided much better simulations for the 1-hour, 3-hour and 24-hour average concentrations at the individual monitors and for the overall monitoring network. At most of the monitors, the LAPPES model's predictions were less than a factor of two higher than the measured concentrations. In contrast, the RTDM/MPTER model's predictions were usually much higher than the measured concentrations.

5.3 Fractional Bias on Average of Top N Values

As noted in the other 1-, 3- and 24-hour average measures, LAPPES outperformed RTDM/MPTER in predicting the magnitude of the high second-high monitored concentrations, and points were awarded to LAPPES because the predicted concentrations were within a factor of two of the monitored concentrations. In the top N value measures, the point threshold was set at a lower FB of 0.40 (which corresponds to an over/underprediction of 50 percent). Neither model scored on this measure for either the 1-, 3- or 24-hour averaging periods, though LAPPES was within a factor of two overprediction (average fractional bias = 0.6667) for all of these cases.

Figure 5–1a

Cross–Sectional View of the Laurel/Chestnut Ridge Model Comparison Study Area with the Penelec Power Plant Stacks, Meteorological Towers and Sulfur Dioxide Monitoring Sites (Facing North)



Legend:

SO2 Monitors:

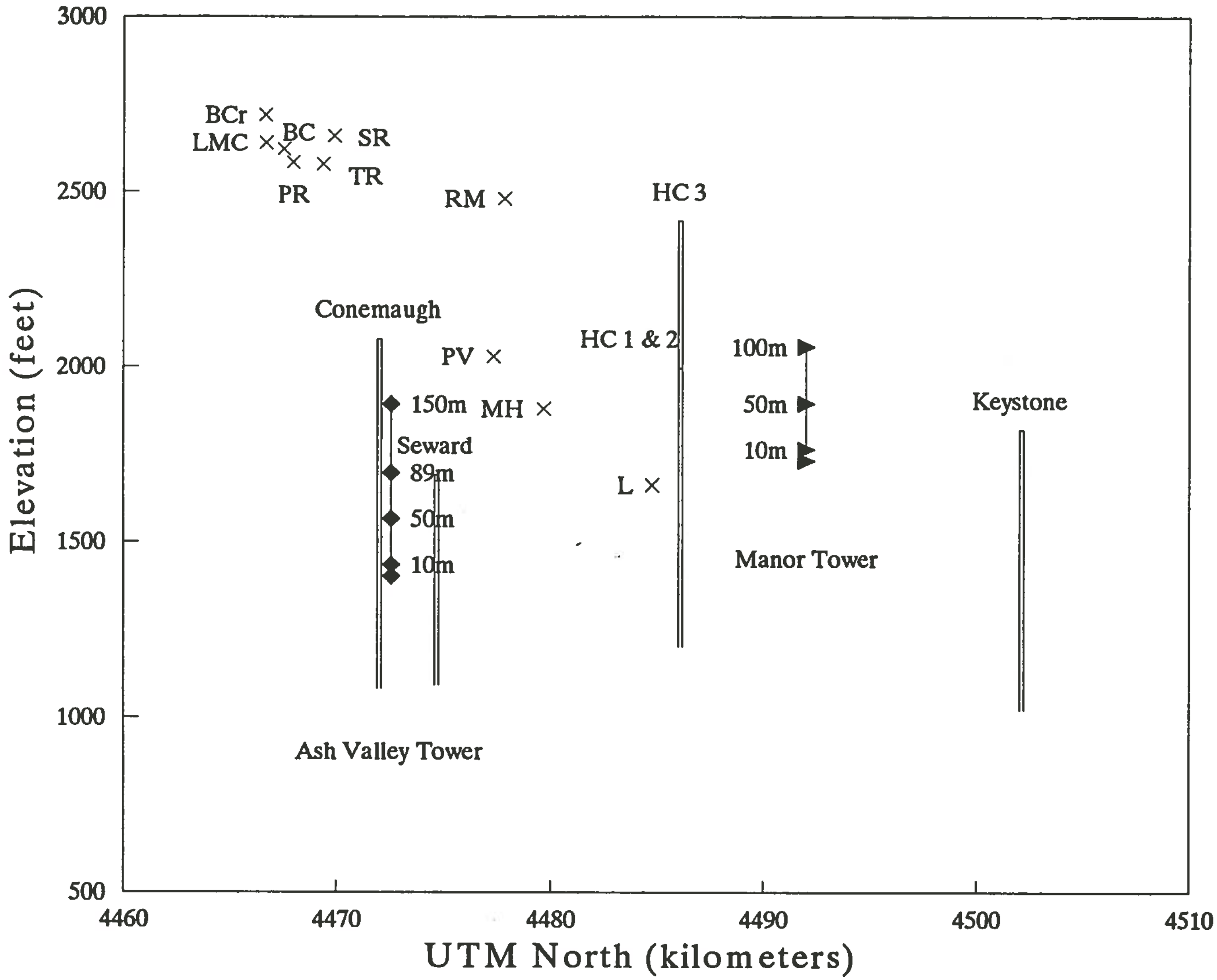
BC = Bear Cave
BCr = Baldwin Creek
L = Luciusboro
LMC = Little Mill Creek
MH = Marshall Heights
PR = Powdermill Run
PV = Penn View
RM = Rager Mountain
SR = Sugar Run
TR = Terrys Run

Power Plants:

HC1 = Homer City 1
HC2 = Homer City 2
HC3 = Homer City 3

Figure 5–1b

Cross–Sectional View of the Laurel/Chestnut Ridge Model Comparison Study Area with the Penelec Power Plant Stacks, Meteorological Towers and Sulfur Dioxide Monitoring Sites (Facing West)



Legend:

SO2 Monitors:

BC = Bear Cave
BCr = Baldwin Creek
L = Luciusboro
LMC = Little Mill Creek
MH = Marshall Heights
PR = Powdermill Run
PV = Penn View
RM = Rager Mountain
SR = Sugar Run
TR = Terrys Run

Power Plants:

HC1 = Homer City 1
HC2 = Homer City 2
HC3 = Homer City 3

Figure 5–2

Comparisons Of the Modeled and Monitored

High Second High 1–Hour Average Concentrations (μg/m ^ 3)

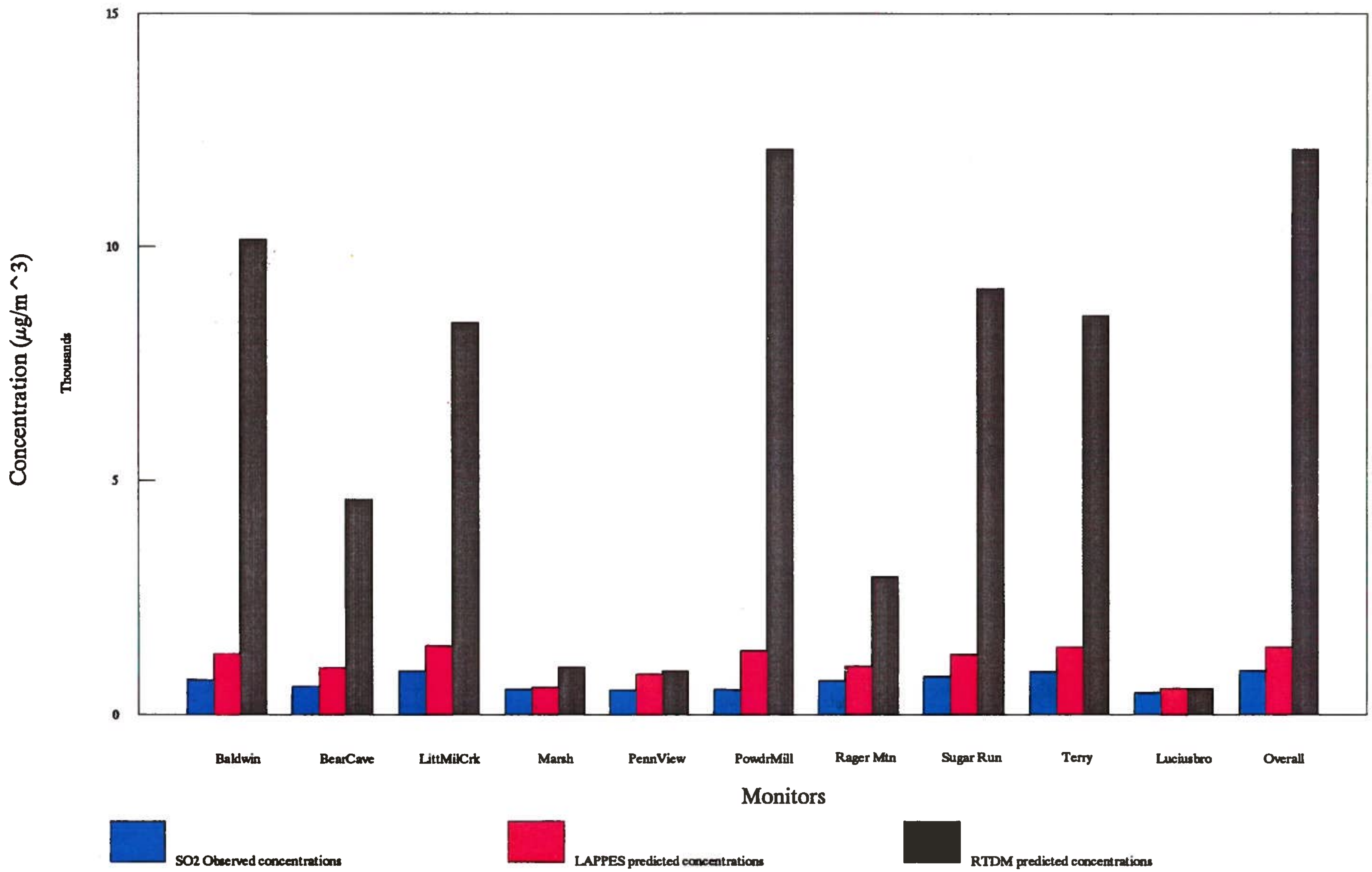


Figure 5–3
Comparisons of the Modeled and Monitored
High Second High 3–Hour Average Concentrations (µg/m ^ 3)

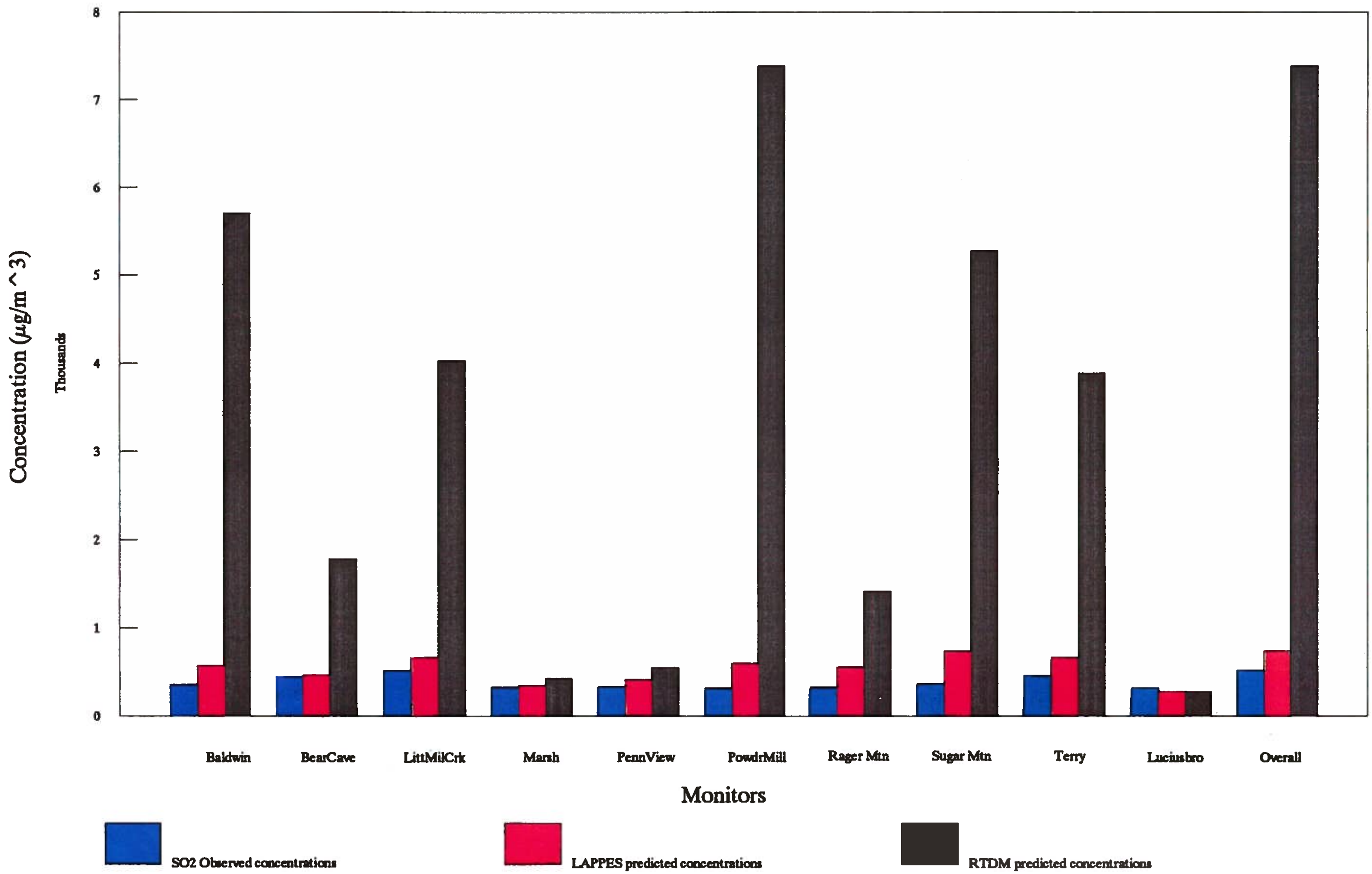
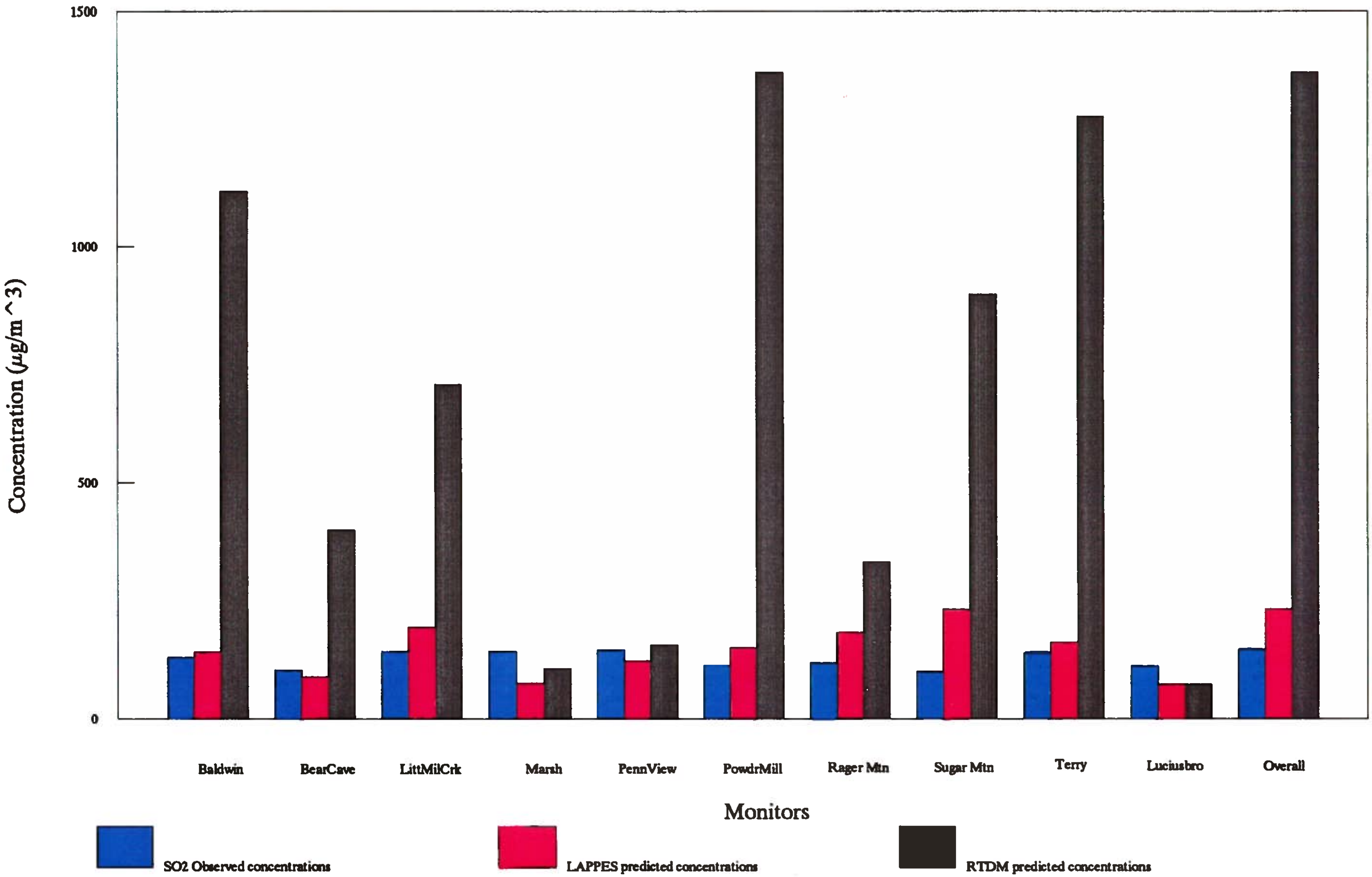


Figure 5–4
Comparisons of the Modeled and Monitored
High Second High 24–Hour Average Concentrations ($\mu g/m^3$)



Although the scoring results do not indicate which model performed better in this measure, Figure 5-5, for example, definitely demonstrates that the LAPPES model's predictions were much better than those of the RTDM/MPTER model.

5.4 Second High by Meteorological Category

The performance of Gaussian dispersion models can be dependent upon meteorological conditions. Therefore the measured and predicted SO_2 concentration data were sorted into five stability/wind speed categories based on the classifications described in Section 4.2 so that model performance could be graded by meteorology. The distribution of hours by category was used to determine the number of predicted and observed values to be compared in the next performance measure. Table 5-3 and Figure 5-6 show the calculated distribution of hours by meteorological category for the Ash Valley data set. Appendix B contains detailed information regarding the observed data and modeled predictions for LAPPES and RTDM/MPTER sorted by meteorological category.

The models predicted the highest second-high concentrations more accurately under unstable atmospheric conditions (Category 1) than they did under stable conditions (Categories 4 and 5). RTDM/MPTER scored its first points of the evaluation on this measure, as it predicted within a factor of two in unstable and high wind speed neutral meteorology.

