SO_2 NAAQS Designations
Source-Oriented Monitoring
Technical Assistance Document

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Executive Summary

This document is one of two technical assistance documents being provided by the EPA to assist state, local, and tribal air agencies in the characterization of ambient air quality in areas with significant sulfur dioxide (SO_2) emission sources. The primary purpose of this Source-Oriented SO_2 Monitoring Technical Assistance Document (TAD) is to provide suggestions on how air agencies might appropriately and sufficiently monitor ambient air in proximity to an SO_2 emission source to create ambient monitoring data for comparison to the SO_2 National Ambient Air Quality Standards (NAAQS). This TAD presents recommended steps to prepare for the source-oriented SO_2 monitor site identification process that may proceed under the EPA's upcoming SO_2 data requirements rule, and discusses three different approaches air agencies might take to identify where a sufficient number of SO_2 monitors may be located to characterize the peak SO_2 concentrations that occur in an area around or impacted by an SO_2 emissions source. The three different potential approaches presented are to: 1) conduct new modeling to aid in monitoring site placement; 2) conduct exploratory monitoring to inform permanent monitor placement; and 3) take advantage of existing emissions data, existing monitoring data, and existing modeling, where possible, to determine permanent monitoring site placement.

This TAD does not impose binding and enforceable requirements or obligations on any person, and is not final agency action. It is intended to provide recommendations for others to consider as they develop information to be used in future separate final actions, such as area designations and other NAAQS implementation actions. The TAD is subject to change and does not represent the culmination of any agency proceeding or a final interpretation by the EPA of any pre-existing statutory or regulatory requirements.

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1. Introduction

1.1 Background

The traditional NAAQS implementation process begins with the area designations process described in section 107 of the Clean Air Act (CAA), which generally relies on air quality concentrations to be characterized by ambient monitoring data collected by the air agency to identify areas that are exceeding the relevant standard. The preamble to the final SO_2 NAAQS noted that although the current SO_2 ambient monitoring network included 400+ monitors nationwide, the scope of the network had certain limitations, and approximately two-thirds of the monitors are not located to characterize maximum concentration source-oriented impacts. It was observed that some areas without monitoring likely have concentrations violating the NAAQS. To address these potential public health impacts, the SO_2 NAAQS preamble and subsequent draft guidance issued in September 2011 recommended that air agencies submit substantive attainment demonstration state implementation plans (SIPs) based on air quality modeling by June 2013 [under Clean Air Act section 110(a)(1)] that would show how areas expected to be designated unclassifiable and have sources emitting over 100 tons of SO_2 per year would attain and maintain the NAAQS in the future.

A number of stakeholders expressed concern with this suggested implementation approach, particularly with the number of sources to be modeled (more than 1680 sources had emissions exceeding 100 tons in 2008), and the recommended SIP submission date for areas *without* monitoring being before the SIP due date for violating areas *with* monitoring data. In response, the EPA Assistant Administrator, Gina McCarthy, sent letters to state Environmental Commissioners on April 12, 2012, indicating that the EPA wanted to further consult with stakeholders regarding how to best implement this standard and protect public health in an effective manner. The letters also stated that the agency would not expect air agencies to submit attainment demonstrations by June 2013 for areas not designated as "nonattainment" based on ambient monitoring data. The EPA developed a white paper on possible implementation approaches and proceeded to convene three stakeholder meetings in May- June 2012 with environmental group representatives; state, local, and tribal air agency representatives; and industry representatives. On July 27, 2012, the EPA also announced that it was extending the deadline for SO_2 NAAQS area designations by an additional year, to June 3, 2013, based on the unavailability of data.

1.2 Purpose

This draft Source-Oriented Sulfur Dioxide (SO_2) Monitoring Technical Assistance Document (TAD) is one of two TADs[1] being provided by the EPA to assist state, local, and tribal air agencies in the characterization of ambient air quality[2] in areas around or impacted by significant

[1] The companion document is the SO_2 NAAQS Designations Modeling Technical Assistance Document.
[2] Ambient air is defined in 40 CFR Part 50, 50.1 as that portion of the atmosphere, external to buildings, to which the general public has access.

SO_2 emission sources. This characterization is needed to support the implementation of the SO_2 NAAQS. This TAD provides technical background to an anticipated SO_2 data requirements rule which the EPA intends to propose to require states to characterize ambient air quality in areas around and impacted by the nation's larger SO_2 emission sources.

The purpose of this TAD is to provide suggestions on how state, local, and tribal air agencies might appropriately and sufficiently monitor ambient air in areas proximate to or impacted by an SO_2 emission source to create ambient monitoring data for comparison to the SO_2 NAAQS. Although there is already an SO_2 monitoring network, the EPA expects that some air agencies may consider using monitoring to provide additional air quality data that might be needed as part of the anticipated data requirements rule. The EPA expects monitoring conducted in response to the future data requirements rule to be targeted, source-oriented monitoring, for which the primary objective would be to identify peak SO_2 concentrations in the ambient air that are attributable to an identified emission source or group of sources. This TAD presents recommended steps to prepare for the source-oriented SO_2 monitor site identification process and three different potential approaches a state, local, or tribal air agency might consider when identifying where one or more SO_2 monitors may be needed to characterize the peak SO_2 concentrations that are occurring in an area around or impacted by an SO_2 emissions source or group of sources. The EPA also notes that this monitoring effort may be most effective when there is collaboration among air agencies and other affected stakeholders (e.g., industry and other parties). Collaboration on this effort may also ease the burden on all parties from the collection of existing data on air quality, emissions, and other case-specific information, designing a monitoring network, , and implementing, operating, and maintaining the monitors.

The approach taken by a state, local, or tribal air agency to determine where a sufficient number of SO_2 monitors may be sited to characterize ambient peak SO_2 concentrations should take into account as much available data as possible. Such data might include: all the available data with respect to relevant source emission profiles, existing air quality data, existing modeling results, meteorological data and analyses (e.g., wind roses), terrain, general knowledge of a source or sources and the surroundings, and general knowledge about an area with respect to monitoring site feasibility. This TAD presents methods by which a state might consider all the available information regarding the site selection process, and suggests three approaches that a state might use to find suitable source-oriented SO_2 monitoring sites. The three suggested approaches are: 1) take advantage of existing emissions data, existing monitoring data, and existing modeling to identify candidate monitor sites, 2) conduct new modeling to aide in candidate site identification, and 3) conduct exploratory monitoring to inform permanent monitor placements.

In the anticipated data requirements rule mentioned earlier, which the EPA will develop in 2013 and 2014, the EPA envisions proposing requirements for state, local, and tribal air agencies to characterize SO_2 air quality conditions around and in areas impacted by an SO_2 emissions source. Any monitoring conducted by a state, local, or tribal air agency pursuant to the anticipated future requirements in the upcoming data requirements rule would be subject to EPA Regional

Administrator approval. In the projected timeline included in the February 2013 EPA SO_2 Strategy Paper, the EPA anticipates proposing that any new monitoring would be included in the state's Annual Monitoring Network Plan due to be submitted July of 2016 or such other date determined in the future rule. Further, the EPA anticipates proposing that monitors would be expected to be operational by January 1, 2017, or other such date determined by the future rule. The EPA expects that in cases where monitoring is conducted in response to the future data requirements rule, monitors are eligible to also satisfy monitoring required in 40 CFR part 58, Appendix D, Section 4.4.2, *Requirement for Monitoring by Population Weighted Emissions Index* (PWEI), if they are within an area subject to PWEI required monitoring. However, all PWEI required monitors may not necessarily satisfy the future data requirements rule. The EPA expects that those PWEI monitors that are source-oriented monitors, and in proximity to a source identified by the future data requirements rule, as currently envisioned, may be included in the consideration of what monitoring is necessary to appropriately and sufficiently characterize air quality around that identified source.

No matter what approach is used to site monitors to comply with the future data requirements rule, the EPA expects to propose to require that the monitors to be operated in a manner equivalent to those monitors operated elsewhere in the State and Local Air Monitoring Stations (SLAMS) network. Specifically, the EPA expects to propose to require that the monitors to use Federal Reference Methods (FRMs) or Federal Equivalent Methods (FEMs) and meet the requirements of 40 CFR part 58 Appendices A, C, and E. Further, the EPA intends to propose that resulting data should be reported to the Air Quality Subsystem (AQS), be subject to annual data reporting and certification requirements listed in 40 CFR parts 58.15 and 58.16, and meet other requirements that may be specified by an EPA Regional Administrator.

2. Information Gathering to Support the Site Selection Process

This section is intended to guide the collection of existing information to support the source-oriented SO_2 monitor site selection process. The EPA suggests pursuing the acquisition and evaluation of each type of information presented here. Having all the available information will ensure a thorough evaluation in the determination of a sufficient number of source-oriented SO_2 monitoring sites. These data will provide support for a rationale of why a site or set of sites are appropriate when a state engages the EPA for future Annual Monitoring Network Plan approval.

2.1 SO_2 Emission Sources

It is anticipated that the forthcoming data requirements rule would propose to require the characterization of ambient air quality conditions around larger SO_2 emissions sources. These sources would likely be identified by a combination of: 1) emissions on a tons per year basis and, 2) proximity to population. When those selection criteria are established through the rulemaking process, state, local, and tribal air agencies will be aware of which SO_2 sources and their surrounding or impacted areas must be characterized, and will be in a position to decide which areas would be characterized via monitoring.

The first recommended step in determining where and how many monitors will be needed to appropriately and sufficiently characterize ambient SO_2 air quality conditions in proximity to a SO_2 emission source is to evaluate the source itself. States should collect and review all available information they have about the source, including:

- Facility Name and owner
- Facility function (EGU, smelter, etc.)
- Fuel source or other information on SO_2 producing components and operations
- Emissions data (annual, sub-annual, etc., as available)
- Continuous Emissions Monitoring (CEM) data
- Long-term emissions trend data
- Emissions profile (plant operations 24 hours a day, diurnal, seasonal, on-demand, etc.)
- Emissions metrics (stack height(s), stack dimensions, emission temperatures, emission velocities, etc.)
- Emissions controls in place (also identify if control installations are planned, with committed timetable as available)
- Permit related data (which should include the identification of the existence of any Title V, PSD, or related modeling, permit limits, etc.)

Many of these data may be available in routinely produced Facility Level Reports and Process Level Reports which are submitted by states to the EPA on an annual basis for inclusion in the Emissions Inventory System (EIS). Data suggested for collection (above) which are not included in those reports most likely will be found in state-maintained permitting records, if available.

It is also important to understand the setting and surroundings of the SO_2 source, including whether there are neighboring SO_2 emission sources. States should also ascertain whether an identified SO_2 source is an isolated source in either an urban or rural setting, or a source within an area with multiple SO_2 sources of varying magnitudes.

2.2 Existing Air Quality Data

In situations where existing air quality data are available in an area containing an SO_2 source, states should collect all the available data for review to assist in making reasoned decisions about monitor placement. The EPA believes this data collection activity should include those data from any state, local, or tribal monitors, and an investigation on whether any monitoring data from industry or third party sources exists that could be made available to air agencies. Although industry and third party monitoring data may not necessarily be appropriate for use in designation activities (e.g., they do not represent ambient air and/or they do not meet requirements in 40 CFR Part 58 Appendices A, C, and E), such data likely will be very valuable in aiding any process in determining where appropriate ambient air monitoring should be conducted to satisfy the anticipated data requirements rule. Further, it may be discovered that existing industry or third party monitoring infrastructure and monitoring operations could be modified to meet all necessary requirements to produce data of appropriate quality for comparison to the NAAQS and thus minimize the need for additional monitors. An example of such a situation might be an industry operated monitor sited at a location of expected maximum concentration, in ambient air, which only needs to be quality assured by a state (where the state becomes the Primary Quality Assurance Organization (PQAO)) or otherwise operated in a manner appropriate to meet 40 CFR part 58 Appendix A quality assurance requirements. In this example, collaboration between industry and the state could allow existing data collection activities to be used in characterizing ambient air quality that could help satisfy future requirements in the anticipated data requirements rule. Although the use of industry operated monitors may not always be an option, the EPA expects that there are opportunities to leverage industry or other third party operated ambient air monitors to help satisfy the future data requirements rule requirements.

2.3 Existing Modeling

Large SO_2 sources likely to be identified in the forthcoming data requirements rule may have been modeled at some point in time, possibly in order to receive a state, Title V, and/or PSD related permit or as part of a SIP. It should be noted that relatively older sources could have been in operation before PSD rules were enacted, and as a result, there may not be modeling data for those ‘grandfathered’ sources if they have not significantly increased their net SO_2 emissions since PSD was introduced. However, for many sources, the EPA expects that there are modeling results available, and on public record. If existing modeling results are identified and available, they should be included in the monitoring site evaluation process, as those modeling results will likely provide data indicating where locations of ambient SO_2 concentration maxima may occur.

2.4 Meteorological Data

Understanding the meteorological regime within which an SO_2 source is situated is critical in understanding how SO_2 emissions may most often be dispersed and where the location or locations of maximum ground-level concentrations may be expected to occur. Therefore, the selection of meteorological data for analysis for monitoring site evaluations should be considered carefully.

The *Guideline on Air Quality Models*[3] published as 40 CFR part 51, Appendix W (Appendix W) offers guidance on selecting meteorological data for dispersion modeling and is relevant here. The selection of meteorological data should be based on spatial and climatological (temporal) representativeness (Appendix W, Section 8.3). The representativeness of the data is based on: 1) the proximity of the meteorological monitoring site to the area under consideration, 2) the complexity of terrain, 3) the exposure of the meteorological site, and 4) the period of time during which data are collected. Spatial representativeness of the meteorological data can be adversely affected by large distances between the source and receptors of interest and the complex geographic characteristics of the area (Appendix W, Section 8.3.a and 8.3.c; and discussed in Section 2.5 of this TAD, respectively). Care should be taken when selecting a meteorological data source if the area of interest has complex terrain. While an identified SO_2 source and meteorological station may be in close proximity, there may be complex terrain between them such that conditions at the meteorological station may not be representative of conditions at the source. An example would be a source located on the windward side of a mountain chain with a meteorological station a few kilometers away on the leeward side of the mountain. When using data from a NWS station alone or in conjunction with site-specific or other data, it is important that the data be spatially and temporally representative of conditions in which the target SO_2 source is situated. Appendix W addresses spatial representativeness issues in Sections 8.3.a and 8.3.c.