However, neither model scored any points for predictions during high wind speed stable meteorology conditions (Category 5). Under high wind speed neutral and stable conditions, the LAPPES SO_2 concentration predictions were much closer to the monitored values than were the predictions from RTDM/MPTER. LAPPES scored points in Categories 1 through 4 and missed scoring in Category 5 by overpredicting by just over a factor of two (AFB of 0.81). The RTDM/MPTER SO_2 concentration predictions were much higher in Categories 2,

Figure 5–5
Comparisons of the Modeled and Monitored
Top 20 3–Hour Average Concentrations ($\mu g/m^3$)

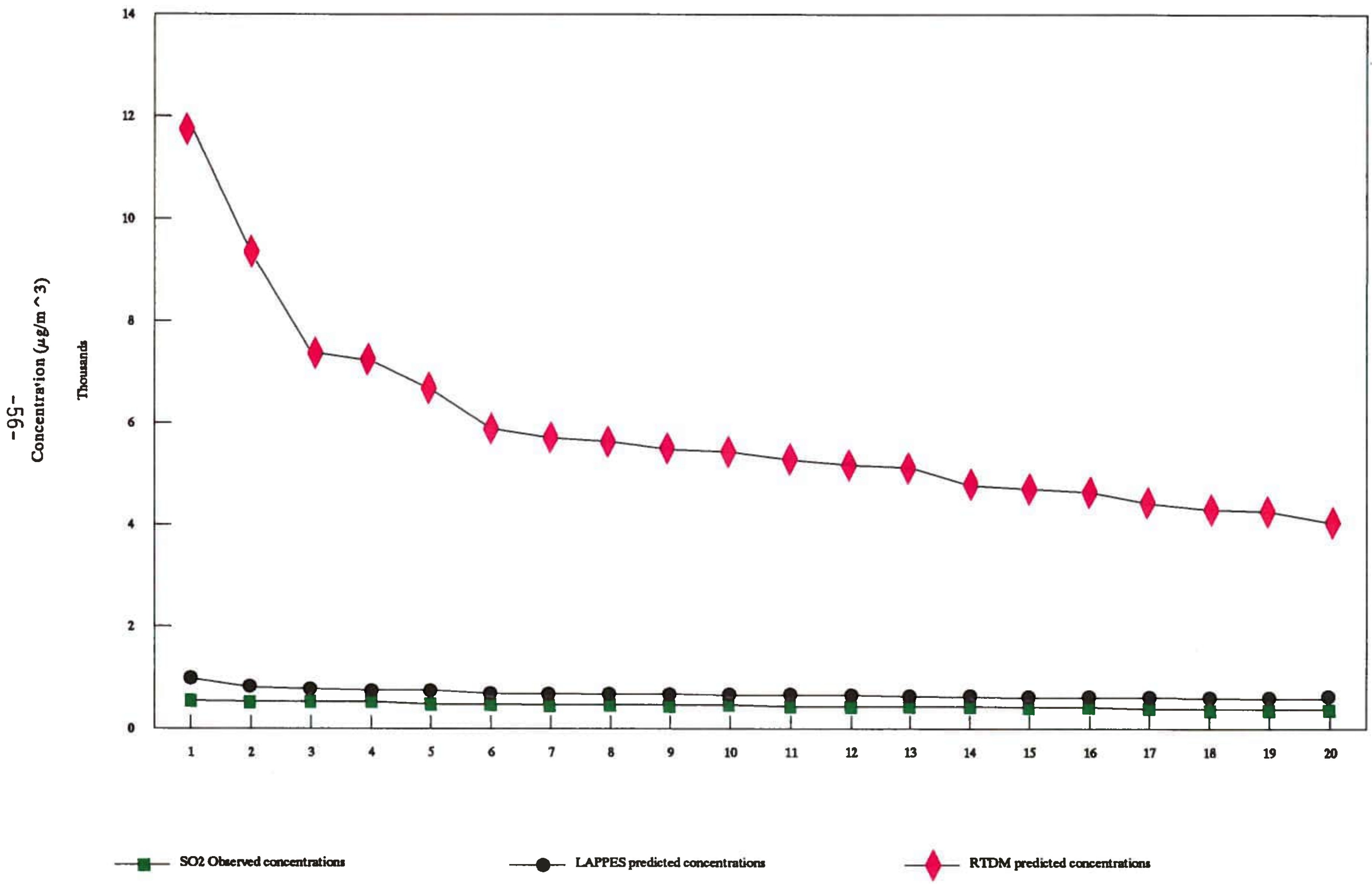


TABLE 5-3

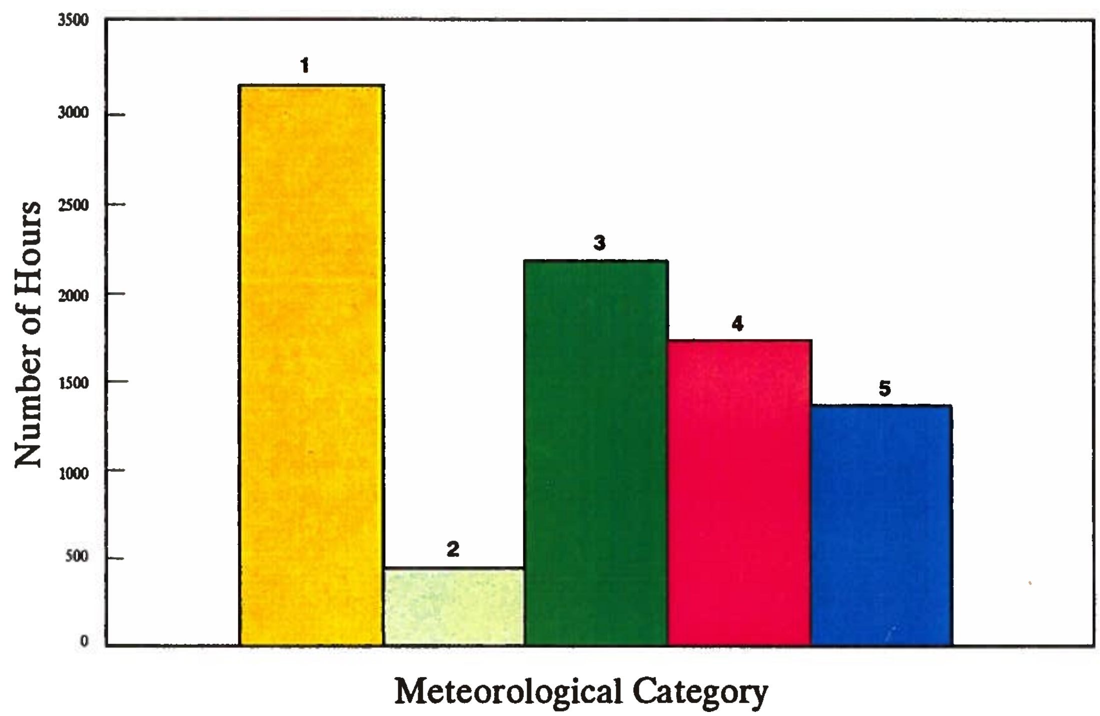
DISTRIBUTION OF HOURS
BY METEOROLOGICAL CATEGORY
FROM THE ASH VALLEY DATA SET

Meteorological Category	Number of Hours	One Percent of Hours (N)
1	3,154	32 *25
2	405	4 *10
3	2,154	22
4	1,706	17
5	1,341	13

* (10 < = N < = 25)

Figure 5-6

Distribution of Hours
by Meteorological Category
from the Ash Valley Data Set



1 = unstable, low wind speed
2 = neutral, low wind speed
3 = neutral, high wind speed
4 = stable, low wind speed
5 = stable, high wind speed

4 and 5, with the highest overpredictions occurring in stable, low wind speed conditions (Category 4). For this category, LAPPES had a fractional bias of 0.55 compared to a fractional bias of 1.75 for RTDM/MPTER. Although not fully reflected in the scoring, the performance of LAPPES in three of the five meteorological categories was considerably better than that of RTDM/MPTER for predicting the magnitude of the highest second-high 1-hour average values.

5.5 Top N Values Sorted by Meteorological Category

For each model, the top N values were compared for each of the five meteorological categories described above.

In support of the results discussed in Section 5.4, both models again scored points when the averages of the top 25 concentrations measured and predicted in unstable meteorological conditions (Category 1) were examined. In this case, LAPPES underpredicted by approximately 16 percent, while RTDM/MPTER overpredicted by approximately 15 percent. For meteorological category 2, LAPPES overpredicted by less than a factor of 1.6. For stable and low wind speed conditions (Category 4), RTDM/MPTER overpredicted by approximately a factor of 16, while LAPPES overpredicted by approximately a factor of two. However, no points were attained by either model in any meteorological category other than category 1.

5.6 All Values Paired in Time and Space

Predictions for both models were evaluated at each monitor location, for each hour of the study period. The absolute fractional bias on average differences for all values was calculated, as well as the mean square error, normalized by the average observed value. Most Gaussian formulations have trouble with this measure. Point by point correlations are typically low, but this is not considered important because only the maximum or second-high values for a given averaging time, regardless of location, are typically used in regulatory modeling. Point by point fractional bias and the normalized error were very large for both models in this study. Neither model scored any points on this measure.

5.7 Annual Average: Highest Observed vs. Highest Predicted

LAPPES performed better than RTDM/MPTER in predicting the overall highest annual average. LAPPES also predicted the location correctly for this performance measure. However, the highest predicted annual average SO_2 concentration was 23 percent lower than the actual observed value at the Rager Mountain monitor site (M7). RTDM/MPTER overpredicted for this measure by a factor of over two and did not score any points.

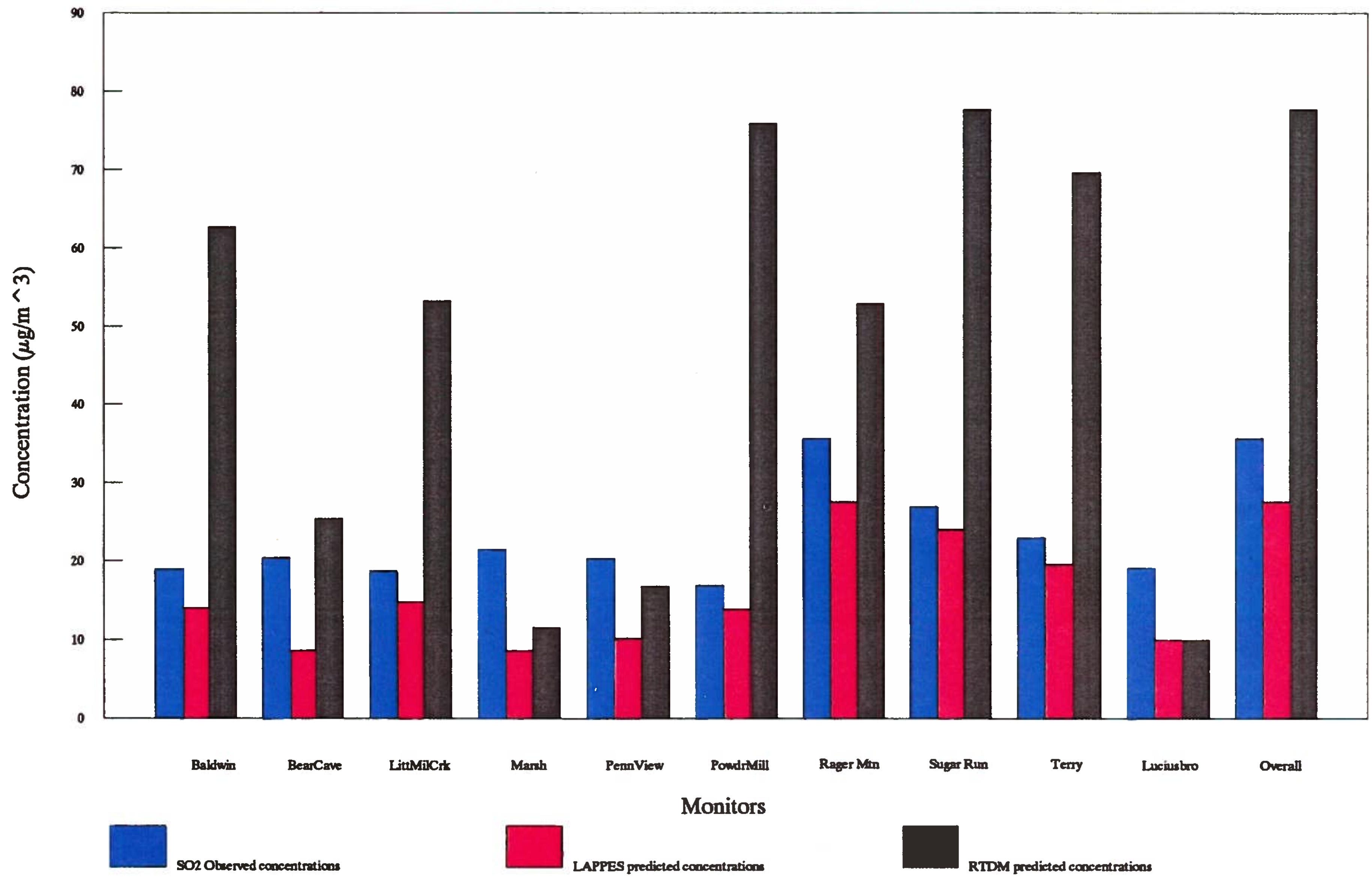
5.8 Annual Average: Average Observed vs. Average Predicted

LAPPES performed reasonably well when averages of the annual average model predictions and observed values were compared. However, LAPPES underpredicted the average annual observed value at all the monitoring locations. Nonetheless, the average predicted value over all locations was within 32 percent of the average of the annual observed values.

RTDM/MPTER again overpredicted by a factor of over two for the average of the annual values. As did LAPPES, RTDM/MPTER also underpredicted for the Marshall Heights (M4), Penn View (M5) and Luciusboro (M10) monitoring locations. At the Powermill Run (M6) monitor, RTDM/MPTER overpredicted by a factor of approximately 4.5.

As shown in Figure 5-7, the LAPPES model always underpredicted the annual average concentrations, while RTDM/MPTER frequently greatly overpredicted the concentrations.

Figure 5–7
Comparisons of the Modeled and Monitored
High Annual Average Concentrations ($\mu g/m^3$)



6.0 CONCLUSIONS

LAPPES/MPTER clearly outperformed the reference model in this revised study. The total score for LAPPES/MPTER was 52.03, and this was much greater than the 2.73 points scored by the reference model, RTDM/MPTER. The point total for the LAPPES/MPTER model also exceeded the 30 points required of an alternative model by the model comparison protocol. LAPPES/MPTER overpredicted on the 3- and 24-hour average Top N measured values by approximately a factor of 1.5 for both cases, therefore no underprediction correction will be necessary.

In general, the study pointed out some of the known weaknesses of the Gaussian models. They do not predict well in stable atmospheric circumstances where local flows may dominate and the spatial representativeness of single point meteorology is limited. These types of models also generally do poorly in point by point comparison statistics because small, short period atmospheric motions are simply impossible to anticipate or simulate exactly.

Conversely, LAPPES/MPTER has demonstrated that it is a far superior model to RTDM/MPTER at this site. The stringent cut-off which prevented either model from scoring if the prediction was over a factor of two greater than the observed value (or a factor of 1.5 in some of the scoring) means that a LAPPES/MPTER prediction which was a factor of 2.5 greater than the observed value was given the same score (0) as an RTDM/MPTER prediction that was 10 or more times larger than the observed value. This happened often in this study.

According to the model comparison protocol, the implications of this study are as follows:

- LAPPES/MPTER will be applied to estimate impacts at elevated terrain locations above stack top on Laurel Ridge and Chestnut Ridge. Regulatory modeling procedures will be used to estimate impacts at any other locations.
- For Seward, RTDM/MPTER will be used to predict impacts.

- MPTER will be used to predict impacts at all receptors below stack top, for each source.

- Receptor grids will utilize actual terrain elevations at receptor locations.

- Meteorological inputs will be developed using the same procedures applied for the performance comparison. Meteorological data collected for the performance comparison will be used for the model application.

- Emissions from all sources will be modeled at maximum load and maximum allowable emissions.

- Model options will be chosen to match those selected for the performance comparison.

- Hourly background concentrations will be determined from air quality measurements, following the performance comparison procedures.

7.0 REFERENCES

EPA, "User's Guide for MPTER - A Multiple Point Gaussian Dispersion Algorithm with Optional Terrain Adjustment," April 1980.

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Slowik, A.A., J.M. Austin, and G.N. Pica, "Plume Dispersion Modeling in Complex Terrain Under Stable Atmospheric Conditions," Paper for Presentation at the 70th Annual Meeting of the Air Pollution Control Association, June 1977.

TRC, "Modeling Analysis to Determine Predicted Concentrations and to Assess the Existing Monitoring Network for the Laurel Ridge/Chestnut Ridge Region," September 1987.

TRC, "Protocol for Model Performance Comparison Study for Laurel Ridge and Chestnut Ridge," February 1991.

APPENDIX A

PERFORMANCE SCORING FOR LAUREL/CHESTNUT RIDGE MODEL COMPARISON STUDY - SUMMARY OF STATISTICAL SCORING

TRC

MODEL COMPARISION STUDY
SUMMARY OF STATISTICAL SCORING
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M. ANDERSON 8/6/92

Penelec Ambient SO2 Monitors

name	elev	no.	UTM E	UTM N
M1 BALDWIN	2720 ft.	1	668.05	4466.68
M2 BEARCAVE	2623 ft.	2	650.66	4467.53
M3 LITTMCR	2640 ft.	3	669.65	4466.70
M4 MARSH	1880 ft.	4	655.76	4479.66
M5 PENNVIEW	2030 ft.	5	655.97	4477.32
M6 POWDRMILL	2584 ft.	6	667.42	4467.98
M7 RAGER MTN	2480 ft.	7	677.49	4477.86
M8 SUGAR RUN	2660 ft.	8	670.90	4469.90
M9 TERRY	2580 ft.	9	669.91	4469.39
M10 LUCIUSBORO	1660 ft.	10	660.50	4484.76

Performance Scoring :

1. HIGHEST SECOND–HIGH CONCENTRATION VALUES : ABSOLUTE FRACTIONAL BIAS

	Concentrations in μg/m3		Absolute Fractional Bias		SCORE: = P(1–1.5 AFB), AFB<= 2/3 = 0.00, AFB> 2/3		
	3–hour	24–hour	3–hour	24–hour			
SO2 OBS.	525.73	167.95			SCORE:	3 hr	24 hr
LAPPES	740.54	231.99	0.3393	0.3202	LAPPES	7.37	7.79
RTDM	7383.24	1369.85	1.7341	1.5631	RTDM	0.00	0.00

Running Subtotals:	
LAPPES	15.16
RTDM	0.00

2. HIGHEST SECOND HIGH BY STATION:

1–HOUR AVERAGE CONCENTRATION: HIGHEST SECOND–HIGH

Concentrations in μg/m3

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
SO2 OBS.	736.20	607.80	928.50	542.30	518.80	534.50	725.70	817.40	914.40	463.70
LAPPES	1299.36	995.18	1472.57	579.28	856.13	1374.03	1028.68	1283.56	1440.69	549.86
RTDM	10148.70	4591.44	8362.16	1014.59	933.39	12074.25	2946.73	9082.95	8508.00	549.86

TRC

2a. AVERAGE DIFFERENCE – 1 hour average

FB:

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR	AFB
	(observed−predicted) / (0.5(observed+predicted)										
LAPPES	−0.5533	−0.4833	−0.4532	−0.0659	−0.4907	−0.8798	−0.3454	−0.4438	−0.4469	−0.1700	0.4332
RTDM	−1.7295	−1.5324	−1.6002	−0.6067	−0.5710	−1.8304	−1.2096	−1.6697	−1.6118	−0.1700	1.2531

SCORE:
= P(1−1.5 AFB), AFB<= 2/3
= 0.00, AFB> 2/3

LAPPES:	1.75
RTDM:	0.00

Running Subtotals:

LAPPES	16.91
RTDM	0.00

2b. MEAN SQUARE ERROR (Normalized) – 1 hour average

Normalized RMS Error (NRMSE)
Score = p(1–0.5 NRMSE), NRMSE <= 2
Score = 0, NRMSE <= 2

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR	MSE 1/N Sum (OI –PI) ^2
(OI –PI) ^2											
LAPPES	317149.2	150063.3	296012.2	1367.52	113791.5	704810.6	91796.88	217305.1	276981.2	7423.546	217670.1
RTDM	88595156	15869388	55259301	223057.8	171884.9	1.3E+08	4932974	68319317	57662761	7423.546	42420709

	NRMSE:	SCORE:
LAPPES:	0.687186	1.31
RTDM:	9.59321	0.00

Running Subtotals:	
LAPPES	18.22
RTDM	0.00

3–HOUR AVERAGE CONCENTRATION: HIGHEST SECOND–HIGH

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
	Concentrations in μg/m3									
SO2 OBS.	360.70	454.10	524.00	332.73	338.83	324.00	334.47	374.67	464.63	320.50
LAPPES	577.87	470.95	669.59	347.49	416.81	601.24	562.02	740.54	671.07	278.96
RTDM	5705.61	1785.66	4029.74	431.38	557.66	7383.24	1417.02	5270.73	3884.37	278.96

2A. AVERAGE DIFFERENCE – 3 hour average

FB:

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR	AFB
	(observed–predicted) / (0.5(observed+predicted)										
LAPPES	−0.4628	−0.0364	−0.2440	−0.0434	−0.2064	−0.5993	−0.5076	−0.6561	−0.3635	0.1386	0.2981
RTDM	−1.7622	−1.1890	−1.5397	−0.2582	−0.4882	−1.8318	−1.2361	−1.7345	−1.5727	0.1386	1.1474