There are a number of sources from which meteorological data might be obtained for the monitoring site evaluation process, including on-site data, the National Weather Service (NWS), the Federal Aviation Administration (FAA), AQS, AIRNow-Tech, universities, and military facilities, among others. Of these data sources, the most valuable data for this application is meteorological data collected very nearby or even on the property of an identified SO_2 emitting facility (a.k.a., on-site or "site specific" data), if those data are of adequate quality. These data typically have very good spatial representativeness of the area in which the identified SO_2 source is situated, and thus, provide the best information to understand the actual conditions in which SO_2 emissions are being dispersed. Meteorological data produced by the NWS, which routinely collects data at airports and other locations nationwide, are available from the National Climatic Data Center (NCDC) in many formats, with the most common format in recent years being the Integrated Surface Hourly data (ISH). Data from other sources mentioned above may be more varied in availability and format, but can be useful when routine data sources are not representative of the SO_2 source area or are unavailable, and may also be useful in augmenting available on-site or NWS data.

In the event that local or otherwise similar and suitable meteorological data are not available, the EPA suggests that state, local, and tribal air agencies evaluate the installation of one or more meteorological stations to inform the site selection process. Regardless of the method by which state, local, and tribal air agencies determine where and how many SO_2 monitors are necessary to characterize air quality in areas around or impacted by an identified source, the lack of representative meteorological data will severely limit confidence in monitor siting outcome. An

[3] http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

example of a situation where state, local, and tribal air agencies should consider installing local meteorological stations is when a source exists in a valley where no meteorological data are available, and the nearest available meteorological data are from adjacent and separate neighboring valleys. In this and any other case where regional meteorology is highly variable and location dependent, often due to geographic related influences (discussed below), on-site or nearby local meteorological data would be of greatest value.

2.5 Geographic Influences

The geographic setting of an SO_2 source can have substantial impacts on emissions dispersion and thus on the appropriate location or locations of any source-oriented SO_2 monitors. States should evaluate both the immediate and larger scale geographic setting of each potential identified SO_2 source to understand if plume or emissions behavior are routinely subject to topographic, terrain, or water-body influenced air flows. For those SO_2 sources in relatively non-complex terrain, e.g., largely flat terrain or low relief topography and not near large water bodies, the pollutant dispersion will be largely dominated by the overarching synoptic meteorology (i.e., the prevailing wind flow and atmospheric stabilities). If the source is in complex terrain, such as in the midst of mountains and valleys, topographical influence becomes a much larger factor in pollutant transport and dispersion. The evaluation and investigation of topographical influence becomes especially important if no meteorological data are available within a valley where emissions originate. In those situations, the available meteorological data are likely not locally representative. Rather, they would be representative of the larger synoptic scale regime or possibly a different and separate valley. The primary focus in understanding the topographical influences in complex terrain is to determine the differences between the broad synoptic winds that exist above ridges and the wind behavior below the ridges within a valley. Sources can also be in proximity to large water bodies, which can have a profound impact on pollutant dispersion. It is critical to understand these influences during any monitor site evaluation process. The following examples discuss how geographic and meteorologically coupled influences can affect pollutant dispersion in complex terrain or near large water bodies, including thermally driven winds (i.e., mountain/valley winds and sea/lake breezes), vertically coupled flow, pressure-induced channeling, and forced channeling. The examples are somewhat simplified and although we present them individually it is often the case for complex terrain that more than one of these physical influences can be in effect at once (sans sea/lake breezes), creating a complicated flow pattern in an area of interest. It is critical to understand these influences in determining proper placement of source-oriented SO_2 monitoring sites.

2.5.1 Thermally Driven Winds

Thermally driven winds are air circulations caused by air density and pressure gradients developed due to differential or uneven surface heating across an area (Whiteman and Doran, 1993; Arya, 1999; Birdwell, 2011). In basic effect, air is warmed as it sits over a heating surface area (due to surface insolation) and begins to expand. Adjacent air parcels, which are relatively cooler (due to less or a lack of heating), are denser than the warmer air parcel over the warming surface, leading to a density gradient between the two air parcels. As a consequence, the cooler, denser air will flow towards the area of warmer, less dense air, displacing the warmer air upwards. Aloft, the warmer air cools as it rises, and is often displaced in the horizontal towards the origination of the cooler air, where it eventually will sink back down to the surface and move to displace warming air, thus completing the thermally driven circulation. Thermally driven circulations or winds are typically diurnal, having day/night patterns, independent of synoptic air flow (e.g., the prevailing wind and/or those winds above the ridge lines in complex terrain), and are enhanced or otherwise least disrupted when synoptic winds are light and when surface heating potential is maximized with clear skies and/or a dry air mass (Weber and Kaufman, 1998; Stewart et al., 2002; Birdwell, 2011). These winds can be subdivided into a number of categories. This TAD will discuss several situations that may be most relevant to monitor siting processes in areas of complex terrain (mountain and valley winds) or in locations near large water bodies (lake/sea breezes).

In the case of mountain and valley winds, there are two circulations that may be in play: the slope or valley wall circulations and the flows that can develop along valley axes. Daytime thermally driven circulations are driven by daytime surface heating which causes up-slope and up-valley (along the valley axis) flow to develop throughout the day. Slope flows are particularly due to the temperature difference of air over the mountain slope compared to the air at the same altitude over the valley floor (Monti et al., 2002). As night falls, the pattern reverses, exacerbated by radiational cooling at the surface, causing down-slope and down-valley flow to develop as cooler air from aloft 'fills' back into the valley (Whiteman and Doren, 1993; Weber and Kaufman, 1998; Arya, 1999). Notably, Whiteman and Doren, 1993, suggest that thermally driven up/down valley winds, which are generally along the valley axis, "…can be expected to be quite weak in shallow valleys because horizontal pressure differences depend strongly on valley depth." These mountain and valley winds are important to understand if a future identified SO_2 source is in a setting where these flows can often have significant influence on emission transport and dispersion throughout the diurnal flow cycle.

Lake or sea breezes can be influential on pollutant transport and dispersion in locations near large water bodies due to temperature differences between water bodies and the adjacent land. Water has a much larger thermal capacity than land, which can lead to sharp thermal contrasts between lake or sea surface temperatures and land surface temperature throughout the diurnal heating and cooling cycle. In particular, land heats more quickly than water during the day, and likewise cools more quickly at night. During the day, this leads to surface temperature differences which cause a shallow thermal low pressure area over the land as that air expands and begins to rise. The cooler air over the adjacent water body will begin to flow inland to replace the rising warmer air, creating what is known as a lake or sea breeze. Aloft, the risen warmer air will often move out over the water body where it can cool and sink, completing the thermal circulation. At night this circulation reverses when the land cools relative to the water body; however, the night-time land breeze circulation is typically not as strong as the daytime lake or sea breeze, as the difference in temperatures at night is typically not as large as during the day (Arya 1999; Laird et al., 2001; Sills et al., 2011). Arya, 1999, also notes that sea breezes are strongest in the afternoon when land surface temperatures are typically at a maximum, and in certain conditions, can extend several tens of kilometers inland in coastal regions. This diurnal circulation pattern is important to consider when siting monitors in coastal areas, as the lake or sea breeze may be a dominant influence on pollutant transport and dispersion.

2.5.2 Vertically Coupled Flow or Downward Momentum Transport

Vertically coupled flow is an effect of the downward transport of momentum from winds aloft directing or deflecting the in-valley air flow or circulation so that it is similar to the air flow above. This coupled flow is enabled or exacerbated during relatively unstable or neutral conditions and a well mixed boundary layer with stronger upper level winds (Whiteman and Doran, 1993; Birdwell, 2011). Whiteman and Doran, 1993, suggest vertically coupled flow might be expected more commonly in wide, flat-bottomed valleys with low sidewalls. The in-valley winds predominantly under the influence of vertically coupled flow would be expected to be roughly in the same direction of the upper air flow, except for a deflection of approximately 25° (Whiteman and Doren, 1993; Weber and Kaufman, 1998) or a range of 25° to 40° (Birdwell, 2011) due to friction with decreasing altitude over the valley floor.

2.5.3 Pressure Driven Channeling

Pressure driven channeling can be described as the flow of air through a valley that is driven by differences in the larger, synoptic scale air pressures in a region (e.g., opposing high pressure and low pressure centers) where air flow within a valley is moving from areas of relatively high pressure towards those with relatively low pressure along the valley axis. Whiteman and Doran, 1993, suggest pressure driven channeling is a situation where winds in a valley below the ridge line are simply driven by the along-valley pressure gradient within that valley, balanced by friction from the valley floor and sidewalls, constrained by topography to blow along the valley's axis. Unlike forced channeling (discussed below), which seems to be most prevalent in smaller, short and narrow valleys as noted above, pressure driven flows may have stronger potential influence in relatively wider valleys (on the order of tens of kilometers or more across), and possibly shallower valleys which are less subject to thermally driven wind influences, based on examples presented in literature by Gross and Wipperman, 1987; Whiteman and Doran, 1993; and Birdwell, 2011. Appendix B has a more detailed discussion of pressure driven channeling.

2.5.4 Forced Channeling

When wind is largely or solely re-directed by terrain, largely irrelevant of overlying pressure or thermal gradients, it can be characterized as forced channeling. Forced channeling is most prevalent in relatively smaller, short and narrow valleys (Weber and Kaufman, 1998; Kossman and Sturman, 2003). Depending on mesoscale or synoptic scale flow and valley axis orientation, air flow within a small valley affected by forced channeling can be deflected up to 90° from the direction of the prevailing winds in a generally neutrally buoyant atmosphere (Birdwell, 2011). The largest deflections can occur when prevailing winds are nearly perpendicular to the valley axis, where the winds have only two paths to follow, and the resulting wind is forced along the axis of the valley that is within 90° of the heading of the prevailing winds.

3. Approaches to Ambient Monitor Siting

The EPA suggests that the more data and analysis that goes into a source-oriented monitoring site evaluation process, the more appropriate the resulting monitoring network proposal will be. It is anticipated that air agencies electing to use monitoring as part of the future data requirements rule would be expected provide adequate reasoning in support of a monitoring network proposal to demonstrate adequate characterization of an area around or impacted by an identified SO_2 source, including location(s) where peak 1-hour SO_2 concentrations are expected to occur. Although this TAD is intended to provide options and direction on how a sufficient number of source-oriented SO_2 monitors might be sited, it is anticipated that each identified source will need a case-specific evaluation. The objective of such an evaluation is to use all the available data, through one or more of the suggested approaches provided here, to formulate a proposal to site monitors that would appropriately and sufficiently characterize air quality in areas around or impacted by a an SO_2 emission source. Since each situation will be case-specific, the TAD will not recommend minimum criteria for a number of SO_2 monitors in a network or an area to characterize air quality in order to satisfy the anticipated data requirements rule. As noted earlier, specific elements of a network, including the appropriate number of monitors would be determined through analysis and subsequent discussion with the EPA for eventual approval by EPA Regional Administrators.

3.1 Modeling to Inform Monitor Placement

Modeling is a powerful tool that should be strongly considered to inform the identification of potential monitoring sites intended to satisfy the expected data requirements rule. Generally, this modeling can follow the recommendations of the SO_2 NAAQS Designations Modeling Technical Assistance Document (Modeling TAD)[4], which offers recommendations for modeling sources for designations. In general, the modeling TAD identifies the following suggested actions:

- Emissions data preparation, including sources to model, formatting of hourly emissions when available, and calculating temporally varying emissions
- Selection and processing of input meteorological data
- Source characterization including urban vs. rural treatment of sources in the modeling
- Design value calculations from model output

However, there are two areas where modeling to inform monitor placement would differ from the actions taken to model for designations to satisfy the anticipated data requirements rule. First, the modeling that is used to inform monitor placement could use normalized emissions. The modeling discussed in the Modeling TAD uses the actual emissions from modeled sources. The use of normalized emissions can be used when modeling to inform monitor siting decisions because the result of the modeling is not to determine the attainment status of an area, but still identifies local maxima of concentrations. The normalization of the emissions preserves the relative magnitude of emissions forecast at each receptor by the model and the spatial distribution of modeled normalized design values. To normalize the emissions, the input emissions could be initially calculated using the relevant sections of the Modeling TAD. Subsequently, all of the input emissions could be divided by a reference emission rate, which can be the overall highest emission rate or any reference emission rate. In cases where multiple sources are included in an analysis, the same approach would be used, with all emission values being divided by the reference emission rate. The key is that all emissions would be divided by the same emission rate.

The second difference between modeling for designations and modeling to inform monitor site placement is in the receptor placement strategy. For the designations modeling, receptors would be placed in all available ambient air locations around a source, i.e. where the public has access, regardless of whether there is the potential for a monitor to be sited in that location. When modeling to inform monitor placement, receptors would similarly be placed around a source, however removing or ignoring those locations which are not feasible as ambient monitoring locations (i.e., water bodies, military reservation, etc.) may be allowable. Again, the purpose of the modeling is to identify potential areas where state, local, and tribal air agencies may be able

[4] Please note that the SO2 NAAQS Designations Modeling TAD supersedes the EPA's March 2011 air quality modeling guidance intended for the designations process, which recommended the use of allowable emissions only to characterize air quality.

to site a monitor to characterize peak, ambient SO_2 concentrations. Once modeling has been conducted to determine areas where monitoring may be necessary, further evaluation of specific site locations which are feasible can be conducted. An example of modeling to inform monitoring is presented in Appendix B.

In general, the approach presented here and the example analysis in Appendix B provides a potential template for using modeling to inform monitoring site placement. Following this procedure will provide state, local, and tribal air agencies with information to begin evaluating specific areas to determine where SO_2 monitors might be placed to characterize air quality around an SO_2 source. There will be an expectation that due diligence will be carried out to get as close as possible to the location or locations anticipated to have the peak or otherwise highest anticipated concentrations available to them. The EPA expects state, local, and tribal air agencies to provide a rationale based on the available data on whether these monitoring sites are appropriate.

3.2 Using Exploratory Monitoring for Monitor Placement

State, local, and tribal air agencies may wish to conduct exploratory monitoring to either identify potential monitoring sites or more thoroughly evaluate potential monitoring sites identified through the other processes described in this TAD. In the case where exploratory monitoring is intended to be the main tool in informing where permanent SO_2 monitors should be established, a saturation study or a focused monitoring campaign considering existing data and local knowledge of an area is most appropriate. When exploratory monitoring is used as a means to provide increased confidence of candidate locations for permanent monitoring, the resulting data can bolster the rationale of why a site or number of sites will or will not be necessary. For example, if an agency used modeling to identify multiple areas where monitoring might be appropriate, they could use exploratory monitoring to help prioritize the candidate areas or sites before expenditure of resources to acquire or otherwise access a location or locations for a permanent site begin. These exploratory data may also support the rationale for the proposed number of permanent SO_2 monitors included in a network.