SCORE:
= P(1–1.5 AFB), AFB<= 2/3
= 0.00, AFB> 2/3

LAPPES:	8.29
RTDM:	0.00

Running
Subtotals:

LAPPES	26.52
RTDM	0.00

TRC

2b. MEAN SQUARE ERROR (Normalized) – 3 hour average

Normalized RMS Error (NRMSE)
Score = p(1–0.5 NRMSE), NRMSE <= 2
Score = 0, NRMSE > 2

(OI – PI) ^2; MSE = 1/N Sum (OI – PI) ^2

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR	MSE 1/N Sum (OI – PI) ^2
LAPPES	47162.81	283.9225	21196.45	217.8576	6080.88	76862.02	51779	133860.9	42617.47	1725.572	38178.68
RTDM	28568063	1773052	12290213	9731.823	47886.57	49832869	1171915	23971404	11694622	1725.572	12936148

	NRMSE:	SCORE:
LAPPES:	0.510349	4.47
RTDM:	9.394185	0.00

Running
Subtotals:

LAPPES	30.99
RTDM	0.00

TRC

24–HOUR AVERAGE CONCENTRATION: HIGHEST SECOND–HIGH

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
	Concentrations in µg/m3									
SO_2 OBS.	129.49	103.33	142.85	143.50	145.85	112.21	118.63	99.81	139.18	111.73
LAPPES	141.75	88.57	194.18	76.02	122.21	149.68	182.57	231.99	160.91	72.06
RTDM	1117.38	399.44	707.48	106.26	156.35	1369.85	332.25	896.35	1275.07	72.06

2A. AVERAGE DIFFERENCE -- 24 hour average

FB:

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR	AFB
	(observed–predicted) / (0.5(observed+predicted)										
LAPPES	–0.0904	0.1538	–0.3046	0.6148	0.1764	–0.2862	–0.4246	–0.7967	–0.1448	0.4317	0.3424
RTDM	–1.5846	–1.1779	–1.3280	0.2982	–0.0695	–1.6972	–0.9476	–1.5992	–1.6063	0.4317	1.0740

SCORE:
= P(1–1.5 AFB), AFB<= 2/3
= 0.00, AFB> 2/3

LAPPES: 7.30
RTDM: 0.00

Running Subtotals:
LAPPES 38.28
RTDM 0.00

TRC

2b. MEAN SQUARE ERROR (Normalized) – 24 hour average

Normalized RMS Error (NRMSE)
Score = p(1–0.5 NRMSE), NRMSE <= 2
Score = 0, NRMSE <= 2

	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR	MSE 1/N Sum (Oi –Pi) ^ 2
	(Oi –Pi) ^ 2										
LAPPES	150.3076	217.8576	2634.769	4553.55	558.8496	1404.001	4088.324	17471.55	472.1929	1573.709	3312.511
RTDM	975926.7	87681.13	318807	1386.818	110.25	1581658	45633.5	634476	1290246	1573.709	493750

	NRMSE:	SCORE:
LAPPES:	0.461699	4.61
RTDM:	5.63681	0.00

Running Subtotals:	
LAPPES	42.90
RTDM	0.00

3. Top N Values – fractional bias on average values

3a. 1 – hour (N = 25) Concentrations in μg/m3

Rank	SO2 OBS.	LAPPES	RTDM
1	1032.30	1641.90	12864.80
2	982.50	1591.91	12074.25
3	945.80	1512.53	11966.89
4	943.20	1472.57	11437.26
5	922.20	1440.69	10970.30
6	914.40	1413.97	10834.92
7	822.70	1391.85	10409.07
8	817.40	1378.29	10408.97
9	788.60	1374.03	10341.76
10	772.90	1357.81	10180.34
11	770.30	1321.87	10148.7
12	765.00	1315.26	9959.96
13	757.20	1314.45	9798.45
14	749.30	1299.36	9533.84
15	746.70	1283.56	9506.57
16	736.20	1275.81	9338.52
17	733.60	1266.30	9315.87
18	725.70	1262.11	9288.62
19	723.10	1255.19	9097.51
20	720.50	1242.35	9082.95
21	712.60	1223.95	8900.11
22	712.60	1220.36	8822.72
23	702.20	1216.08	8691.91
24	696.90	1206.83	8598.60
25	694.30	1206.78	8508.78
Average Values	795.53	1339.43	10003.27

Fractional Bias On Average Values :		SCORE: P (1 – 2.5 AFB), AFB <= 0.4 0, AFB > 0.4	Running Subtotals:	
LAPPES	0.509522	0.00	LAPPES	42.90
RTDM	1.705327	0.00	RTDM	0.00

TRC

3b. 3 – hour (N = 20) Concentrations in μg/m3

Rank	SO2 OBS.	LAPPES	RTDM
1	544.10	978.31	11826.13
2	525.73	802.41	7330.13
3	524.00	761.93	7383.24
4	524.00	740.54	7199.86
5	464.63	739.61	6646.04
6	464.63	671.07	5888.93
7	458.50	669.59	5705.61
8	458.50	668.57	5631.02
9	454.10	661.99	5468.92
10	454.10	648.24	5420.90
11	422.70	643.96	5270.73
12	422.70	639.28	5160.79
13	419.20	622.12	5118.91
14	419.20	607.72	4769.04
15	418.33	601.94	4702.67
16	410.47	601.24	4634.53
17	374.67	596.68	4412.92
18	374.67	591.91	4288.27
19	374.67	578.78	4253.96
20	374.67	577.87	4035.86
Average Values	444.18	670.19	5757.42

Fractional Bias On Average Values :		SCORE: P (1 – 2.5 AFB), AFB <= 0.4 0, AFB > 0.4	Running Subtotals:	
LAPPES	0.405629	0.00	LAPPES	42.90
RTDM	1.713507	0.00	RTDM	0.00

TRC

3c. 24 – hour (N = 10) Concentrations in μg/m3

Rank	SO2 OBS.	LAPPES	RTDM
1	174.88	286.07	1485.78
2	167.95	269.61	1369.85
3	146.99	254.00	1361.67
4	146.68	239.13	1290.67
5	145.84	235.21	1275.07
6	143.50	231.99	1207.49
7	143.50	217.08	1169.83
8	142.85	202.87	1117.38
9	142.85	194.18	1069.74
10	139.18	182.57	992.28
Average Values	149.42	231.27	1233.98

Fractional Bias On Average Values :		SCORE: P (1 – 2.5 AFB), AFB <= 0.4 0, AFB > 0.4	Running Subtotals:	
LAPPES	0.430000	0.00	LAPPES	42.90
RTDM	1.567957	0.00	RTDM	0.00

TRC

4. Second High By Meteorological Category
(1 – hour only, Five Categories)
Concentrations in µg/m3

	Category 1	Category 2	Category 3	Category 4	Category 5
SO2 Obs.	945.80	626.20	725.70	817.40	676.00
LAPPES	765.30	781.47	1314.45	1440.69	1591.91
RTDM	968.74	1392.8	1377.88	12074.25	4685.21

Fractional Bias :

	Category 1	Category 2	Category 3	Category 4	Category 5
LAPPES	0.210975	0.220606	0.577163	0.552051	0.807713
RTDM	0.023964	0.759386	0.620067	1.746378	1.495636

SCORE: P (1–1.5*AFB) , AFB <= 2/3

						Subtotal:
LAPPES	1.367074	1.338183	0.268510	0.343848	0.00	3.317615
RTDM	1.928108	0.00	0.139800	0.00	0.00	2.067908

Running Subtotals:	
LAPPES	46.21
RTDM	2.07

TRC

5. Top N Values by Meteorological Category
(1 – hour only, Five Categories)
Concentrations in $\mu g/m3$

N = one percent of hours in category

Fractional bias on average values – each category

Scoring: 5 points (1 point each category)

Number of Hours In Each Category :		N	
cat	hours	1%	
1	3154	32	*25
2	405	4	*10
3	2154	22	
4	1706	17	
5	1341	13	

* 10 <= N <= 25

TRC

Category 1
Top N (N=25) Hours
1– hour Concentration in $\mu g/m3$

Rank	SO2 Obs.	LAPPES	RTDM
1	1032.30	929.57	1062.23
2	945.80	765.30	968.74
3	943.20	743.95	944.96
4	922.20	723.13	925.92
5	914.40	716.88	909.48
6	822.70	692.42	907.38
7	772.90	646.09	883.31
8	770.30	626.08	881.39
9	765.00	623.36	872.55
10	757.20	623.02	861.31
11	749.30	613.10	851.93
12	723.10	598.26	843.68
13	712.60	593.75	837.52
14	696.90	589.14	831.74
15	694.30	585.75	818.56
16	689.10	582.09	816.51
17	676.00	571.19	815.92
18	662.90	569.73	815.91
19	655.00	569.71	814.94
20	652.40	568.11	807.90
21	649.80	566.83	804.02
22	641.90	564.80	801.45
23	636.70	563.77	790.02
24	620.90	558.90	786.52
25	613.10	556.13	785.14

Average Values :	748.80	629.64	857.56

Fractional Bias on Average Values :

SCORE: P (1 – 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

	Fractional Bias	SCORE
LAPPES	0.172887	0.567782
RTDM	0.135413	0.661467

Running Subtotals:

LAPPES	46.78
RTDM	2.73

TRC

Category 2
Top N (N=10) Hours
1– hour Concentration in μg/m3

Rank	SO_2 Obs.	LAPPES	RTDM
1	720.50	1255.19	1408.60
2	626.20	781.47	1392.80
3	448.00	724.16	1332.03
4	445.40	715.56	1220.68
5	432.30	689.53	1093.27
6	419.20	666.48	992.61
7	408.70	627.39	911.39
8	398.20	615.97	908.68
9	393.00	598.81	829.57
10	387.80	598.51	803.78

Average Values :	467.93	727.31	1089.34

Fractional Bias on Average Values :

SCORE: P (1 – 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

	Fractional Bias	SCORE
LAPPES	0.434018	0.00
RTDM	0.798077	0.00

Running Subtotals:

LAPPES	46.78
RTDM	2.73

TRC

Category 3
Top N (N=22) Hours
1– hour Concentration in μg/m3

Rank	SO2 Obs.	LAPPES	RTDM
1	746.70	1321.87	1557.45
2	725.70	1314.45	1377.38
3	550.20	1180.20	1282.77
4	542.30	1173.37	1244.06
5	534.50	1158.02	1216.84
6	487.30	1068.12	1207.70
7	461.10	1067.39	1188.27
8	427.10	1031.33	1184.32
9	424.40	1011.16	1140.78
10	421.80	970.87	1130.92
11	419.20	952.54	1122.17
12	414.00	901.06	1115.68
13	403.50	892.45	1058.49
14	403.50	856.95	1042.60
15	398.20	848.27	1008.59
16	398.20	843.92	981.55
17	390.40	830.03	972.74
18	382.50	806.22	953.34
19	379.90	801.94	924.53
20	366.80	799.92	911.06
21	364.20	793.11	904.13
22	353.70	789.61	885.13

Average Values :	454.33	973.31	1109.57

Fractional Bias on Average Values :

SCORE: P (1 – 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

LAPPES	0.72705	0.00
RTDM	0.83796	0.00

Running
Subtotals:

LAPPES	46.78
RTDM	2.73

Category 4
Top N (N=17) Hours
1– hour Concentration in μg/m3

Rank	SO2 Obs.	LAPPES	RTDM
1	982.50	1512.53	12864.80
2	817.40	1440.69	12074.25
3	788.60	1413.97	11966.89
4	736.20	1391.85	11437.06
5	733.60	1378.29	10970.30
6	712.60	1374.03	10834.92
7	681.20	1357.81	10409.07
8	652.40	1315.26	10408.97
9	584.30	1299.36	10341.76
10	537.10	1283.56	10180.34
11	518.80	1275.81	10148.70
12	510.90	1266.30	9959.96
13	503.00	1262.11	9798.45
14	495.20	1242.35	9533.84
15	492.60	1223.95	9506.57
16	489.90	1216.08	9338.52
17	474.20	1206.83	9315.87

Average Values :	673.74	1351.66	10876.57

Fractional Bias on Average Values :

SCORE: P (1 – 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

	Fractional Bias	SCORE
LAPPES	0.669420	0.00
RTDM	1.766677	0.00

Running Subtotals:

LAPPES	46.78
RTDM	2.73

TRC

Category 5
Top N (N=13) Hours
1– hour Concentration in μg/m3

Rank	SO2 Obs.	LAPPES	RTDM
1	702.20	1641.90	5345.56
2	676.00	1591.91	4685.21
3	600.00	1472.57	4517.95
4	586.90	1220.36	4355.83
5	571.20	1206.78	4203.94
6	568.50	1136.82	3993.08
7	563.30	1104.63	3805.17
8	560.70	946.21	3795.14
9	542.30	942.55	3794.04
10	516.10	941.06	3785.69
11	510.90	929.17	3757.63
12	510.90	896.82	3746.29
13	503.00	889.64	3726.35
Average Values :	570.15	1147.72	4116.30

Fractional Bias on Average Values :

SCORE: P (1 – 2.5 AFB), AFB <= 0.4
0, AFB > 0.4

	Fractional Bias	SCORE
LAPPES	0.672423	0.00
RTDM	1.51336	0.00

Running Subtotals:

LAPPES	46.78
RTDM	2.73

TRC

6. All Values – Paired in time and Location

a. Average Difference – fractional bias

THE AVERAGE FRACTIONAL BIAS FOR LAPPES IS : 1.57
THE AVERAGE FRACTIONAL BIAS FOR RTDM IS : 1.56

b. MS Error (normalized)

THE NRMSE FOR LAPPES IS : 3.71
THE NRMSE FOR RTDM IS : 16.50

SCORING: No points (NRMSE >2, AFB > 2/3)

7. Annual Average – Each Station

a. Highest Observed vs. Highest Predicted (fractional bias)

b. Average Observed vs. Average Predicted (fractional bias)

Average by station :	M1 BDWN	M2 BCVE	M3 LMCR	M4 MRSL	M5 PNVW	M6 PWML	M7 RGMT	M8 SGRN	M9 TERY	M10 LUBR
SO2 Obs.	18.94	20.35	18.70	21.47	20.33	16.92	35.58	26.93	22.98	19.11
LAPPES	13.94	8.59	14.75	8.59	10.16	13.80	27.52	24.07	19.58	9.94
RTDM	62.68	25.40	53.22	11.52	16.76	75.95	52.91	77.70	69.65	9.94

a. Highest Observed =	35.58				
LAPPES Highest =	27.52	fractional bias =	0.255468	a. LAPPES score =	3.083994
RTDM Highest =	77.70	fractional bias =	0.743644	a. RTDM score =	0.00
b. Average Observed =	22.13				
LAPPES Average =	15.09	fractional bias =	0.378079	b. LAPPES score =	2.164406
RTDM Average =	45.57	fractional bias =	0.692485	b. RTDM score =	0.00

GRAND TOTALS :	
LAPPES	52.03
RTDM	2.73

TRC

APPENDIX B

LISTINGS OF 25 MAXIMUM CONCENTRATIONS BY METEOROLOGICAL CATEGORY

Top 25 1–hour Average SO2 Concentrations
Predicted by LAPPES, Sorted by
Meteorological Category

Category 1

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	929.57	30,18	1
2	765.30	152,17	1
3	743.95	30,17	1
4	723.13	168,12	1
5	716.88	168,12	1
6	692.42	152,17	1
7	646.09	152,13	1
8	629.08	222,17	1
9	623.36	69,14	1
10	623.02	164,11	1
11	613.10	147,16	1
12	598.26	182,15	1
13	593.75	263,18	1
14	589.14	17,15	1
15	585.75	69,16	1
16	582.09	190,11	1
17	571.19	344,15	1
18	569.73	213,15	1
19	569.71	152,18	1
20	568.11	241,14	1
21	566.83	152,16	1
22	564.80	213,16	1
23	563.77	130,15	1
24	558.90	222,17	1
25	556.13	13,13	1

Top 25 1-hour Average SO2 Concentrations Predicted by LAPPES, Sorted by Meteorological Category

Category 2

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	1255.19	297,19	2
2	781.47	79,19	2
3	724.16	39,03	2
4	715.56	297,19	2
5	689.53	351,03	2
6	666.48	6,22	2
7	627.39	318,05	2
8	615.97	89,21	2
9	598.81	39,03	2
10	598.51	351,03	2
11	592.19	79,19	2
12	589.37	351,03	2
13	579.78	351,03	2
14	556.45	284,19	2
15	523.93	39,05	2
16	520.72	39,05	2
17	515.95	323,21	2
18	487.55	6,24	2
19	472.62	297,19	2
20	469.81	6,20	2
21	458.95	89,21	2
22	443.72	30,19	2
23	430.30	6,23	2
24	416.96	56,07	2
25	338.95	351,03	2

Top 25 1-hour Average SO2 Concentrations Predicted by LAPPES, Sorted by Meteorological Category

Category 3

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	1321.87	2,24	3
2	1314.45	38,21	3
3	1180.20	2,24	3
4	1173.37	84,19	3
5	1158.02	38,18	3
6	1068.21	84,19	3
7	1067.39	219,21	3
8	1031.33	38,23	3
9	1011.16	38,22	3
10	970.87	38,18	3
11	952.54	218,24	3
12	901.06	38,24	3
13	892.45	38,24	3
14	856.95	39,02	3
15	848.27	108.01	3
16	843.92	54,07	3
17	830.03	39,01	3
18	806.22	299,02	3
19	801.94	2,24	3
20	799.92	219,21	3
21	793.11	38,21	3
22	789.61	84,19	3
23	769.69	57,19	3
24	752.62	56,02	3
25	742.25	260,22	3

Top 25 1–hour Average SO2 Concentrations Predicted by LAPPES, Sorted by Meteorological Category

Category 4

Rank	Concentration (μg/m3)	Day,hr	Meteorological Category
1	1512.53	219,22	4
2	1440.69	298,09	4
3	1413.97	10,09	4
4	1391.85	219,22	4
5	1378.29	219,22	4
6	1374.03	171,07	4
7	1357.81	171,07	4
8	1315.26	10,09	4
9	1299.36	340,22	4
10	1283.56	324,09	4
11	1275.81	197,23	4
12	1266.30	1,02	4
13	1262.11	184,04	4
14	1242.35	351,02	4
15	1223.95	351,02	4
16	1216.08	184,04	4
17	1206.83	353,20	4
18	1203.64	324,21	4
19	1184.39	184,07	4
20	1168.16	192,01	4
21	1154.57	261,02	4
22	1150.09	351,04	4
23	1148.64	171,07	4
24	1143.56	71,03	4
25	1137.18	36,23	4

Top 25 1–hour Average SO2 Concentrations
Predicted by LAPPES, Sorted by
Meteorological Category

Category 5			
Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	1641.90	299,23	5
2	1591.91	3,03	5
3	1472.57	213,05	5
4	1220.36	164,22	5
5	1206.78	213,05	5
6	1136.82	164,22	5
7	1104.63	299,23	5
8	946.21	213,05	5
9	942.55	244,23	5
10	941.06	107,03	5
11	929.17	31,23	5
12	896.82	164,22	5
13	889.64	2,23	5
14	851.41	73,03	5
15	848.02	2,21	5
16	808.30	128,21	5
17	790.27	58,06	5
18	749.06	54,20	5
19	737.69	139,01	5
20	737.04	57,20	5
21	725.07	336,23	5
22	718.10	3,03	5
23	705.85	134,23	5
24	699.21	155,05	5
25	696.11	327,08	5

Top 25 1–hour Average SO2 Concentrations
Predicted by RTDM, Sorted by
Meteorological Category

Category 1			
Rank	Concentration (μg/m3)	Day,hr	Meteorological Category
1	1062.23	168,12	1
2	968.74	168,12	1
3	944.96	164,11	1
4	925.92	30,18	1
5	909.48	182,15	1
6	907.38	124,18	1
7	883.31	17,15	1
8	881.39	168,12	1
9	872.55	152,17	1
10	861.31	124,14	1
11	851.93	213,12	1
12	843.68	168,13	1
13	837.52	115,12	1
14	831.74	182,16	1
15	818.56	168,13	1
16	816.51	69,14	1
17	815.92	213,12	1
18	815.91	69,16	1
19	814.94	152,16	1
20	807.90	152,13	1
21	804.02	152,17	1
22	801.45	196,13	1
23	790.02	152,18	1
24	786.52	152,15	1
25	785.14	344,15	1