Saturation studies typically involve a large number of low-cost, portable samplers to “saturate” an area to identify the spatial variability of pollutant concentrations. In this case, the agency would deploy many samplers or devices at a number of locations around a source to determine which areas might have relatively higher pollutant levels.

Focused exploratory monitoring could create data for comparison or evaluation at a specific number of sites, such as those derived from the evaluation of available data discussed in Section 2, or to further verify the highest priority candidate monitoring sites identified through the site selection processes discussed in Sections 3.1 and 3.2. This approach is also more appropriate when the resources to conduct the study are reduced or minimal as compared to a saturation study.

Two key considerations in exploratory monitoring are the method used and the timing and duration of the study. The recently (2010) revised 1-hour SO_2 NAAQS is intended to protect public health by reducing exposure to high, short-term concentrations of SO_2. Therefore, exploratory monitoring conducted with highly time resolved data (i.e., data production on the order of minutes to hours) will be most useful. Continuous methods are most appropriate to target short-term peak SO_2 concentrations because of the high time resolution data they provide. A problem with continuous methods has been the cost and associated logistical burdens that they require to install and operate. Recent technological advances in sensor and sampler technology have introduced increasingly smaller and cheaper continuous methods. These so-called "sensors" are not reference or equivalent methods, but have shown promise for use in a number of applications, including exploratory monitoring. Most of these new sensors use proprietary methods, but in general are electrochemical methods in basic design. A key issue in the use of these new sensor methods is assessing accuracy and precision, which can be better understood through the use of collocated sensors in the field.

Passive SO_2 methods commonly used in the past for saturation studies are commercially available, easy to use, and are relatively inexpensive. However, passive methods are integrated samples collected over days to weeks. Although they can be used to determine long-term concentration trends, they do not offer the same insight into where the short-term peak SO_2 concentrations may be occurring in an area around or otherwise impacted by an SO_2 source. Passive SO_2 methods are not the recommended method of choice for conducting exploratory monitoring to aid in determining where to place source oriented SO_2 monitors and should be considered as only a complementary or back-up strategy to other methods and approaches to identify SO_2 monitoring sites.

The other key consideration in saturation or focused exploratory monitoring is the timing and duration of the study. The objective of the monitoring is to characterize peak, short-term SO_2 concentrations, however when these peaks occur may not be well known. As such, a study should consider not only where to monitor, but also for how long. It is most logical to monitor throughout the course of a year, to gain at least some confidence that variations in facility operations (e.g., diurnal, seasonal, other emission profiles) and/or meteorological influences are reflected in the study data. If a particular season or time period, whether due to facility operations or meteorology, or both, is expected to be most likely to lead to peak SO_2 concentrations, then monitoring during those times could be an acceptable alternative to a year-round study. Finally, any exploratory monitoring would need to be completed in sufficient time such that the data from the study could be used to inform air agency decisions regarding network implementation in a timely manner. As described in the EPA's February 2013 SO_2 Strategy Paper, it is anticipated that under a future data requirements rule, the state would need to describe any planned changes to its monitoring network in the relevant Annual Monitoring Network Plan and be prepared to have the monitoring network operational by a date that would be defined by that rule.

3.3 Monitor Siting Based on Existing Data

In the event that a network designer has a sufficient amount and understanding of those data suggested in Section 2 (e.g., emissions data and source profile, air quality data, existing modeling data, meteorological data, topographical/terrain characterization), state, local, and tribal air agencies may be able to use those data to evaluate where source-oriented SO_2 monitors will be needed without conducting additional modeling and/or exploratory monitoring. The ultimate number and location of monitors that might be necessary to characterize air quality around an identified SO_2 source needs to be based on all available data and have a clear, technical rationale. The more that data are documented, considered, and explained, the more robust and supportable the resulting monitoring plan will be.

The EPA recommends the review and inclusion of any existing modeling data in the site evaluation process. Existing modeling data likely would be from PSD or permit related activities. Although these modeling efforts were not originally intended for use in siting monitors, those data will likely be very useful in highlighting areas where ambient, peak 1-hour ground level concentrations might be expected to be highest around a particular SO_2 source. Once one or more areas are identified by reviewing existing model data, a more detailed reconnaissance of each of these areas can be conducted in harmonious review of other available data to determine where one or more monitor sites may be feasible (including considerations for access, permissions, and utilities). In the event that old modeling data do not exist for an identified source, the EPA encourages state, local, and tribal air agencies to strongly consider conducting modeling to inform monitoring site selection as discussed above in Section 3.1.

4. Source-oriented SO_2 Monitor Site Selection

Source-oriented SO_2 monitoring sites that could be used to satisfy the anticipated data requirements rule would be classified as SLAMS or otherwise subject to all requirements in 40 CFR part 58 and Appendices A, C, and E. State, local, and tribal air agencies would also be expected to use due diligence in acquiring or otherwise accessing space for monitoring in the location or locations that have been identified through one or more of the site identification approaches discussed in Section 3 above. As is the case with any SLAMS, the site should be installed with the intention of operating over the long-term. If sites identified as appropriate monitoring sites are not available for a permanent monitoring site, the air agency should be able to document why a preferred location was not selected or available.

In some cases, there may be industrial or other stakeholder monitoring in areas around or impacted by SO_2 sources identified by the future data requirements rule. If one or more of those non-SLAMS sites is identified to be in one or more of the desired locations to characterize air quality around the identified source, there is potential for such monitors to be used to satisfy the upcoming data requirements rule. Any such monitor would need to comply with the monitoring requirements in 40 CFR part 58, Appendices A, C, and E. These include only using FRMs or FEMs, subjecting the monitors to routine QA, and requirements for reporting data. The EPA encourages the pursuit of partnerships between state, local, and tribal air agencies with other stakeholders wherever possible to use existing infrastructure, increase communication between stakeholders, and use available resources as efficiently as possible. As with any SLAMS site, the use of these sites, including the means by which all requirements in 40 CFR part 58 would be met, would need to be documented and included in state Annual Monitoring Network Plans.

The process and outcome of determining how to appropriately and sufficiently characterize air quality conditions around an identified SO_2 source with ambient monitoring will be case specific. Air agencies should document the process they undertake to identify where monitoring sites will be planned, installed, or modified (i.e., leveraging industry monitoring) with the explicit purpose of providing a rationale behind their monitoring network design decisions. These monitoring sites are expected to be part of a state Annual Monitoring Network Plan in the summer preceding the date by which monitoring is to begin and would be subject to EPA Regional Administrator approval. In regard to the number of monitoring sites that could be in a network design, the EPA recognizes that increasing the number of monitoring sites around a single facility can present resource and logistical burdens. However, the benefits of considering multiple monitor sites include increased spatial representation, increased population exposure coverage, and the potential to increasingly capture and characterize some portion of the emissions from the identified SO_2 source. Even in situations where the measured concentrations at any given monitor are not the peak values that would be driving the design values in the area, the characterization of SO_2 concentrations around the SO_2 source are enhanced, furthering the understanding of exposures and dispersion in that area. These data will allow for a more complete understanding of the likely SO_2 concentration gradients in an area, increased understanding of the frequency at which certain locations see SO_2 concentration maxima, and increased detail and confidence in any NAAQS determination activity.

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Appendix A: Example of Modeling to Inform Monitoring Placement Using Normalized Emissions

As discussed in Section 3.1 of this TAD, modeling with normalized emission rates can be used to inform the identification of potential SO_2 monitoring sites. This appendix presents an example of using the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) to identify potential monitoring sites for an area influenced by a single source. Modeling procedures from the SO_2 NAAQS Designations Modeling Technical Assistance Document were followed with the exception of the layout of the receptor network and the used of normalized emissions.