Top 25 1–hour Average SO_2 Concentrations Predicted by RTDM, Sorted by Meteorological Category

Category 2			
Rank	Concentration (μg/m3)	Day,hr	Meteorological Category
1	1408.60	284,20	2
2	1392.80	284,20	2
3	1332.03	284,20	2
4	1220.68	297,19	2
5	1093.27	351,03	2
6	992.61	25,09	2
7	911.39	284,20	2
8	908.68	284,20	2
9	829.57	6,22	2
10	803.78	297,19	2
11	774.74	284,20	2
12	739.03	318,05	2
13	735.60	79,19	2
14	731.02	213,07	2
15	716.11	213,07	2
16	709.54	6,23	2
17	680.90	213,07	2
18	657.03	6,09	2
19	648.23	39,05	2
20	622.64	122,22	2
21	608.95	323,21	2
22	605.04	39,03	2
23	603.74	6,24	2
24	600.42	39,03	2
25	599.93	297,19	2

Top 25 1–hour Average SO2 Concentrations Predicted by RTDM, Sorted by Meteorological Category

Category 3

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	1557.45	2,24	3
2	1377.38	2,24	3
3	1282.77	2,24	3
4	1244.06	84,19	3
5	1216.84	2,24	3
6	1207.70	2,24	3
7	1188.27	38,21	3
8	1184.32	38,22	3
9	1140.78	219,21	3
10	1130.92	38,23	3
11	1122.17	84,19	3
12	1115.68	38,18	3
13	1058.49	38,22	3
14	1042.60	38,23	3
15	1008.59	38,24	3
16	981.55	219,21	3
17	972.74	39,02	3
18	953.34	218,24	3
19	924.53	39,01	3
20	911.06	38,24	3
21	904.13	38,21	3
22	885.13	219,21	3
23	866.52	39,02	3
24	862.50	38,18	3
25	848.27	108,01	3

Top 25 1–hour Average SO2 Concentrations
Predicted by RTDM, Sorted by
Meteorological Category

Category 4

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	12864.80	165,01	4
2	12074.25	36,24	4
3	11966.89	36,23	4
4	11437.26	36,22	4
5	10970.30	142,23	4
6	10834.92	341,07	4
7	10409.07	345,06	4
8	10408.97	75,05	4
9	10341.76	75,05	4
10	10180.34	360,23	4
11	10148.70	165,01	4
12	9959.96	36,24	4
13	9798.45	340,22	4
14	9533.84	133,21	4
15	9506.57	152,23	4
16	9338.52	36,23	4
17	9315.87	341,07	4
18	9288.62	69,02	4
19	9097.51	75,01	4
20	9082.95	131,01	4
21	8900.11	183,06	4
22	8822.72	219,24	4
23	8691.91	36,22	4
24	8598.60	36,24	4
25	8508.78	131,01	4

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Top 25 1-hour Average SO2 Concentrations
Predicted by RTDM, Sorted by
Meteorological Category

Category 5

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	5345.56	190,01	5
2	4685.21	213,23	5
3	4517.95	138,03	5
4	4355.83	134,24	5
5	4203.94	134,02	5
6	3993.08	190,01	5
7	3805.17	217,22	5
8	3795.14	69,05	5
9	3794.04	101,04	5
10	3785.69	30,09	5
11	3757.63	44,23	5
12	3746.29	258,21	5
13	3726.35	134,02	5
14	3720.33	3,03	5
15	3715.98	137,22	5
16	3691.50	128,21	5
17	3662.00	30,09	5
18	3613.55	213,04	5
19	3536.18	101,04	5
20	3519.53	101,02	5
21	3506.18	213,23	5
22	3470.28	107,02	5
23	3431.97	3,03	5
24	3350.92	121,21	5
25	3308.03	134,24	5

Top 25 1–hour Average Measured SO2 Concentrations
Sorted by Meteorological Category

Category 1

Rank	Concentration (μg/m3)	Day,hr	Meteorological Category
1	1032.20	131,12	1
2	945.80	253,12	1
3	943.20	128,11	1
4	922.20	177,11	1
5	914.40	323,14	1
6	822.70	75,13	1
7	772.90	223,12	1
8	770.30	128,13	1
9	765.00	238,13	1
10	757.20	270,15	1
11	749.30	323,13	1
12	723.10	227,10	1
13	712.60	342,12	1
14	696.90	131,14	1
15	694.30	227,10	1
16	689.10	324,12	1
17	676.00	75,12	1
18	662.90	270,14	1
19	655.00	160,13	1
20	652.40	323,13	1
21	649.80	128,12	1
22	641.90	240,09	1
23	636.70	223,12	1
24	620.90	128,16	1
25	613.10	261,15	1

Top 25 1–hour Average Measured SO2 Concentrations
Sorted by Meteorological Category

Category 2

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	720.50	224,08	2
2	626.20	254,08	2
3	448.00	324,10	2
4	445.40	227,09	2
5	432.30	197,08	2
6	419.20	354,09	2
7	408.70	144,07	2
8	398.20	253,09	2
9	393.00	164,08	2
10	387.80	107,09	2
11	382.50	220,08	2
12	356.30	227,09	2
13	351.10	254,08	2
14	343.20	194,24	2
15	322.30	93,03	2
16	309.20	144,07	2
17	254.10	354,08	2
18	230.60	324,10	2
19	222.70	37,20	2
20	217.50	254,08	2
21	214.80	171,08	2
22	212.20	254,08	2
23	212.20	235,09	2
24	212.20	289,20	2
25	209.60	71,10	2

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Top 25 1-hour Average Measured SO2 Concentrations
Sorted by Meteorological Category

Category 3			
Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	746.70	359,24	3
2	725.70	319,08	3
3	550.20	305,03	3
4	542.30	195,21	3
5	534.50	40,24	3
6	487.30	234,09	3
7	461.10	166,08	3
8	427.10	240,08	3
9	424.40	52,23	3
10	421.80	161,08	3
11	419.20	19,09	3
12	414.00	52,24	3
13	403.50	60,20	3
14	403.50	77,22	3
15	398.20	342,11	3
16	398.20	305,10	3
17	390.40	234,24	3
18	382.50	53,01	3
19	379.90	100,24	3
20	366.80	319,24	3
21	364.20	121,01	3
22	353.70	31,01	3
23	345.80	39,22	3
24	345.80	11,02	3
25	343.20	53,06	3

Top 25 1-hour Average Measured SO_2 Concentrations
Sorted by Meteorological Category

Category 4			
Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	982.50	85,02	4
2	817.40	68,08	4
3	788.60	85,01	4
4	736.20	228,04	4
5	733.60	68,09	4
6	712.60	227,06	4
7	681.20	107,04	4
8	652.40	234,07	4
9	584.30	228,03	4
10	537.10	157,06	4
11	518.80	194,23	4
12	510.90	228,04	4
13	503.00	235,07	4
14	495.20	68,09	4
15	492.60	298,02	4
16	489.90	68,08	4
17	474.20	85,02	4
18	463.70	93,06	4
19	453.30	241,03	4
20	448.00	235,06	4
21	442.80	85,01	4
22	434.90	234,05	4
23	434.90	85,02	4
24	429.70	345,08	4
25	421.80	185,05	4

Top 25 1-hour Average Measured SO_2 Concentrations
Sorted by Meteorological Category

Category 5

Rank	Concentration (µg/m3)	Day,hr	Meteorological Category
1	702.20	240,07	5
2	676.00	44,03	5
3	600.00	319,07	5
4	586.90	43,24	5
5	571.20	129,06	5
6	568.50	305,08	5
7	563.30	319,06	5
8	560.70	318,24	5
9	542.30	305,09	5
10	516.10	166,06	5
11	510.90	346,08	5
12	510.90	240,07	5
13	503.00	346,02	5
14	503.00	346,05	5
15	497.80	346,01	5
16	497.80	345,23	5
17	489.90	30,08	5
18	487.30	163,01	5
19	484.70	43,24	5
20	469.00	359,23	5
21	437.50	305,01	5
22	437.50	330,24	5
23	432.30	342,08	5
24	429.70	43,24	5
25	427.10	346,04	5

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TRC Environmental Corporation

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Attachment D

TRC 2003 AERMOD Modeling Analysis for SO_2 NAAQS for Laurel and Chestnut Ridges

TRC
Customer-Focused Solutions

AERMOD MODELING ANALYSES FOR SO_2 NAAQS COMPLIANCE FOR POWER PLANTS IN THE LAUREL RIDGE AND CHESTNUT RIDGE REGION OF PENNSYLVANIA

Prepared for
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Johnstown, PA

Prepared by
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EXECUTIVE SUMMARY

Reliant Energy Mid-Atlantic Power Holdings, LLC. (Reliant Energy) operates three major coal-fired electric generating facilities in the Laurel Ridge and Chestnut Ridge area of southwestern Pennsylvania: Keystone, Conemaugh and Seward. Another major power plant, Edison Mission Energy's Homer City Station (formerly operated by GPU Genco) is also located within this area. These plants are clustered over a relatively small geographical region with complex terrain, which has led to regulatory concerns regarding the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO_2).

This report is the latest update to the compliance demonstrations prepared at the behest of the Pennsylvania Department of Environmental Protection (PADEP). The informal request to update the modeling resulted from emission source changes at Seward Generating Station due to the Seward CFB Repowering Project. This study supersedes the supplemental AERMOD Modeling Analyses for SO_2 NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania (TRC, 1999) that were performed in support of the Modeling Analyses for SO_2 NAAQS Compliance for Power Plants in the Laurel Ridge and Chestnut Ridge Region of Pennsylvania (Compliance Demonstration). These original analyses were performed using the Multiple Point with Terrain (MPTER) model, the Rough Terrain Diffusion Model (RTDM), and the Large Area Power Plant Effluent Study (LAPPES) model (TRC, 1998b). Other supporting studies previously completed include the CALPUFF Application for Laurel Ridge (Earth Tech, 1998) and the Model Comparison Study for Seward Generating Station (TRC 1998a). The Compliance Demonstration (TRC, 1998b) was intended to provide the basis to establish appropriate SO_2 emission rate limits for the four Laurel Ridge and Chestnut Ridge power plants that will assure attainment and maintenance of the SO_2 NAAQS.

In 1991, The American Meteorology Society (AMS) and the U.S. Environmental Protection Agency (EPA) formed a joint working group to develop a single model to replace the current guideline models for industrial sources and complex terrain. Since 1991, the AMS/EPA Regulatory Model Improvement Committee (AERMIC) has been developing and testing the AERMIC Model (AERMOD) using several EPA data bases. The results of those tests indicate that AERMOD out-performs the current guideline models. AERMIC has proposed that AERMOD become a guideline model following public review and comment. Since 1999, AERMIC has released several Beta test versions of AERMOD (01247 and 02222) that incorporate the PRIME building downwash algorithms. In April 2000, EPA released a Proposed Rule in the Requirements for Preparation, Adoption, and Submittal of State Implementation Plans (SIP) (Guideline on Air Quality Models) that proposed *"revising section 4 of the Guideline to replace ISC3 by AERMOD as a state-of-the-art practice technique for many air quality impact assessments."* (EPA, 2000a) Currently, EPA anticipates that AERMOD will become the Guideline model sometime in 2003.

When the new, state-of-the-art AERMOD complex terrain dispersion model became available, Reliant Energy agreed to provide the additional analyses contained in the previous AERMOD report (TRC, 1999). The objective of the revised AERMOD modeling analyses described in this updated report is to use the latest version of the model and current plant data to demonstrate compliance with the SO_2 NAAQS in support of the previous compliance demonstrations for the Laurel/Chestnut Ridge region sources combined.

As described herein, the updated AERMOD compliance demonstration modeling was performed by TRC Environmental Corporation (TRC) in general accordance with the previous AERMOD and MPTER/RTDM/LAPPES compliance demonstrations, and the model performance evaluation for Seward submitted to the PADEP (TRC, 1999, 1998b and 1998a, respectively). The revised AERMOD compliance demonstration modeling analyses were performed using revised emission rates and stack parameter data provided by Reliant Energy are based on the following modifications to the Laurel/Chestnut Ridge sources: 1) Seward Station re-powered and 2) Homer City Unit 3 scrubbed. Because AERMOD is designed to predict air pollutant concentrations in all terrain settings, it has been used to evaluate simple, intermediate and complex terrain impacts from the four power plants combined for the compliance demonstration.

The revised AERMOD modeling results for the Laurel/Chestnut Ridge region show compliance with the 3-hour, 24-hour and annual average SO_2 NAAQS, based on Seward Station re-powered and Homer City Unit 3 scrubbed. Thus, compliance has been shown based on the following SO_2 emission rates for each source:

Station	3-hour average	Annual and 24-hour average
Conemaugh Units 1 and 2	0.2 lbs/MMBtu	0.2 lbs/MMBtu
Keystone Unit 1	3.92 lbs/MMBtu	4.0 lbs/MMBtu
Keystone Unit 2	3.92 lbs/MMBtu	4.0 lbs/MMBtu
Homer City Unit 1	4.0 lbs/MMBtu	4.0 lbs/MMBtu
Homer City Unit 2	4.0 lbs/MMBtu	4.0 lbs/MMBtu
Homer City Unit 3	0.4 lbs/MMBtu	0.4 lbs/MMBtu
Seward Units 4 and 5	0.6 lbs/MMBtu	0.6 lbs/MMBtu

All of the results are consistent with the sources' current allowable SO_2 emission rate with the exception of Keystone Units 1 and 2. The current allowable limits at these sources are 4.0 pounds per million British thermal units (lbs/MMBtu) as opposed to the modeled maximum emission rate of 3.92 lbs/MMBtu.

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1.0 INTRODUCTION

Energy Mid-Atlantic Power Holdings, LLC (Reliant Energy) operates three major coal-fired electric generating facilities in the Laurel Ridge and Chestnut Ridge area of southwestern Pennsylvania: Keystone, Conemaugh and Seward. Another major power plant, Edison Mission Energy's Homer City Station (formerly operated by GPU Genco) is also located within this area. These plants are all clustered over a relatively small geographic region. The size of the facilities, their close proximity to one another, and the complex terrain that characterizes the region have led to regulatory concerns regarding the attainment and maintenance of the National Ambient Air Quality Standards (NAAQS) for sulfur dioxide (SO_2) in the region. This report is the latest update to the compliance demonstrations prepared at the behest of the Pennsylvania Department of Environmental Protection (PADEP). The informal request to update the modeling resulted from emission source changes at Seward Generating Station due to the Seward CFB Repowering Project.

For many years, Reliant Energy and its predecessors, initially the Pennsylvania Electric Company (Penelec) and later GPU Genco, have been working in cooperation with the PADEP, formerly the Pennsylvania Department of Environmental Resources (PADER), and the U.S. Environmental Protection Agency (EPA) Region III to determine appropriate emission limits for the four affected power plants. This report presents supporting AERMOD modeling analyses related to that effort.

In the absence of an approved alternative when the studies were initially undertaken, EPA guidance would have required the use of two models to determine air quality impacts in the region: the Multiple Point with Terrain (MPTER) model (EPA, 1980) for simple and intermediate terrain, and the Rough Terrain Diffusion Model (RTDM) (ERT, 1987) for intermediate and complex terrain. As an alternative, Penelec proposed to use the Large Area Power Plant Effluent Study (LAPPES) model which Penelec developed from a field program conducted from 1967 to 1972 in the Laurel/Chestnut Ridge region of Pennsylvania. Previous studies at other locations have shown that RTDM over-predicted at elevated terrain locations by more than a factor of two. In contrast, LAPPES has proven to be a modest over-predictor. Therefore, it represented the station operators' preferred model for establishing emission limits. A model performance comparison study was carried out to gain PADEP and EPA approval to use LAPPES instead of RTDM to set emission limits for the then Penelec-operated power plants. EPA's "Interim Procedures" document (EPA, 1984) was followed from the beginning of the study and culminated in a model comparison report which showed the LAPPES model to be superior to RTDM/MPTER for determining air quality impacts at elevated locations in the Laurel/Chestnut Ridge area of Pennsylvania (TRC, 1993).

Although LAPPES was demonstrated to be the best model for use in the compliance modeling analyses for the Laurel/Chestnut Ridge area, its use was limited under the criteria of the model performance comparison study. Initially, it was anticipated that RTDM/MPTER would be used in the compliance modeling for Seward Station because prospective monitoring locations on a small portion of the elevated terrain on Laurel Ridge were judged to be either inaccessible or logistically prohibitive, presumably leaving the testing of model performance for Seward incomplete. However, based on model comparison studies, subsequent analyses (TRC, 1998a) have demonstrated that LAPPES is more appropriate than RTDM/MPTER for Seward Station.

Since 1995, Conemaugh has used limestone flue gas de-sulfurization wet scrubbers (scrubbers) to control SO_2 emissions to satisfy Phase I of the Acid Rain provisions of the 1990 Clean Air Act Amendments (CAAA). The scrubbers exhaust from a new, shorter stack with significantly reduced plume rise that could not be evaluated in the model performance comparison study. Furthermore, no model comparisons have been conducted to evaluate the performance of LAPPES on a plume similar to that produced by the Conemaugh scrubbers. Therefore, RTDM/MPTER were used in the compliance modeling to determine SO_2 emission limits in elevated terrain for Conemaugh, while LAPPES was used in elevated terrain for Keystone, Homer City and Seward. MPTER was used for all plants for receptors below stack top and in combination with RTDM for intermediate terrain (i.e., between stack top and plume height) for Conemaugh. However, to support the compliance modeling analyses obtained using the combination of RTDM, MPTER and LAPPES, it was recommended that AERMOD be used in a subsequent modeling analysis to confirm the emission limits that were derived from the original compliance demonstration (TRC, 1998b) for each power plant.

Since the initial AERMOD modeling analyses were performed (TRC, 1999), Seward Station has been re-powered with clean coal technology circulating fluidized bed (CFB) boilers designated to combust coal refuse and coal (TRC, 2000), and Homer City has recently installed a wet scrubber on

Unit 3. Revised AERMOD modeling analyses have been performed for all the Laurel/Chestnut Ridge sources to confirm that the modifications to the Seward Station and Homer City Unit 3 sources continue to demonstrate compliance with the NAAQS for SO_2.