A.1 Model setup

- The modeled source is a facility with three boilers located near a coastal region.
- 3 years of hourly boiler emissions were normalized using the maximum facility hourly rate.
- These hourly rates were modeled in AERMOD using concurrent meteorological data.
- The provided outputs do not provide an indication of NAAQS exceedances, just information on where maxima occur and the frequency of how often a receptor had the highest relative concentration per day.

A traditional Cartesian receptor grid was centered on the identified facility and extended to a distance of 20 km. The receptor spacing from the facility to 10 km was 250 meters and the spacing from 10 to 20 km was 500 meters. The full Cartesian receptor grid, typical of most modeling applications, can be seen in Figure 1. The SO_2 emission source is marked in the center of the receptor grid and the source of meteorological data used for the modeling exercise is denoted by the black triangle.

When modeling to inform monitor site placement, it would be unnecessary to have receptors located in areas or locations prohibitive to establishing fixed monitoring sites, such as open water, etc. It would also be unnecessary to have receptors on the fenced property of an SO_2 source or facility, as those locations are not likely to be representative of ambient air accessible to the public. These concepts are reflected in Figure 2, where receptors in locations prohibitive to ambient monitoring have been removed prior to running the model. Alternatively, an air agency could keep all receptors in a model run, and simply ignore receptors in prohibitive monitoring locations during the post-processing analysis.

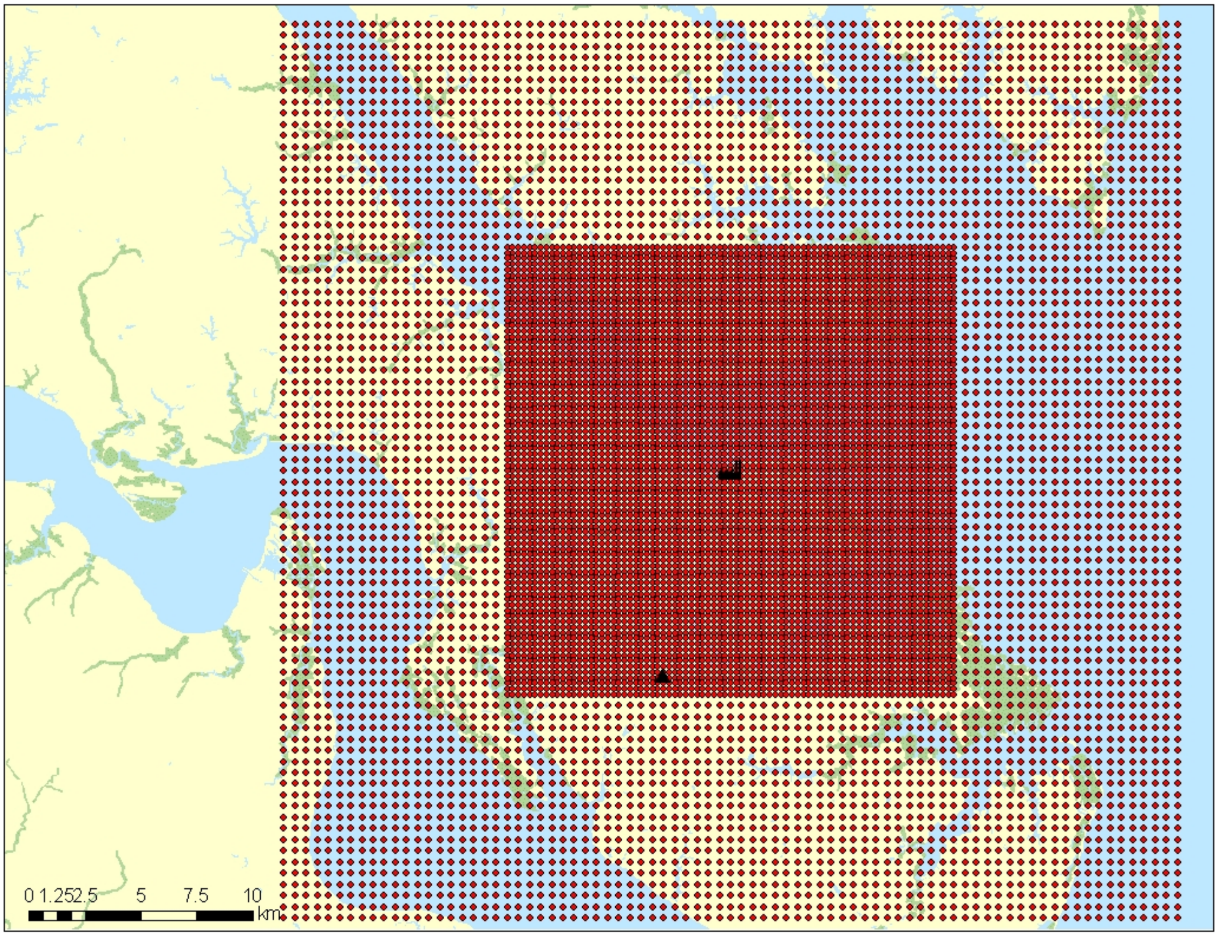

Figure 1. Traditional Cartesian receptor grid. This figure shows a traditional Cartesian receptor grid centered on an SO_2 facility in a coastal area. Grid spacing is 250 meters from the center to 10 kilometers out, and 500 meters from 10 to 20 kilometers out.