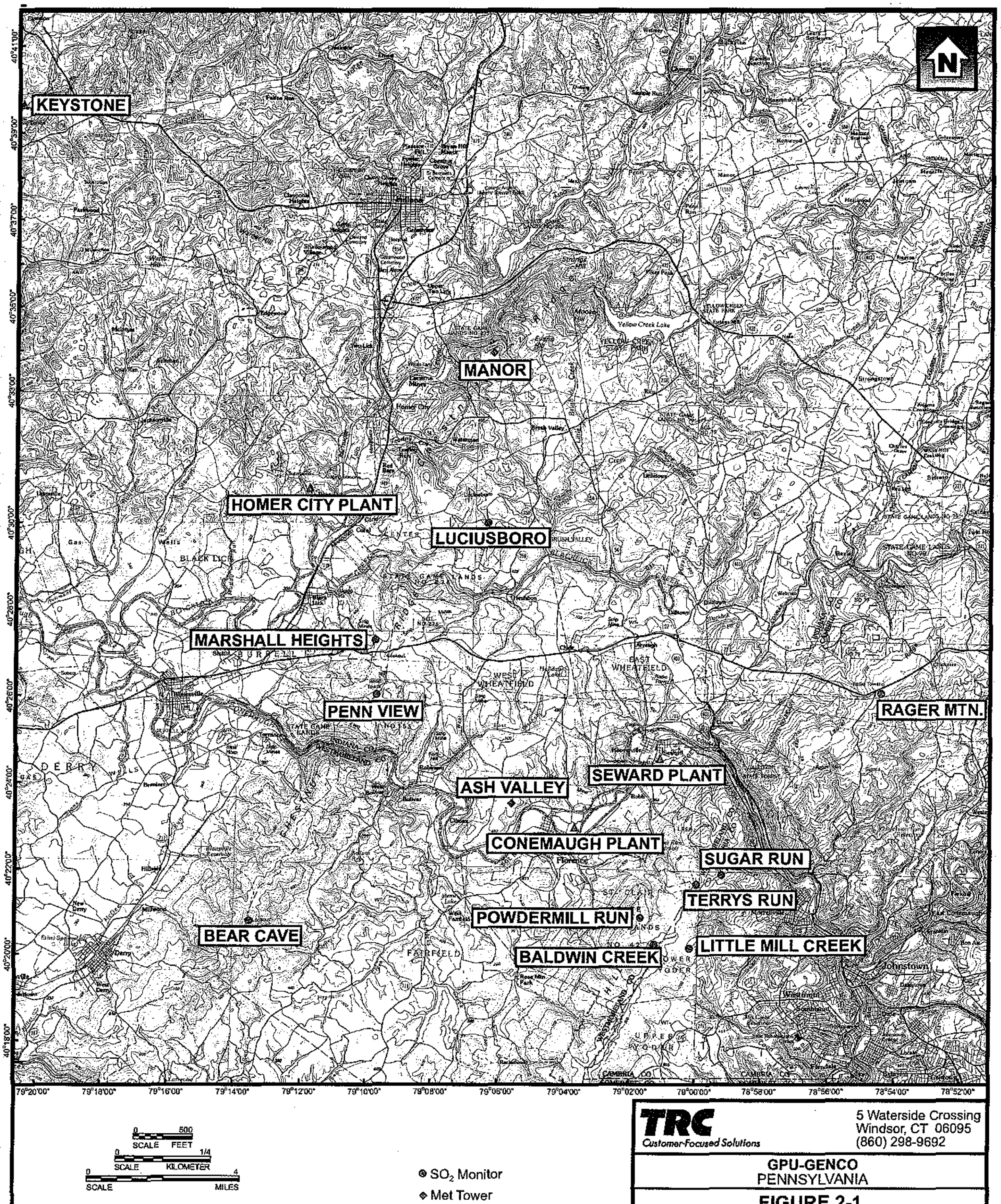
TRC, on behalf of Penelec, submitted a modeling protocol (TRC, 1994) outlining the RTDM/MPTER and LAPPES modeling procedures for all of the then Penelec-operated power plants in the Laurel/Chestnut Ridge region. PADEP and EPA reviewed the modeling protocol and provided comments in letters dated May 22, 1996 (PADEP, 1996a) and May 28, 1996 (EPA, 1996). GPU Genco responded to those comments in a letter dated October 31, 1996 (GPU Genco, 1996), and PADEP approved the protocol with minor changes in a letter dated December 11, 1996 (PADEP, 1996b). The results presented herein reflect the modeling methodology outlined in that protocol, as amended in accordance with the PADEP and EPA comments, and modified to use AERMOD for all the Laurel/Chestnut Ridge power plants, as discussed above.

2.0 OVERVIEW OF THE AERMOD COMPLIANCE MODELING ANALYSES

The locations of the power plants in the Laurel/Chestnut Ridge area and the regional terrain are shown in Figure 2-1. Previous dispersion modeling has indicated that peak short-term SO_2 concentrations should be expected on the higher terrain of Laurel Ridge and Chestnut Ridge, just northwest of Johnstown, Pennsylvania. The RTDM/MPTER model combination predicts violations of the short-term NAAQS for SO_2 at current allowable emission rates. However, for over 13 years, an extensive SO_2 monitoring network operated by Reliant Energy measured peak concentrations much lower than those predicted. For the model comparison study period, the monitors recorded second high concentrations that were all less than 60 percent of the short-term NAAQS. This pattern of disparity led to the aforementioned efforts to obtain regulatory approval for the use of the LAPPES model and the submittal of the Compliance Demonstration based on MPTER/RTDM/LAPPES (TRC, 1998b).

Under agreement of the affected parties in 1999, a new, more sophisticated model, AERMOD, was investigated to support the MPTER/RTDM/LAPPES Compliance Demonstration of the NAAQS for SO_2. Since 1991, the American Meteorological Society (AMS) and the U.S. Environmental Protection Agency (EPA) Regulatory Model Improvement Committee, (AERMIC) have been developing and testing the AERMIC Model (AERMOD) using several approved EPA atmospheric dispersion data sets. The model development process consisted of initial model development, evaluation, internal review, revised model formulation, performance evaluation and sensitivity testing, external review and submission to EPA's Office of Air Quality Planning and Standards (OAQPS) for consideration as a regulatory model (EPA, 1998a). The intent of EPA is to use AERMOD as a guideline model to be incorporated into the Guideline on Air Quality Models (EPA, 2001).

AERMOD has been subjected to model performance evaluations against several of the current guideline models such as the ISCST3, CTDMPLUS and RTDM models. The results show that AERMOD performed just as well as or better than current guideline models in terms of predicting concentrations in simple and complex terrain settings. In 1999, the first version of AERMOD (98314) was used to support the MPTER/RTDM/LAPPES SO_2 NAAQS Compliance Demonstration for all sources in the Laurel/Chestnut Ridge region. For this updated report, the latest Beta Test



⊗ SO_2 Monitor
◈ Met Tower
△ Emission Source

BASE CREATED WITH TOPO™ © 1996
WILDFLOWERS PRODUCTIONS, www.topo.com
7.5' USGS TOPOGRAPHIC MAPS

TRC Customer-Focused Solutions

5 Waterside Crossing
Windsor, CT 06095
(860) 298-9692

GPU-GENCO
PENNSYLVANIA

FIGURE 2-1
STUDY REGION AND MONITORING SITES

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version of AERMOD with PRIME (02222) has been used to support an additional SO_2 NAAQS compliance demonstration for all sources in the Laurel/Chestnut Ridge region.

For the RTDM, MPTER and LAPPES Compliance Demonstration modeling analyses, PADEP identified two additional sources in the region which had not been included in previous modeling: Cambria Cogen, Inc. and Ebensburg Power Company. These additional sources were also modeled using AERMOD and are included in the predictions of the previous and current reports. Since there are no other major sources of SO_2 in the region, background SO_2 concentrations were developed from the monitored data to represent the contributions of all other SO_2 sources.

Previously, AERMOD was used to predict concentrations in simple, intermediate and complex terrain for all SO_2 emission sources in the Laurel/Chestnut Ridge area. AERMOD was run with the same 3 and 24 hour emission rate limits that were developed for the previous MPTER/RTDM/LAPPES Compliance Demonstration modeling analyses. For the current modeling analyses, AERMOD was run with the revised allowable SO_2 emission rates.

For the updated AERMOD analyses, four initial polar receptor grids were developed around Keystone, Homer City, Conemaugh and Seward, respectively, using the AERMAP terrain preprocessor program. The program requires Digital Elevation Model (DEM) data available from the U.S. Geological Survey to extract receptor locations and their heights for each receptor grid. The 30 meter horizontal resolution, 7.5 minute DEMs were used as AERMAP input. The receptor spacing included 0.5 km increments from 0.5 to 5 km, 1 km increments from 5 to 10 km and 2 km increments from 10 to 20 km in the four grids. The Keystone, Homer City, Conemaugh and Seward receptor grids consisted of 720 receptor points each. This methodology produced a total of 2,880 receptor points throughout the Laurel/Chestnut Ridge region. The receptor networks were designed for evaluating the single source and combined source impacts of all the Laurel/Chestnut Ridge power plants using AERMOD. Additional refined arrays were included in the areas of predicted maximum combined impacts.

The sources of meteorological input data used for the updated AERMOD compliance modeling were the same as those used for the previous MPTER/RTDM/LAPPES Compliance Demonstration, i.e., measurements from two on-site meteorological towers at Ash Valley and Manor developed from the one-year period from August 1, 1990 through July 31, 1991. The meteorological data were processed using AERMOD's meteorological preprocessor AERMET. This program extracted wind speed, wind direction, temperature and the turbulence measurements from the two on-site meteorological towers at Ash Valley and Manor from all levels to calculate planetary boundary parameters for the surface file and profile file that the AERMOD modeling system uses to predict concentrations.

The concentration predictions from AERMOD were added to the background concentrations and compared to the NAAQS for SO_2, as shown below.

NAAQS		Background Concentrations
Averaging Time	Concentrations (μg/m^3)	
3-hour 24-hour Annual	1,300* 365* 80	See Section 3.5

* Highest second-high values

3.0 MODELING PROCEDURES

The objective of the modeling analyses is to demonstrate compliance with the SO_2 NAAQS for the Laurel/Chestnut Ridge sources using AERMOD with the revised source parameter data and allowable SO_2 emission rates to supplement and support the previous MPTER/RTDM/LAPPES and AERMOD compliance demonstrations (TRC, 1998b and 1999, respectively). The modeling procedures used for the updated AERMOD compliance modeling analyses were conducted following the 1994 modeling protocol for these sources (TRC, 1994), the agency comments on the protocol (PADEP, 1996a and b), the latest EPA Guideline on Air Quality Modeling (EPA, 2001) and the Revised Draft User's Guide For The AMS/EPA Regulatory Model-AERMOD, (EPA 2002a, 2002b, and 2002c).

The revised source parameter and allowable SO_2 emissions data were used for this updated AERMOD study. The receptor and meteorological data were re-processed using the latest versions of AERMAP and AERMET, AERMOD's terrain and meteorological data pre-processors, respectively. These pre-processors are part of the AERMOD modeling system and can only be used with AERMOD at the present time. Four polar receptor arrays, centered around each of the Laurel/Chestnut Ridge power plants, were developed using the AERMAP terrain pre-processor, and DEMs of the surrounding area. The same on-site meteorological monitoring period used in the previous MPTER/RTDM/LAPPES and AERMOD compliance demonstrations was used in the updated AERMOD modeling. However, the on-site meteorological data were processed using the latest version of the AERMOD meteorological pre-processor AERMET. A detailed discussion of the meteorological data processing is presented in Section 3.4. The same method used to calculate background concentrations in the MPTER/RTDM/LAPPES Compliance Demonstration (TRC, 1998b) was used in this analysis. The default model options for AERMOD, which follow regulatory default model options, were used (listed in Section 3.6).

In the RTDM/MPTER versus LAPPES model performance comparison protocol (TRC, 1994), it was found that 100 percent load conditions for each station produced the maximum impacts. Therefore, all power plants were modeled at 100 percent load and allowable SO_2 emission rates for the AERMOD compliance analyses.

3.1 Source Data

Characteristics of the power plant stacks and the other modeled sources in the Laurel Ridge and Chestnut Ridge area are summarized in Tables 3-1 and 3-2.

Stack heights for the major sources range from 160 m (525 feet) for Conemaugh to 260 m (853 feet) for Homer City Unit 3. Most of the stacks were constructed prior to 1970 and are not subject to Good Engineering Practice (GEP) stack height limitations. The exceptions are Conemaugh, Homer City Unit 3 and Seward. The Conemaugh stack was constructed to the GEP formula height of 160 m (525 feet) to service the scrubber. The new Homer City Unit 3 stack was modeled at actual scrubber stack height of 260 m (853 feet). This height conforms to GEP stack height based on the results of a fluid modeling study to assess downwash due to cooling towers (Peterson, 1987).

The Seward stack was built after 1970 and exceeds the GEP formula height based on building dimensions. A fluid modeling study for Seward determined that the existing 183 m (600 feet) stack height is required to avoid excessive concentrations due to terrain-induced downwash effects (Peterson, 1989). However, as a result of the CFB re-powering project, Seward Station's emission characteristics changed, along with the construction of new structures that affected the calculated GEP formula height (TRC, 2001). For the SO_2 compliance demonstration, the CFB boilers' stack was modeled at the revised GEP formula height of 152 m (500 feet).

3.2 Receptor Grid

Four initial receptor grids were developed using AERMOD's terrain preprocessor, AERMAP. AERMAP defines a height scale (h_c) that represents terrain in the vicinity of the receptor. The AERMAP processor is a required portion of the AERMOD model package and must be used to develop the receptor arrays.

The receptor grids were constructed using rings of receptors spaced at 10 degree intervals on 36 radials out to a distance of 20 kilometers for the Keystone, Homer City, Conemaugh and Seward grids. The grid origins were placed at the locations of the Keystone, Homer City, Conemaugh and Seward Stations. The receptor spacing was:

TABLE 3-1
Fixed Stack Parameters Compiled for the
Laurel/Chestnut Ridge Compliance Modeling Analyses

	UTM Coordinates (km)				
Source	East	North	Stack Height	Stack Diameter	Stack Base Elevation (m)
Keystone Unit 1	640.18	4,502.15	243.8 m (800 ft)	8.29 m (27.2 ft)	308
Keystone Unit 2	640.18	4,502.15	243.8 m (800 ft)	8.29 m (27.2 ft)	308
Homer City Unit 1	652.77	4,486.11	243.8 m (800 ft)	7.32 m (24.0 ft)	366
Homer City Unit 2	652.77	4,486.11	243.8 m (800 ft)	7.32 m (24.0 ft)	366
Homer City Unit 3	652.77	4,486.11	370.6 m(1) (1,216 ft)	6.90 m (22.6 ft)	366
Conemaugh Units 1 & 2	664.54	4,471.81	160 m (525 ft)	12.1 m(2) (39.8 ft)	332
Seward Units 4 & 5	666.81	4,474.68	182.9 m(3) (600 ft)	5.26 m (17.3 ft)	331
Cambria Cogen, Inc. Units 1 & 2	694.80	4,483.30	70.1 m (230 ft)	2.29 m (7.5 ft)	664
Ebensburg Power	691.10	4,481.54	76.2 m (250 ft)	2.59 m (8.5 ft)	660

1) GEP height: 260 m (853 ft) used for compliance modeling
2) Effective stack diameter for two adjacent flues within a single stack
3) GEP height: 152.4 m (500 ft) used for compliance modeling

TABLE 3-2
Maximum Capacity (100%) Emission Rates and Stack Parameters
Compiled for the Laurel/Chestnut Ridge Compliance Modeling Analyses

Source	**SO_2 Emission Factor Limit (lb/MMBtu)**	**Heat Input (MMBtu/hour)**	**SO_2 Emission Rate (grams/second)**	**Exit Velocity**	**Exit Temperature**
Keystone Unit 1	3.92 (3-hour) 4.0 (24-hour and annual)	8,551 8,717	4,309.5 (3-hour) 4,393 (24-hour and annual)	26.8 m/s (87.9 ft/s)	423°K (301°F)
Keystone Unit 2	3.92 (3-hour) 4.0 (24-hour and annual)	8,551 8,717	4,309.5 (3-hour) 4,393 (24-hour and annual)	26.8 m/s (87.9 ft/s)	423°K (301°F)
Homer City Unit 1	4.0 (3, 24 and annual)	6,500	3,276 (3, 24 and annual)	27.4 m/s (90.0 ft/s)	422°K (300°F)
Homer City Unit 2	4.0 (3, 24 and annual)	6,500	3,276 (3, 24 and annual)	27.4 m/s (90.0 ft/s)	422°K (300°F)
Homer City Unit 3	0.4 (3, 24 and annual)	6,800	343 (3, 24 and annual)	27.4 m/s (90 ft/s)	330°K (135°F)
Conemaugh Units 1 & 2	0.2 (3, 24 and annual)	16,560	417 (3, 24 and annual)	20.1 m/s (66 ft/s)	323°K (122°F)
Seward Units 4 and 5	0.6 (3, 24 and annual)	5,064	383 (3, 24 and annual)	32.0 m/s (105 ft/s)	347°K (165°F)
Cambria Cogen, Inc. Units 1 & 2	0.495	968	60.5	27.6 m/s (90.5 ft/s)	466°K (380°F)
Ebensburg Power	0.537	645	43.6	18.3 m/s (59.9 ft/s)	422°K (300°F)

- 500 meter spacing from 0.5 km to 5 km from the stacks
- 1 km spacing from 5 km to 10 km from the stacks
- 2 km spacing beyond 10 km from the stacks

Figures 3-1 through 3-5 depict the four radial receptor grids that were used in the updated AERMOD modeling analyses. Figure 3-1 covers the entire study region and shows all the receptors in the four radial receptor grids for the four power plants. Figures 3-2 through 3-5 depict only the inner portions (i.e., within 10 km) of the radial receptor grids for the Keystone, Homer City, Conemaugh and Seward Stations, respectively. Although there were no predicted violations on the radial receptor grids, maximum impact "hot spots" were predicted at a receptor on the Keystone radial grid (3-hour and 24-hour average) and a receptor on the Homer City radial grid (annual average). Additional modeling was therefore conducted for two refined Cartesian receptor arrays (2 km by 2 km rectangles with 100 meter spacing), which were centered on these two "hotspots." The predicted 3-hour and 24-hour average "hotspots" were primarily attributable to Keystone Station, whereas the predicted annual average "hotspot" was attributable to all four power plants. The refined Keystone and Homer City receptor arrays are shown on Figures 3-1 and 3-2, respectively. A total of 3,760 receptors were therefore used in the updated AERMOD modeling analyses.

AERMOD calculates impacts at all receptor locations (simple, intermediate and complex terrain); therefore, AERMAP receptors were not eliminated or modified for AERMOD modeling throughout the Laurel/Chestnut Ridge region.

3.3 Meteorological Data

On-site meteorological data collected from the Ash Valley (AV) and Manor towers during the period of August 1, 1990 through July 31, 1991 were processed for this AERMOD modeling study. The instrumentation, their placement on the towers, and data acquisition and processing were consistent with regulatory guidance. The tower site locations are depicted in Figure 2-1. Table 3-3 shows the tower elevations and coordinates.

The AV meteorological tower is located approximately 3 km northwest of Conemaugh Station, at a base elevation of 1,401 feet. Data from this tower are representative of transport and dispersion conditions in its region and for Conemaugh and Seward Stations.

TABLE 3-3
Meteorological Monitoring Sites for the
Laurel/Chestnut Ridge Compliance Modeling Analyses

Location Description	Elevation MSL (ft.)	Above Grade (ft.)	Parameters* Monitored
(a) Ash Valley 150 Meter Tower			
Tower UTM coordinates E = 661,722 (m) N = 4,472,558 (m)			
Tower Base Plate	1,401	---	---
Lower Sensor Level	1,434	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1,565	164 (50 m)	WD, WS
Upper Sensor Level	1,695	292 (89 m)	WD, WS
Top Sensor Level	1,893	492 (150 m)	WD, WS
(b) Manor 100 Meter Tower			
Tower UTM coordinates E = 660,560 (m) N = 4,492,006 (m)			
Tower Base Plate	1,730	---	---
Lower Sensor Level	1,763	33 (10 m)	WD, WDST, WS, AT
Intermediate Sensor Level	1,894	164 (50 m)	WD, WS
Upper Sensor Level	2,058	328 (100 m)	WD, WS

* Parameter Identifiers
WD = Wind Direction
WDST = Standard Deviation of Wind Direction (Sigma Theta)
WS = Wind Speed
AT = Ambient Temperature

The Manor meteorological tower is located approximately 9 km northeast of Homer City Station, with a base elevation of 1,730 feet. Data from this tower are representative of transport and dispersion conditions in its region and for Keystone and Homer City Stations.

3.4 Meteorological Data Processing

The AERMOD meteorological pre-processor, AERMET, was used to process the August 1, 1990 to July 31, 1991 AV and Manor tower data with NWS surface and morning upper air data (RAWINSONDE data) from Pittsburgh, PA. AERMET is a multi-stage processing package that ultimately produces two meteorological input files used by AERMOD, the surface file and the profile file. The surface file contains the calculated Planetary Boundary Layer parameters such as: friction velocity, Monin-Obukov length, convective velocity scale, mechanical and convective mixing heights, sensible heat flux, and the lowest level of observed wind data, turbulence and temperature. Surface characteristics of the modeling domain region were selected using site-specific and wind directionally-dependant median roughness lengths, Bowen ratios and Albedo. The median surface roughness lengths were calculated using a FORTRAN program that was developed in accordance with the latest on-site meteorological guideline (EPA, 2000b). The program reads in the site-specific 10 and 50 meter levels of wind data and calculates the median surface roughness lengths. The profile file contains all levels of tower wind speed and direction data, and the 10 meter level temperature and sigma theta data. The multiple sensor levels provide measurements to determine vertical profiles of wind speed and wind direction. The following sections describe each stage of the meteorological data processing using AERMET.

3.4.1 AERMET Stage 1

Stage 1 processing entails extraction and quality assessment of the National Climatic Data Center (NCDC) TD-1440 format and TD-6201 format hourly surface and upper air sounding data from Pittsburgh, respectively. The period of record was the same as for the on-site data collection. AERMET reads in the data and quality assesses (QA) for missing data, values outside of the upper and lower bound default values and data inconsistencies. Currently, AERMET does not replace missing or suspect data. AERMET reads the on-site data from the AV and Manor towers in a formatted Fortran READ statement. The data were quality assured and missing data were reported.

3.4.2 AERMET Stage 2

Stage 2 of the processing combines the hourly surface data, upper air data and on-site meteorological data into a single ASCII file. The output file is formatted so that each block of data contains 24-hours of on-site, NWS surface and upper air observations.

3.4.3 AERMET Stage 3

The final stage of processing reads in the merged file output from Stage 2 and site-specific parameters that characterize the modeling domain and produce two output meteorological files for input to AERMOD. For the Manor and AV towers, the Albedo and Bowen ratios were derived from Tables 4-1 and 4-2 contained in the AERMET User's Guide. The land use in the general vicinity of the towers was judged to be grassland. In addition, hourly Pittsburgh surface data were reviewed and it was determined that the winter of 1990 had below normal snowfall. From this, it was determined that snow cover was not prevalent during the 1990-1991 winter season, and therefore, as recommended in the AERMET User's Guide, the albedo was set to the fall season values throughout the winter. The Bowen ratios were based on normal rainfall throughout each season of the year.

TRC calculated site-specific surface roughness lengths (z_0) using the 10- and 50-meter (m) level wind speed and wind direction data collected from the AV and Manor towers for the period from August 1, 1990 through July 31, 1991. Site-specific surface roughness lengths were calculated using 30 and 90 degree wind direction sectors with wind speeds of greater than or equal to 5 meters per second (m/s). TRC incorporated the methodologies in EPA's <u>On-Site Meteorological Program Guidance For Regulatory Modeling Applications</u> (EPA, 2000b) by calculating the seasonal surface roughness length for the four seasons and two sets of wind direction sectors.

The program uses the following equation to calculate surface roughness values based on hourly wind speed observations at the lowest two levels on each tower:

$z_o = e^{**}[u_U \ln (z_L) - u_L \ln (z_U)]/(u_U - u_L)$

where:

e = the natural log base (2.781828),
** = indicates that the following term is an exponent,
u_U = the scalar wind speed at the middle level of the tower,
z_L = the height of the scalar wind speed measurements at the lower level of the tower (10 m),
u_L = the scalar wind speed at the lower level of the tower, and
z_U = the height of the scalar wind speed measurements at the middle level of the tower (50 m).

Tables 3-4 and 3-5 provide a summary of the site-specific median z_0 values calculated for the AV/Manor towers, by 30 degree wind direction sectors, 90 degree wind direction sectors, and seasons. Averages of the wind direction sector medians and the overall average z_0 values were also computed. The lower z_0 values are associated with small wind speed differences between the 10 and 50 meter levels in a given wind direction sector. These low wind speed differences with height are attributable to the existence of very few obstructions upwind in these sectors. Higher z_0 values are associated with large wind speed differences with height, which are caused by obstructions such as higher terrain and more trees within a given wind direction sector.

Since the number of valid hours in some of the 30 degree wind direction sectors was less than 1 percent of the total valid hours with wind speeds greater than 5 m/s (647 hours for AV and 2,656 hours for Manor), the average of the valid median z_0 values (6.59 cm for AV and 4.73 cm for Manor) was computed and selected for these sectors (per AERMOD User's Guide recommendation). As shown in Table 3-5, the observed median z_0 value was 0.013 cm (0.00013 meters) for the 240-270 degree wind direction sector at the Manor tower. That value, however, is below the AERMET program's minimum z_0 threshold of 0.10 cm (0.001 meters). Since that wind direction sector included many valid hours with wind speeds greater than 5 m/s, the substitute z_0 value used was the 0.10 cm minimum threshold value instead of the aforementioned 4.73 cm average of the valid median values.

When the wind data were binned into four 90 degree wind direction quadrants, the calculated median z_0 values were lower than the mean values for three of the four bins because larger numbers of valid hours with small differences between the wind speeds with height were associated with these three quadrants.

Since the median surface roughness values in 30 degree wind direction sectors provided more resolution, these values were used as input to AERMET. The calculated surface characteristics were put into an input file and AERMET Stage 3 was run with the surface, upper air and on-site data to calculate Planetary Boundary Layer parameters for the surface file. A profile file was also generated that contains all levels of wind speed, direction and 10 meter level turbulence and temperature data

TABLE 3-4
Site-Specific Surface Roughness (Z_0)
Calculated using Ash Valley Met. Data

Wind Direction Sector (deg.)	No. of Valid Hours	Range of z_0 (cm)	Median z_0 (cm)	Mean z_0 (cm)	Selected z_0 (cm)
0-30*	0	0	0	0	6.59
30-60*	2	31.41-40.00	35.71	35.71	6.59
60-90*	0	0	0	0	6.59
90-120*	0	0	0	0	6.59
120-150*	6	0.68-24.50	10.94	10.90	6.59
150-180	31	0.06-55.02	4.70	9.02	4.70
180-210*	5	2.32-20.3	4.43	8.19	6.59
210-240	88	2.91-62.60	18.11	20.16	18.11
240-270	275	0.85-47.99	10.97	12.65	10.97
270-300	182	0.01-47.74	4.01	4.88	4.01
300-330	48	0.04-10.51	1.05	2.06	1.05
330-360	10	0.10-1.81	0.71	0.81	0.71
Average of the valid medians			**6.59**		
0-90*	2	31.41-40.00	35.71	35.71	6.63
90-180	37	0.61-55.02	4.90	9.33	4.90
180-270	368	0.85-62.60	11.72	14.39	11.72
270-360	240	0.14-47.74	3.27	4.15	3.27
Average of the valid medians			**6.63**		
Season					
Winter	275	0.61-55.02	6.18	9.36	6.18
Spring	190	0.01-43.10	7.61	11.39	7.61
Summer	10	5.88-45.43	9.20	16.31	9.20
Autumn	172	10.04-62.60	7.12	10.50	7.12
Average of the valid medians			**7.53**		
Overall	**647**	**0.01-62.60**	**7.13**	**10.37**	

* Too few events to compute a valid median

TABLE 3-5

Site-Specific Surface Roughness (Z_0) Calculated using Manor Met. Data

Wind Direction Sector (deg.)	No. of Valid Hours	Range of z_0 (cm)	Median z_0 (cm)	Mean z_0 (cm)	Selected z_0 (cm)
0-30*	0	0	0	0	4.73
30-60*	0	0	0	0	4.73
60-90*	7	22.85-31.78	28.19	27.63	4.73
90-120	106	0.00-113.62	19.47	30.84	19.47
120-150	326	0.00-165.50	0.32	7.06	0.32
150-180	28	0.005-106.96	9.21	18.66	9.21
180-210	51	0.00-62.36	1.78	6.61	1.78
210-240	546	0.00-32.71	0.22	2.25	0.22
240-270	530	0.00-293.73	0.013	2.75	0.10
270-300	903	0.00-79.18	0.25	2.24	0.25
300-330	157	0.00-27.18	6.54	7.53	6.54
330-360*	2	17.89-55.71	36.80	36.80	4.73
Average of the valid medians			**4.73**		
0-90*	7	22.85-31.78	28.19	27.63	1.09
90-180	460	0.00-165.50	2.34	13.25	2.34
180-270	1127	0.00-293.73	0.43	2.66	0.43
270-360	1062	0.00-79.18	0.50	3.09	0.50
Average of the valid medians			**1.09**		
Season					
Winter	960	0.00-293.73	0.04	3.57	0.04
Spring	830	0.00-165.50	0.32	4.75	0.32
Summer	191	0.00-113.62	0.94	11.02	0.94
Autumn	675	0.00-106.96	0.86	4.58	0.86
Average of the valid medians			**0.54**		
Overall	**2656**	**0.00-293.73**	**0.25**	**4.73**	

* Too few events to compute a valid median

for AERMOD. The profile file contains multiple levels for AERMOD to extrapolate wind speeds up to plume height using its internal power law equation. The surface profile files produced by AERMET from the AV and Manor tower data were used as input to AERMOD.

3.5 Background Concentrations

Background concentrations were developed to represent contributions from distant and unidentified sources not explicitly being modeled in the compliance evaluation of the Laurel Ridge and Chestnut Ridge region. These were determined by meteorological category using the full year of monitored data collected at all 10 monitors during the model evaluation study. A total of 28 meteorological categories was used, with average hourly concentrations determined for each category based on the average of the measurements at all upwind monitors (relative to the plants) under each category. For the compliance evaluation modeling, the background concentration was determined hourly, depending on the meteorological condition.

The procedure used is consistent with guidance provided in EPA's modeling guideline (EPA, 2001). The guideline recommends using data for the meteorological conditions of concern collected at monitors not impacted by the sources being modeled. A constant background concentration was not selected for all 3-hour or 24-hour averages throughout the year because the hourly meteorological conditions do not remain constant throughout the averaging period.

The background analysis was conducted using AV tower wind speed and wind direction data from the 150 meter level and sigma theta stability classification data from the 10 meter level. This tower was used because it is the closer of the two towers to the area of highest predicted concentrations. Wind direction was separated into four 90 degree quadrants, wind speed was divided into low, medium, and high categories, and stability was broken up into stable, unstable, and neutral categories as follows:

Wind Direction Quadrant (degrees)	Stability	Wind Speed (m/s)
1-90	Stable (E,F)	0-3
91-180	Neutral (D)	3.01-8
181-270	Unstable (A, B, C)	>8.01
271-360		

The meteorological data were then examined on an hour-by-hour basis to determine which of the ten monitors were impacted by any of the power plants in the region. For each hour, a monitor was considered to be impacted by a power plant if it lay anywhere within a 90 degree sector downwind of the plant. This was done for each of the power plants and each of the monitors. If a monitor was determined to be impacted by any one of the power plants, its concentration for that hour was not used in the background calculation. The background concentration was calculated for each hour as the average from among all monitors not impacted by one of the power plants during the hour. Under certain wind directions, all monitors were determined to be impacted by at least one power plant. For each of these conditions, the minimum reported concentration from all of the monitors was used for that hour.

Each hourly average concentration from among all monitors not influenced by a power plant during the hour was placed in the appropriate meteorological category bin. For the stable and unstable categories, the medium and high wind speed cases were combined due to the few occurrences of these categories in the data set. Thus, the number of meteorological categories used totaled 28. The concentrations accumulated in the above process for each meteorological data category were then summed and the average concentration among all hours for each category was determined. A file of hourly background concentrations for each of the meteorological categories was created. Table 3-6 lists the resulting background concentrations and related meteorological categories.

The average background concentrations in Table 3-6 were then added to each hour's model-predicted concentrations depending upon the meteorological conditions that cause the prediction. After the background concentrations were added to the hourly predictions, total SO_2 concentrations for all the appropriate averaging periods were calculated using CALMPRO.

3.6 Model Options

Table 3-7 shows the AERMOD model options and source input echo for a sample 24-hour average run. Other averaging periods use different emission parameters as shown in Table 3-2. The default model options shown in Table 3-7 were automatically invoked as per the AERMOD User's Guide and follow the latest EPA modeling guidance. The base elevation of the anemometer heights shown in Table 3-3 for both the Manor and Ash Valley towers were used for all the power plants in the Laurel/Chestnut Ridge area.

TABLE 3-6
Determination of the Background SO_2 Concentrations as a Function of the Meteorological Conditions

Bin Number	Flow Vector Quadrant	Stability	Wind Speed (m/s)	Average ($\mu g/m^3$)	Number of Monitor-hours Used	Number of Times Minimum Was Used	Number of Hours in Bin
1	Northeast	Stable	0-3	34.2	3,725	0	471
2	Northeast	Stable	gt 3	49.6	8,718	0	1,131
3	Northeast	Neutral	0-3	47.5	508	0	65
4	Northeast	Neutral	3-8	45.3	4,355	0	591
5	Northeast	Neutral	gt 8	29.0	3,338	0	479
6	Northeast	Unstable	0-3	65.1	2,462	0	332
7	Northeast	Unstable	gt 3	40.8	8,256	0	1,164
8	Southeast	Stable	0-3	25.9	234	119	157
9	Southeast	Stable	gt 3	19.5	476	218	289
10	Southeast	Neutral	0-3	28.4	66	34	45
11	Southeast	Neutral	3-8	23.0	1,009	566	695
12	Southeast	Neutral	gt 8	20.3	475	176	251
13	Southeast	Unstable	0-3	38.5	272	139	180
14	Southeast	Unstable	gt 3	24.7	1,087	468	644
15	Southwest	Stable	0-3	26.4	975	0	137
16	Southwest	Stable	gt 3	12.1	795	0	108
17	Southwest	Neutral	0-3	20.7	198	0	32
18	Southwest	Neutral	3-8	10.0	643	0	88
19	Southwest	Neutral	gt 8	10.7	68	0	10
20	Southwest	Unstable	0-3	28.8	1,004	0	146
21	Southwest	Unstable	gt 3	8.1	676	0	99
22	Northwest	Stable	0-3	28.0	2,672	0	384
23	Northwest	Stable	gt 3	9.4	2,588	0	364
24	Northwest	Neutral	0-3	24.4	574	0	85
25	Northwest	Neutral	3-8	10.7	1,232	0	177
26	Northwest	Neutral	gt 8	7.1	263	0	39
27	Northwest	Unstable	0-3	32.8	1,881	0	274
28	Northwest	Unstable	gt 3	9.5	2,148	0	321

TABLE 3-7
AERMOD Model Options

Model Is Setup For Calculation of Average CONCentration Values.

Model Uses RURAL Dispersion Only.

Model Uses Regulatory DEFAULT Options:

1. Stack-tip Downwash.
2. Model Accounts for ELEVated Terrain Effects.
3. Use Calms Processing Routine.
4. Use Missing Data Processing Routine.
5. "Upper Bound" Values for Supersquat Buildings.
6. No Exponential Decay

Model Assumes No FLAGPOLE Receptor Heights.

Model Calculates 3 Short Term Average(s) of: 1-HR 3-HR 24-HR and Calculates PERIOD Averages

This Run Includes: 5 Source(s); 5 Source Group(s); and 441 Receptor(s)

The Model Assumes A Pollutant Type of: SO_2

Model Set To Continue RUNning After the Setup Testing.

Output Options Selected:

Model Outputs Tables of PERIOD Averages by Receptor
Model Outputs Tables of Highest Short Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Overall Maximum Short Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Concurrent Values for Postprocessing (POSTFILE Keyword)

NOTE: The Following Flags May Appear Following CONC Values: c for Calm Hours, m for Missing Hours, b for Both Calm and Missing Hours

Misc. Inputs: Base Elev. for Pot. Temp. Profile (m MSL) = 527.30; Decay Coef. = 0.000; Rot. Angle = 0.0; Emission Units = GRAMS/SEC; Emission Rate Unit Factor = 0.10000E+07; Output Units = MICROGRAMS/M3

MODELOPTs:

CONC
DFAULT
ELEV

POINT SOURCE DATA

SOURCE ID	EMMISSION RATE (g/s)	UTM-X (meters)	LOCATION UTM-Y (meters)	Z (meters)	STACK HEIGHT (meters)	EXHAUST TEMP (°K)	EXIT VEL (m/s)	DIAMETER (meters)
KEYS12	0.86190E+04	640180.0	4502150.0	308.0	244.00	423.00	26.80	8.29
HCITY12	0.65520E+04	652770.0	4486110.0	366.0	244.00	422.00	27.40	7.32
HCITY3	0.34300E+03	652770.0	4486110.0	366.0	260.00	330.00	27.40	6.90
CAMBRIA	0.60500E+02	694800.0	4483300.0	664.0	70.20	466.00	27.60	2.29
EBENS	0.43600E+02	691100.0	4481540.0	660.0	76.20	422.00	18.30	2.59

3.7 Model Application

The latest version of AERMOD (02222) was used for this modeling study to update the previous Compliance Demonstration for the SO_2 NAAQS for all the Laurel/Chestnut Ridge region sources combined.

The source input data used by AERMOD for the Laurel/Chestnut Ridge sources are shown in Tables 3-1 and 3-2. The towers and sensors from which the meteorological input data were obtained to model each source are shown in Table 3-3. The receptor grids shown in Figures 3-1 through 3-5 were used with AERMOD to predict impacts from all the sources combined.

In the AERMOD modeling analysis the Ash Valley meteorological data were used to model Conamaugh and Seward Stations, while the Manor data were used to model Keystone and Homer City Stations. This approach was consistent with the MPTER/RTDM/LAPPES Compliance Demonstration utilizing local meteorological measurements to best represent transport conditions. Thus, the available meteorological data were used to represent the closest sources for the aforementioned meteorological data sets.

4.0 MODELING RESULTS

Table 4-1 summarizes the model predicted SO_2 regulatory basis concentrations for the proposed compliance emission rates based on the source-specific meteorological tower locations. The table shows the maximum regulatory averaging period predicted concentrations from any of the modeled receptor grids. The table reiterates the source emission rates, provides the impact contributions of each power plant and shows the total predicted concentrations including background for the 3-hour, 24-hour and annual averaging periods. The table also displays the location coordinates for the receptors where the controlling concentrations were predicted to occur. The Ebensburg Power and Cambria Cogen sources were predicted to contribute little or no impact to the controlling concentrations.

Table 4-1 shows that the predicted controlling highest second-high 3-hour and 24-hour concentrations occur on the Keystone refined grid at two receptors located approximately 3 and 4 kilometers to the east of Keystone Station with elevations of 308 (1,010) and 334 (1,096) meters (feet), respectively. Table 4-1 indicates that the predicted 3-hour and 24-hour concentrations are due primarily to the impacts from Keystone Station (i.e., 96 percent). All the other nearby sources, i.e., Homer City (Units 1, 2 and 3), Conemaugh and Seward, contribute less than 1 percent of the highest second-high 3-hour and 24-hour average concentrations. The background concentrations make approximately 3.8 and 17.5 percent contributions to the highest second-high 3 and 24-hour average concentrations, respectively.

The maximum annual average concentration shown in Table 4-1 occurs on the Homer City coarse grid at a receptor located approximately 21 kilometers to the east of Homer City Station with an elevation of 606 meters (1,988 feet). The maximum predicted annual concentration results from contributions from all the sources. Each of the sources, i.e., Keystone, Homer City (Units 1, 2 and 3), Conemaugh and Seward, contributes between 1 and 14 percent of the highest annual average concentration, with the smallest contribution from Homer City Unit 3 and the largest from Conemaugh Station. The background concentration makes the single largest contribution (56 percent) to the highest annual average concentration.

The updated AERMOD modeling results show that operation of all of the power plants combined at the emission rates specified in Table 3-2 produce modeled compliance with the SO_2 NAAQS for all averaging periods as shown in Table 4-1. All of the results are consistent with the sources' current allowable SO_2 emission rate with the exception of Keystone Units 1 and 2. The current allowable limits at these sources are 4.0 lbs/MMBtu as opposed to the modeled maximum emission rate of 3.92 lbs/MMBtu.