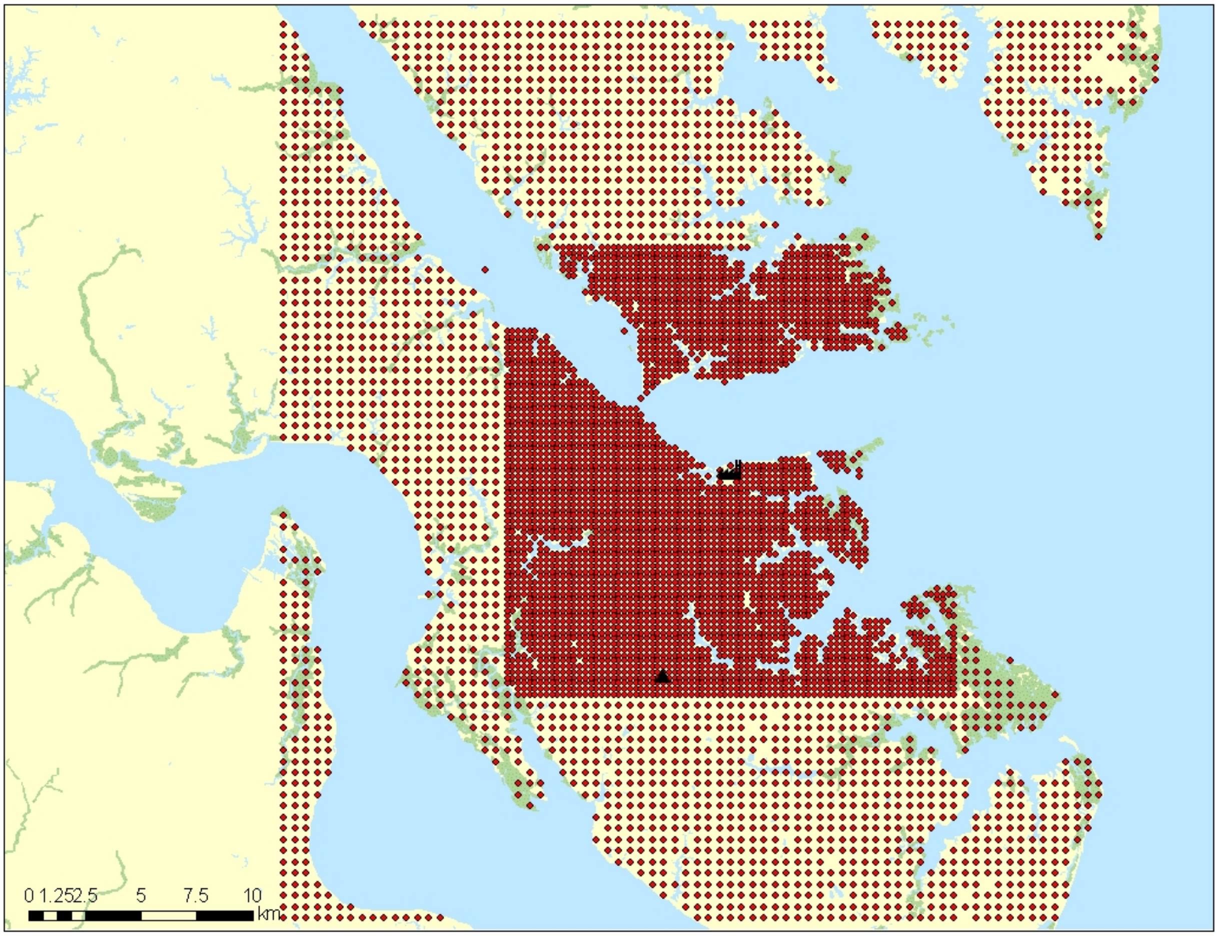

Figure 2. Receptor grid with receptors in locations prohibitive to ambient monitoring removed. This figure is a modification of Figure 1, illustrating the removal of receptors from locations which are not suitable for permanent SO_2 monitoring sites. In this case, such prohibitive locations would be those over water and any within the identified SO_2 source facility boundary.

A.2 <u>Model results</u>

Modeling the normalized hourly SO_2 emissions allows for the calculation of normalized design values (NDVs). NDVs do not indicate exceedance or compliance with the NAAQS, but provide a means to understanding the relative magnitude of ambient SO_2 concentrations across an area. In this example, the NDVs are the 3-year average of each year's 4^{th} daily highest 1-hour maximum concentration, which is an equivalent of the 99^{th} percentile of daily 1-hour maximum concentrations. NDVs for this example are shown in Figure 3, along with the 3-year wind rose of the meteorological station used for modeling. In Figure 3:

- Darker colors represent relatively higher concentrations.
- The dominant winds in this area are from the southwest, which is toward the water, where there are no receptors.
- The overall highest normalized design value is denoted by the red circle, which is just west of the source facility.

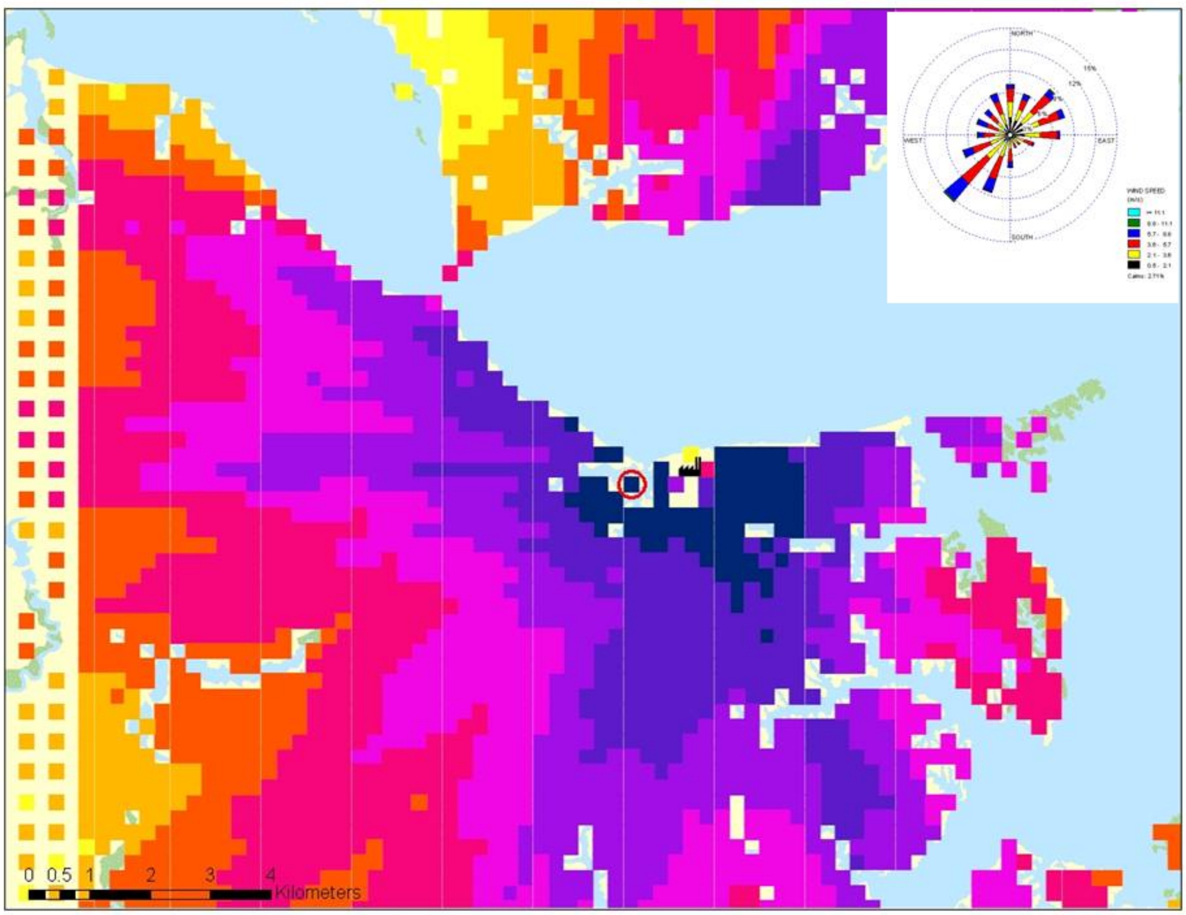

Figure 3. Normalized design values. This figure illustrates the NDV for each modeled receptor. The darker colors indicate relatively higher NDVs. The receptor with the highest overall NDV is circled, and is just west of the SO_2 emission source.

To better understand the relative difference between NDVs across modeled space, Figure 4 shows the ratio of the NDV of each individual receptor to that of the overall maximum NDV.

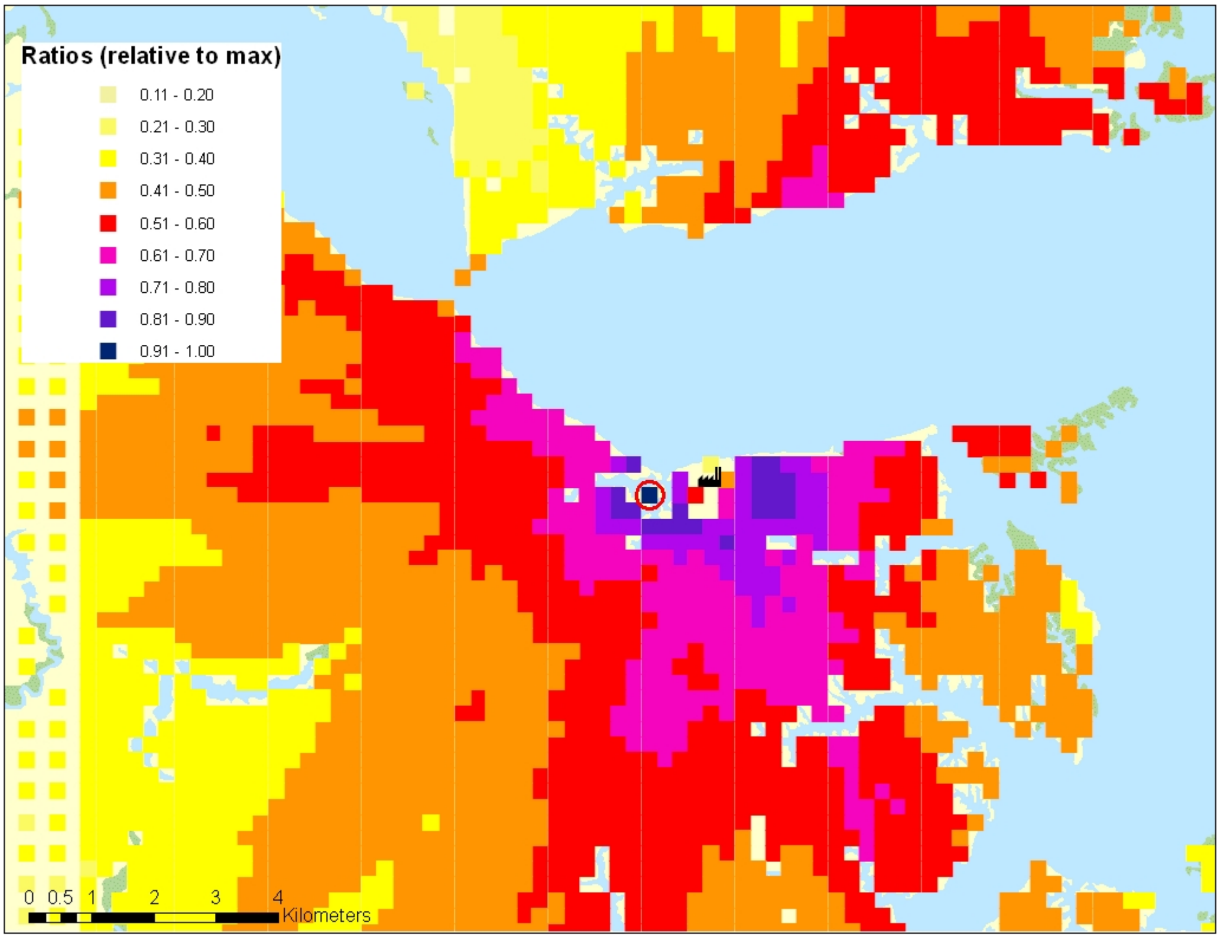

Figure 4. Ratios of individual receptor normalized design values NDVs to the overall maximum NDV. The receptor with the overall maximum NDV is circled in red.

As illustrated in Figures 3 and 4, the receptor with the highest overall NDV is just west of the SO_2 emissions source and is circled. That location, and those receptors denoted by the darkest colors, represents areas where further evaluation for potential monitoring sites should initially be focused. An additional analysis was performed to identify the receptors having the top 200, 100, 25, and 10 NDVs, which is presented in Figure 5.

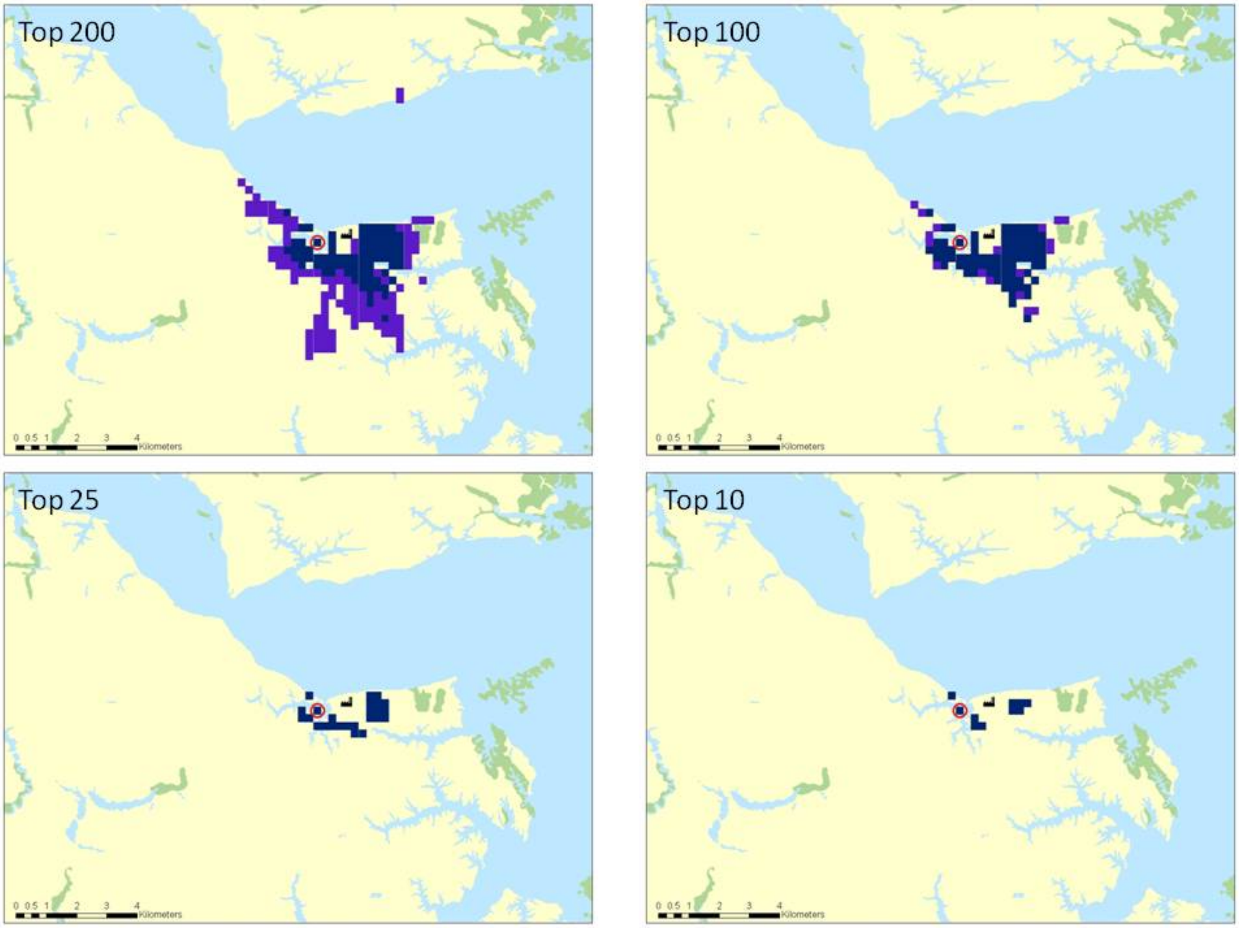

Figure 5. Locations of Top 200, 100, 25, and 10