Table 4-1
Multi-source Impacts for the Source Specific Meteorological Data

3-Hour Average

Averaging Period	Julian Day	Ending Hour	Grid ID	Receptor Location UTM-X (m)	Receptor Location UTM-Y (m)	Receptor Location Elevation (m)	Keystone 1&2	Homer City 1	Homer City 2	Homer City 3	Conemaugh	Seward 4&5	Cambria & Ebensburg	Total w/o Background	Background	Total	NAAQS
							SO₂ Concentrations ($\mu g/m^3$) – Source Contributions Without Background										
3-Hour *	32	15	Keystone	643,080	4,502,250	308	1248.56	0.670	0.670	0.080	0.160	0.170	0.020	1250.33	48.89	1299.22	1,300

	Keystone 1&2	Homer City 1	Homer City 2	Homer City 3	Conemaugh	Seward 4&5
Emission Limits (lbs/MMBtu)	3.92	4.0	4.0	0.4	0.2	0.6
Emission Limits (lbs/hr)	68,408	26,001	26,001	2,722	3,310	3,040

24-Hour Average

Averaging Period	Julian Day	Ending Hour	Grid ID	Receptor Location UTM-X (m)	Receptor Location UTM-Y (m)	Receptor Location Elevation (m)	Keystone 1&2	Homer City 1	Homer City 2	Homer City 3	Conemaugh	Seward 4&5	Cambria & Ebensburg	Total w/o Background	Background	Total	NAAQS
							SO₂ Concentrations ($\mu g/m^3$) – Source Contributions Without Background										
24-Hour *	32	24	Keystone	644,180	4,501,850	334	219.78	0.140	0.140	0.020	0.050	0.050	0.010	220.19	46.80	266.99	365
Annual	N/A	N/A	Homer City	672,870	4,486,110	606	5.15	3.91	3.91	0.50	7.91	3.48	0.100	24.96	32.29	57.25	80

	Keystone 1&2	Homer City 1	Homer City 2	Homer City 3	Conemaugh	Seward 4&5
Emission Limits (lbs/MMBtu)	4.0	4.0	4.0	0.4	0.2	0.6
Emission Limits (lbs/hr)	69,732	26,001	26,001	2,722	3,310	3,040

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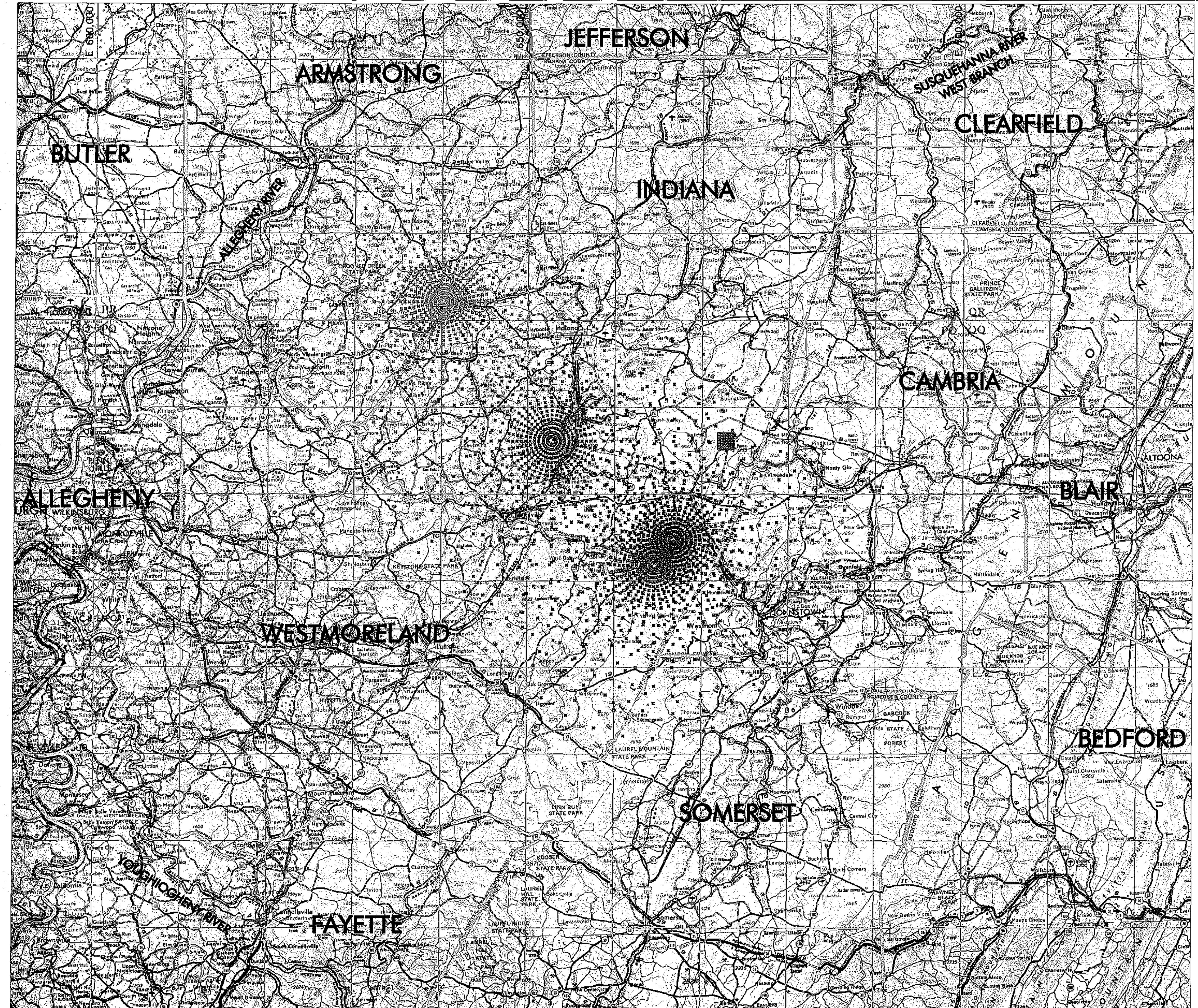


LEGEND

- X KEYSTONE OUTER GRID
- X HOMER CITY OUTER GRID
- X SEWARD OUTER GRID
- X CONEMAUGH OUTER GRID
- X HOMER CITY REFINED GRID

0 12km 24km

GRAPHIC SCALE

TRC Environmental Corporation

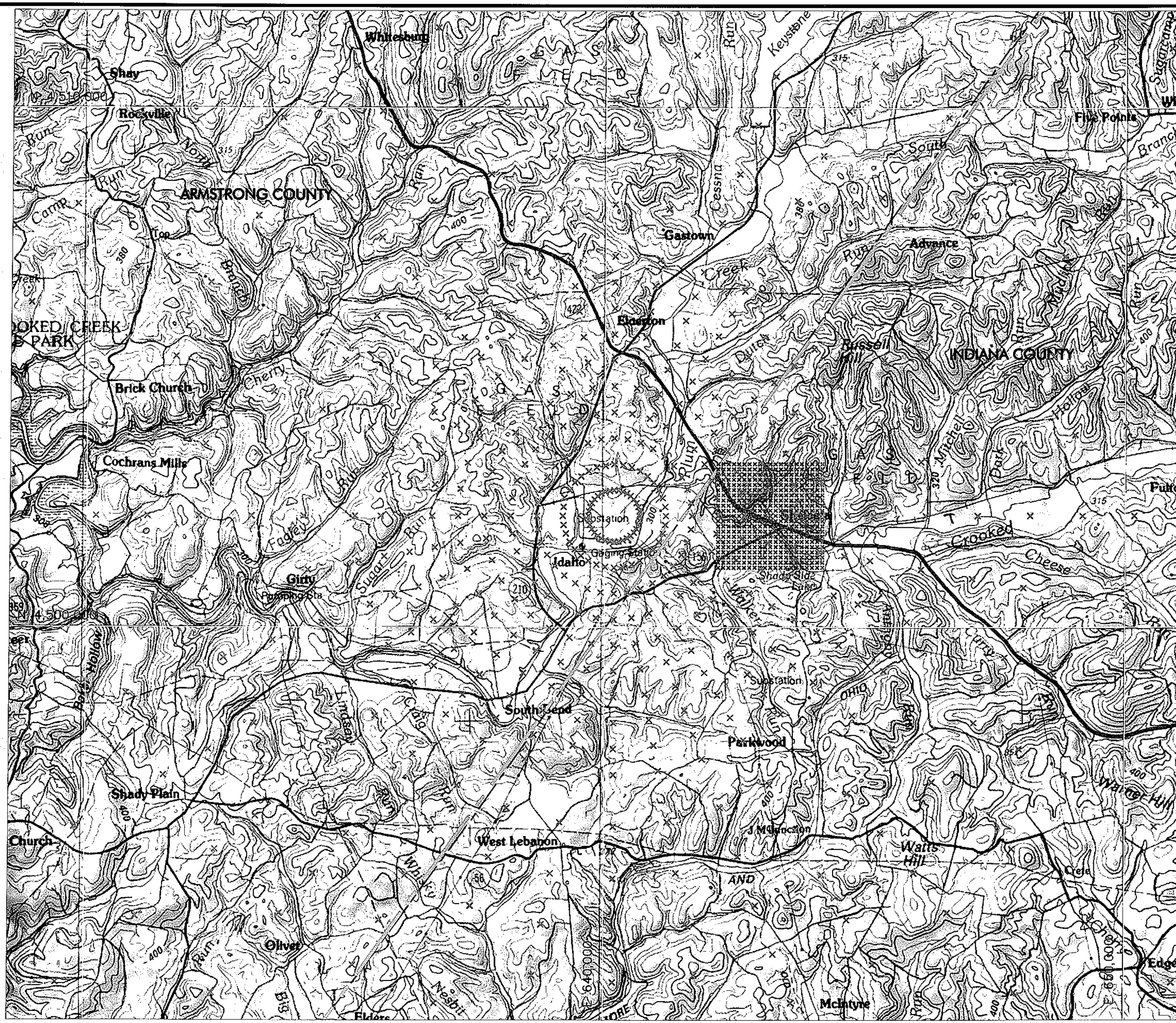
5 Waterside Crossing
Windsor, CT 06095
(860) 289-8631

RELIANT ENERGY
PENNSYLVANIA

FIGURE 3-1
RADIAL RECEPTOR GRIDS
HOMER CITY REFINED GRID
2x2 km, 100 METER SPACING

Date: 02/03 | **Project No.** 33275-0000-00000

33275/L/FIG3-1



N
W E
S
NORTH

LEGEND

X KEYSTONE INNER GRID
X KEYSTONE REFINED GRID

0 2km 4km
GRAPHIC SCALE

TRC Environmental Corporation
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Windsor, CT 06095
(860) 289-8631

RELIANT ENERGY
PENNSYLVANIA

FIGURE 3-2
KEYSTONE INNER GRID-0.5 km TO 9 km
KEYSTONE REFINED GRID
2x2 km, 100 METER SPACING

Date: 02/03 **Project No.** 33275-0000-0000

33275/L/FIG3-2

LEGEND

X HOMER CITY INNER GRID

0 2km 4km

GRAPHIC SCALE

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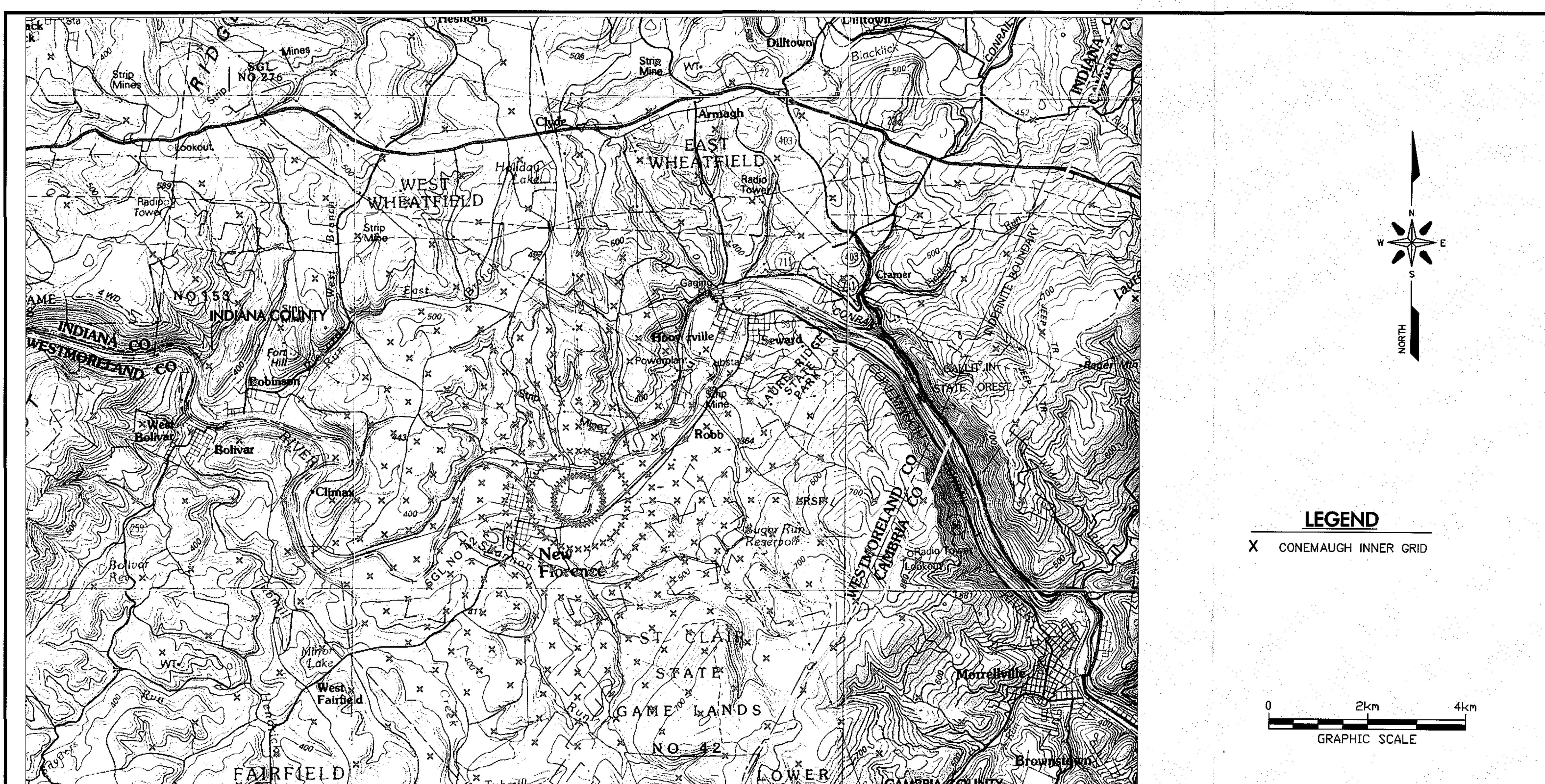
RELIANT ENERGY
PENNSYLVANIA

FIGURE 3-3
HOMER CITY INNER GRID-0.5 km TO 9 km

Date: 02/03 **Project No.** 33275-0000-00000

33275/L/FIG3-3



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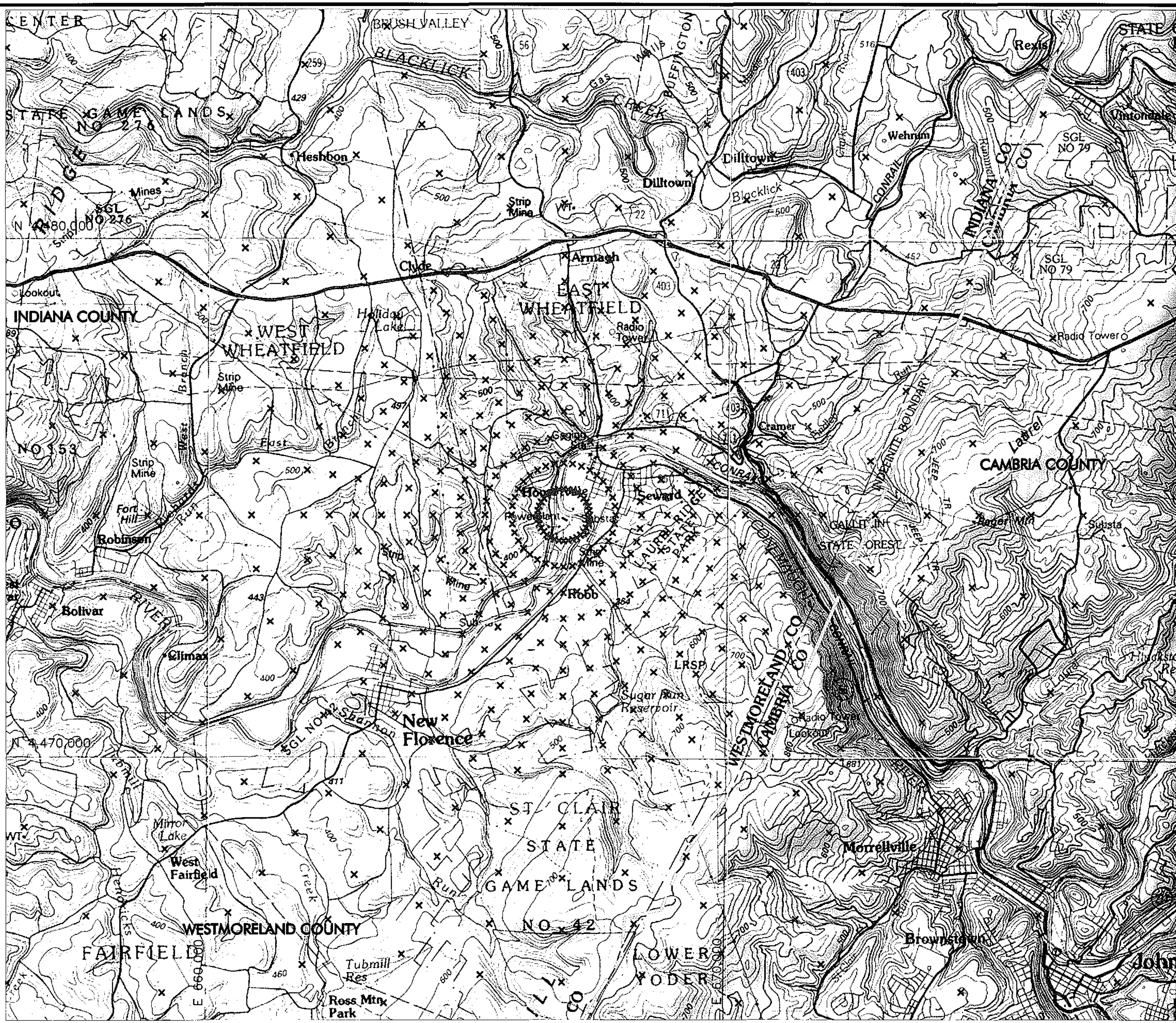
RELIANT ENERGY
PENNSYLVANIA

FIGURE 3-4
CONEMAUGH INNER GRID-0.5 km TO 9 km

Date: 02/03	Project No. 332375-0000-00000

33275/L/FIG3-4



NORTH

LEGEND

X SEWARD INNER GRID

0 2km 4km

GRAPHIC SCALE

TRC Environmental Corporation

5 Waterside Crossing
Windsor, CT 06095
(860) 289-8631

RELIANT ENERGY
PENNSYLVANIA

FIGURE 3-5
SEWARD INNER GRID-0.5 km TO 9 km

Date: 02/03	Project No. 33275-0000-00000

21297/FIG3-5

Attachment E

Letter from EPA Region 3 Requesting Laurel Ridge Study Database

CHESTNUT LAKE / RIDGE
FILE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
841 Chestnut Building
Philadelphia, Pennsylvania 19107-4431

JUN 3 1993

Mr. Vincent J. Brisini
PENELEC
1001 Broad St.
Johnstown, PA 15907

Dear ~~Mr.~~ Vince Brisini:

Approximately two years ago the American Meteorological Society (AMS) and the Environmental Protection Agency (EPA) formed a joint committee - AERMIC (the AMS/EPA Model Improvement Committee) - to introduce state-of-the-science modeling concepts into regulatory dispersion models. AERMIC's primary emphasis is on the replacement of the longstanding PGT stability classification approach to dispersion. The AERMIC intends to replace PGT with an approach that relies of PBL parameterizations. The goal of this effort is to develop a replacement for the EPA ISC model. Additionally, we expect this model to handle complex terrain without invoking an entirely different conceptual framework. If successful we will finally have a regulatory model that is applicable for all source types in all terrain. The AERMIC model would obviate the need for employing an "intermediate terrain analysis."

We have completed the conceptual design of the new model and we are presently in the coding phase. Once the model has been coded, we will need to test its performance. The AERMIC has planned a two phased model performance evaluation. The first phase is designed to help in the final development of the model. The second phase will be an independent test of the model's performance compared with present guideline models.

The success of this new approach rests in its ability to reproduce what has been measured to occur in nature. Since this model is slated to handle many types of applications, the AERMIC must evaluate it against a variety of data bases. The AERMIC has reviewed many data bases that have been collected through out this country. We believe that the Indiana County SO_2 data base could provide an excellent test of the new models capability to accurately predict multi-source impacts in complex terrain. Therefore, on behalf of AERMIC, I am requesting an electronic copy of the full year of source, ambient SO_2, and meteorological data which makeup the Indiana County SO_2 data base. If provided, AERMIC intends to use it as a phase II data bases.

I would like to thank you for your consideration with the hope that we can use this high quality data base in our efforts. If you have any questions, or would simply like to discuss the project please give me a call at (215) 597-6563.

Sincerely,

Alan J. Cimorelli

Attachment F

Land Cover Figures for Comparison of Modeled Sources to Meteorological Tower Site

Table F-1. Land Cover Within 1 km of Conemaugh Station and Ash Valley Tower AERSURFACE Log File (1990)

		Conemaugh Station		Ash Valley Meteorological Tower		Percent Difference
USGS Annual NLCD Category	Description	Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels	%
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	192	5.50%	71	2.03%	3.47%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	232	6.64%	307	8.78%	-2.14%
22	Developed, Low Intensity	386	11.05%	35	1.00%	10.05%
23	Developed, Medium Intensity	416	11.91%	12	0.34%	11.57%
24	Developed, High Intensity	225	6.44%	1	0.03%	6.41%
31	Barren Land (Rock/Sand/Clay)	206	5.90%	12	0.34%	5.56%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	1624	46.51%	2288	65.46%	-18.96%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	0	0.00%	102	2.92%	-2.92%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	50	1.43%	4	0.11%	1.32%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	24	0.69%	642	18.37%	-17.68%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	135	3.87%	21	0.60%	3.27%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	2	0.06%	0	0.00%	0.06%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
	Total	**3492**	**100%**	**3495**	**100%**	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)

Table F-2. Land Cover Within 1 km of Conemaugh Station and Ash Valley Tower AERSURFACE Log File (1991)

		Conemaugh Station		Ash Valley Meteorological Tower		Percent Difference
USGS Annual NLCD Category	**Description**	**Pixel counts**	**Percent of Total Pixels**	**Pixel counts**	**Percent of Total Pixels**	**%**
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	186	5.33%	72	2.06%	3.27%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	227	6.50%	307	8.78%	-2.28%
22	Developed, Low Intensity	386	11.05%	35	1.00%	10.05%
23	Developed, Medium Intensity	429	12.29%	12	0.34%	11.94%
24	Developed, High Intensity	225	6.44%	1	0.03%	6.41%
31	Barren Land (Rock/Sand/Clay)	196	5.61%	12	0.34%	5.27%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	1629	46.65%	2289	65.49%	-18.84%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	0	0.00%	102	2.92%	-2.92%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	54	1.55%	4	0.11%	1.43%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	24	0.69%	640	18.31%	-17.62%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	135	3.87%	21	0.60%	3.27%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	1	0.03%	0	0.00%	0.03%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
	Total	**3492**	**100%**	**3495**	**100%**	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)

Table F-3. Land Cover Within 1 km of Seward Station and Ash Valley Tower AERSURFACE Log File (1990)

		Seward Station		Ash Valley Meteorological Tower		Percent Difference
USGS Annual NLCD Category	Description	Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels	%
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	195	5.56%	71	2.03%	3.53%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	373	10.64%	307	8.78%	1.86%
22	Developed, Low Intensity	290	8.27%	35	1.00%	7.27%
23	Developed, Medium Intensity	43	1.23%	12	0.34%	0.88%
24	Developed, High Intensity	5	0.14%	1	0.03%	0.11%
31	Barren Land (Rock/Sand/Clay)	428	12.21%	12	0.34%	11.87%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	2027	57.83%	2288	65.46%	-7.63%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	4	0.11%	102	2.92%	-2.80%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	29	0.83%	4	0.11%	0.71%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	27	0.77%	642	18.37%	-17.60%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	83	2.37%	21	0.60%	1.77%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	1	0.03%	0	0.00%	0.03%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
	Total	**3505**	**100%**	**3495**	**100%**	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)

Table F-4. Land Cover Within 1 km of Seward Station and Ash Valley Tower AERSURFACE Log File (1991)

		Seward Station		Ash Valley Meteorological Tower		Percent Difference
USGS Annual NLCD Category	Description	Pixel counts	Percent of Total Pixels	Pixel counts	Percent of Total Pixels	%
0	Missing, Out-of-Bounds, or Undetermined	0	0.00%	0	0.00%	0.00%
11	Open Water	196	5.59%	72	2.06%	3.53%
12	Perennial Ice/Snow	0	0.00%	0	0.00%	0.00%
21	Developed, Open Space	373	10.64%	307	8.78%	1.86%
22	Developed, Low Intensity	291	8.30%	35	1.00%	7.30%
23	Developed, Medium Intensity	42	1.20%	12	0.34%	0.85%
24	Developed, High Intensity	5	0.14%	1	0.03%	0.11%
31	Barren Land (Rock/Sand/Clay)	423	12.07%	12	0.34%	11.73%
32	Unconsolidated Shore	0	0.00%	0	0.00%	0.00%
41	Deciduous Forest	2027	57.83%	2289	65.49%	-7.66%
42	Evergreen Forest	0	0.00%	0	0.00%	0.00%
43	Mixed Forest	4	0.11%	102	2.92%	-2.80%
51	Dwarf Scrub	0	0.00%	0	0.00%	0.00%
52	Shrub/Scrub	0	0.00%	0	0.00%	0.00%
71	Grasslands/Herbaceous	33	0.94%	4	0.11%	0.83%
72	Sedge/Herbaceous	0	0.00%	0	0.00%	0.00%
73	Lichens	0	0.00%	0	0.00%	0.00%
74	Moss	0	0.00%	0	0.00%	0.00%
81	Pasture/Hay	27	0.77%	640	18.31%	-17.54%
82	Cultivated Crops	0	0.00%	0	0.00%	0.00%
90	Woody Wetlands	83	2.37%	21	0.06%	1.77%
91	Palustrine Forested Wetland	0	0.00%	0	0.00%	0.00%
92	Palustrine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
93	Estuarine Forested Wetland	0	0.00%	0	0.00%	0.00%
94	Estuarine Scrub/Shrub Wetland	0	0.00%	0	0.00%	0.00%
95	Emergent Herbaceous Wetland	1	0.03%	0	0.00%	0.03%
96	Palustrine Emergent Wetland	0	0.00%	0	0.00%	0.00%
97	Estuarine Emergent Wetland	0	0.00%	0	0.00%	0.00%
98	Palustrine Aquatic Bed	0	0.00%	0	0.00%	0.00%
99	Estuarine Aquatic Bed	0	0.00%	0	0.00%	0.00%
	Total	**3505**	**100%**	**3495**	**100%**	

Rows with percent difference between station and meteorological tower > 5% highlighted.

Source: AERSURFACE (US EPA, 2024d)

Attachment G

Pennsylvania Department of Environmental Protection AIMS Reports 1990 and 1991

Bureau of Air Quality

Best Controlled Detail by Source

Emission Year: 1990
Primary Facility Id: 559131 KEYSTONE CONEMAUGH PROJ LLC/CONEMAUGH STATION
Tax Id/Plant: 83-3299524-1

031 - MAIN BOILER 1 (PC, 8,280 MMBTU/HR)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	603.0000
CO	630080	C RATED FACTOR	2.6000
NOX	10102440	A RATED FACTOR	21,104.0000
NOX	10102440	C RATED FACTOR	12.5000
SOX	7446095	A RATED FACTOR	86,224.7000
SOX	7446095	C RATED FACTOR	10.5000
VOC		C RATED FACTOR	0.1000
VOC		A RATED FACTOR	70.3000
PM10		C RATED FACTOR	507.6000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

032 - MAIN BOILER 2 (PC, 8,280 MMBTU/HR)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	725.5000
CO	630080	C RATED FACTOR	0.9000
NOX	10102440	A RATED FACTOR	25,393.2000
NOX	10102440	C RATED FACTOR	4.1000
SOX	7446095	A RATED FACTOR	99,976.7000
SOX	7446095	C RATED FACTOR	3.4000
VOC		A RATED FACTOR	84.6000
PM10		C RATED FACTOR	610.7000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

033 - STARTUP BOILER 1 (AUX BOILER A)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	0.9000
NOX	10102440	C RATED FACTOR	4.2000
SOX	7446095	C RATED FACTOR	3.5000

034 - STARTUP BOILER 2 (AUX BOILER B)

Emission Year: 1990
Primary Facility Id: 559131 KEYSTONE CONEMAUGH PROJ LLC/CONEMAUGH STATION
Tax Id/Plant: 83-3299524-1

034 - STARTUP BOILER 2 (AUX BOILER B)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	1.2000
NOX	10102440	C RATED FACTOR	5.6000
SOX	7446095	C RATED FACTOR	4.7000

Emission Year: 1991
Primary Facility Id: 559131 KEYSTONE CONEMAUGH PROJ LLC/CONEMAUGH STATION
Tax Id/Plant: 83-3299524-1

031 - MAIN BOILER 1 (PC, 8,280 MMBTU/HR)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	745.6000
CO	630080	C RATED FACTOR	0.4000
NOX	10102440	A RATED FACTOR	26,095.7000
NOX	10102440	C RATED FACTOR	1.8000
SOX	7446095	A RATED FACTOR	100,319.1000
SOX	7446095	C RATED FACTOR	4.1000
VOC		A RATED FACTOR	87.0000
PM10		C RATED FACTOR	621.2000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

032 - MAIN BOILER 2 (PC, 8,280 MMBTU/HR)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	615.5000
CO	630080	C RATED FACTOR	0.5000
NOX	10102440	A RATED FACTOR	21,541.8000
NOX	10102440	C RATED FACTOR	2.3000
SOX	7446095	A RATED FACTOR	86,013.3000
SOX	7446095	C RATED FACTOR	5.3000
VOC		A RATED FACTOR	71.8000
PM10		C RATED FACTOR	512.8000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

033 - STARTUP BOILER 1 (AUX BOILER A)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	0.6000
NOX	10102440	C RATED FACTOR	2.8000
SOX	7446095	C RATED FACTOR	6.6000

034 - STARTUP BOILER 2 (AUX BOILER B)

Pollutant	CAS#	Reliability Code	Amount TPY

Emission Year: 1991
Primary Facility Id: 559131 KEYSTONE CONEMAUGH PROJ LLC/CONEMAUGH STATION
Tax Id/Plant: 83-3299524-1

034 - STARTUP BOILER 2 (AUX BOILER B)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	0.7000
NOX	10102440	C RATED FACTOR	3.3000
SOX	7446095	C RATED FACTOR	7.7000

Pennsylvania Department of Environmental Protection
Bureau of Air Quality
Best Controlled Detail by Source

Emission Year: 1990
Primary Facility Id: 262713 HOMER CITY GEN LP/CENTER TWP
Tax Id/Plant: 80-0833693-1

031 - BOILER NO.1 (UNIT 1)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	422.6000
CO	630080	C RATED FACTOR	1.2000
NOX	10102440	A RATED FACTOR	14,789.3000
NOX	10102440	C RATED FACTOR	5.7000
SOX	7446095	A RATED FACTOR	40,924.0000
SOX	7446095	C RATED FACTOR	5.8000
VOC		A RATED FACTOR	49.3000
PM10		C RATED FACTOR	340.9000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

032 - BOILER NO.2 (UNIT 2)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	447.5000
CO	630080	C RATED FACTOR	1.3000
NOX	10102440	A RATED FACTOR	15,662.9000
NOX	10102440	C RATED FACTOR	6.4000
SOX	7446095	A RATED FACTOR	41,596.1000
SOX	7446095	C RATED FACTOR	6.5000
VOC		A RATED FACTOR	52.2000
VOC		C RATED FACTOR	0.1000
PM10		C RATED FACTOR	361.5000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

033 - BOILER NO.3 (UNIT 3)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	534.3000
CO	630080	C RATED FACTOR	2.7000
NOX	10102440	A RATED FACTOR	18,701.6000
NOX	10102440	C RATED FACTOR	12.8000

Emission Year: 1990
Primary Facility Id: 262713 HOMER CITY GEN LP/CENTER TWP
Tax Id/Plant: 80-0833693-1

033 - BOILER NO.3 (UNIT 3)

Pollutant	CAS#	Reliability Code	Amount TPY
SOX	7446095	A RATED FACTOR	26,048.6000
SOX	7446095	C RATED FACTOR	9.9000
VOC		A RATED FACTOR	62.3000
VOC		C RATED FACTOR	0.1000
PM10		C RATED FACTOR	214.6000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

034 - AUX BOILER A

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	0.2000
NOX	10102440	C RATED FACTOR	0.7000
SOX	7446095	C RATED FACTOR	0.7000

035 - AUX BOILER B

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	0.1000
NOX	10102440	C RATED FACTOR	0.3000
SOX	7446095	C RATED FACTOR	0.3000

Emission Year: 1991
Primary Facility Id: 262713 HOMER CITY GEN LP/CENTER TWP
Tax Id/Plant: 80-0833693-1

031 - BOILER NO.1 (UNIT 1)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	508.4000
CO	630080	C RATED FACTOR	0.8000
NOX	10102440	A RATED FACTOR	17,794.4000
NOX	10102440	C RATED FACTOR	4.1000
SOX	7446095	A RATED FACTOR	49,570.0000
SOX	7446095	C RATED FACTOR	11.4000
VOC		A RATED FACTOR	59.3000
PM10		C RATED FACTOR	510.1000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

032 - BOILER NO.2 (UNIT 2)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	320.0000
CO	630080	C RATED FACTOR	1.1000
NOX	10102440	A RATED FACTOR	11,200.4000
NOX	10102440	C RATED FACTOR	5.2000
SOX	7446095	A RATED FACTOR	30,993.0000
SOX	7446095	C RATED FACTOR	14.7000
VOC		A RATED FACTOR	37.3000
PM10		C RATED FACTOR	320.5000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

033 - BOILER NO.3 (UNIT 3)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	520.3000
CO	630080	C RATED FACTOR	2.1000
NOX	10102440	A RATED FACTOR	18,211.2000
NOX	10102440	C RATED FACTOR	10.3000
SOX	7446095	A RATED FACTOR	24,689.2000

Emission Year: 1991
Primary Facility Id: 262713 HOMER CITY GEN LP/CENTER TWP
Tax Id/Plant: 80-0833693-1

033 - BOILER NO.3 (UNIT 3)

Pollutant	CAS#	Reliability Code	Amount TPY
SOX	7446095	C RATED FACTOR	28.9000
VOC		A RATED FACTOR	60.7000
VOC		C RATED FACTOR	0.1000
PM10		C RATED FACTOR	452.5000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

034 - AUX BOILER A

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	0.2000
NOX	10102440	C RATED FACTOR	0.8000

035 - AUX BOILER B

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	C RATED FACTOR	0.1000
NOX	10102440	C RATED FACTOR	0.5000

Pennsylvania Department of Environmental Protection
Bureau of Air Quality
Best Controlled Detail by Source

Emission Year: 1990
Primary Facility Id: 275229 KEYSTONE CONEMAUGH PROJ LLC/KEYSTONE STATION
Tax Id/Plant: 83-3299524-2

031 - BOILER 1 WITH LOW NOX BURNER

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	776.3000
CO	630080	C RATED FACTOR	0.9000
NOX	10102440	A RATED FACTOR	27,170.9000
NOX	10102440	C RATED FACTOR	4.5000
SOX	7446095	A RATED FACTOR	77,708.6000
SOX	7446095	C RATED FACTOR	5.4000
VOC		A RATED FACTOR	90.6000
PM10		C RATED FACTOR	651.3000

VOC/PM10 Summary
Sum of VOC HAPS: Sum of PM10 HAPS:

032 - BOILER 2 WITH LOW NOX BURNER

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	539.3000
CO	630080	C RATED FACTOR	4.5000
NOX	10102440	A RATED FACTOR	18,875.9000
NOX	10102440	C RATED FACTOR	21.5000
SOX	7446095	A RATED FACTOR	57,139.9000
SOX	7446095	C RATED FACTOR	25.7000
VOC		C RATED FACTOR	0.2000
VOC		A RATED FACTOR	62.9000
PM10		C RATED FACTOR	453.1000

VOC/PM10 Summary
Sum of VOC HAPS: Sum of PM10 HAPS:

Pennsylvania Department of Environmental Protection
Bureau of Air Quality
Best Controlled Detail by Source

Emission Year: 1991
Primary Facility Id: 275229 KEYSTONE CONEMAUGH PROJ LLC/KEYSTONE STATION
Tax Id/Plant: 83-3299524-2

031 - BOILER 1 WITH LOW NOX BURNER

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	605.7000
CO	630080	C RATED FACTOR	2.4000
NOX	10102440	A RATED FACTOR	21,200.6000
NOX	10102440	C RATED FACTOR	11.3000
SOX	7446095	A RATED FACTOR	61,027.3000
SOX	7446095	C RATED FACTOR	29.0000
VOC		C RATED FACTOR	0.1000
VOC		A RATED FACTOR	70.7000
PM10		C RATED FACTOR	476.1000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

032 - BOILER 2 WITH LOW NOX BURNER

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	727.4000
CO	630080	C RATED FACTOR	1.5000
NOX	10102440	A RATED FACTOR	25,459.4000
NOX	10102440	C RATED FACTOR	7.0000
SOX	7446095	A RATED FACTOR	74,705.0000
SOX	7446095	C RATED FACTOR	18.0000
VOC		C RATED FACTOR	0.1000
VOC		A RATED FACTOR	84.9000
PM10		C RATED FACTOR	571.8000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

Pennsylvania Department of Environmental Protection
Bureau of Air Quality
Best Controlled Detail by Source

Emission Year: 1990
Primary Facility Id: 554653 SEWARD GENERATING STATION/SEWARD
Tax Id/Plant: 81-0806945

031 - BOILER 15 (COMB.ENG)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	112.0000
NOX	10102440	A RATED FACTOR	3,919.2000
NOX	10102440	C RATED FACTOR	3.1000
SOX	7446095	A RATED FACTOR	11,063.4000
SOX	7446095	C RATED FACTOR	3.1000
VOC		A RATED FACTOR	13.1000
PM10		C RATED FACTOR	18.3000

VOC/PM10 Summary
Sum of VOC HAPS: Sum of PM10 HAPS:

032 - BOILER 12 (B&W)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	26.8000
CO	630080	C RATED FACTOR	1.1000
NOX	10102440	A RATED FACTOR	937.2000
NOX	10102440	C RATED FACTOR	5.2000
SOX	7446095	A RATED FACTOR	2,506.2000
SOX	7446095	C RATED FACTOR	47.0000
VOC		A RATED FACTOR	3.1000
PM10		C RATED FACTOR	10.4000

VOC/PM10 Summary
Sum of VOC HAPS: Sum of PM10 HAPS:

033 - BOILER 14 (B&W)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	25.6000
NOX	10102440	A RATED FACTOR	896.3000
NOX	10102440	C RATED FACTOR	3.1000
SOX	7446095	A RATED FACTOR	2,513.4000
SOX	7446095	C RATED FACTOR	2.7000
VOC		A RATED FACTOR	3.0000

Emission Year: 1990
Primary Facility Id: 554653 SEWARD GENERATING STATION/SEWARD
Tax Id/Plant: 81-0806945

033 - BOILER 14 (B&W)

PM10	C RATED FACTOR	9.9000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

Emission Year: 1991
Primary Facility Id: 554653 SEWARD GENERATING STATION/SEWARD
Tax Id/Plant: 81-0806945

031 - BOILER 15 (COMB.ENG)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	117.6000
CO	630080	C RATED FACTOR	1.0000
NOX	10102440	A RATED FACTOR	4,115.2000
NOX	10102440	C RATED FACTOR	4.6000
SOX	7446095	A RATED FACTOR	12,457.2000
SOX	7446095	C RATED FACTOR	13.3000
VOC		A RATED FACTOR	13.7000
PM10		A RATED FACTOR	19.8000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

032 - BOILER 12 (B&W)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	24.8000
CO	630080	C RATED FACTOR	0.8000
NOX	10102440	A RATED FACTOR	868.5000
NOX	10102440	C RATED FACTOR	3.8000
SOX	7446095	A RATED FACTOR	2,467.7000
SOX	7446095	C RATED FACTOR	11.0000
VOC		A RATED FACTOR	2.9000
PM10		A RATED FACTOR	9.8000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS:

033 - BOILER 14 (B&W)

Pollutant	CAS#	Reliability Code	Amount TPY
CO	630080	A RATED FACTOR	27.4000
NOX	10102440	A RATED FACTOR	957.7000
NOX	10102440	C RATED FACTOR	2.4000
SOX	7446095	A RATED FACTOR	2,650.2000
SOX	7446095	C RATED FACTOR	6.8000

Emission Year: 1991
Primary Facility Id: 554653 SEWARD GENERATING STATION/SEWARD
Tax Id/Plant: 81-0806945

033 - BOILER 14 (B&W)

VOC	A RATED FACTOR	3.2000
PM10	A RATED FACTOR	10.9000

VOC/PM10 Summary

Sum of VOC HAPS: Sum of PM10 HAPS: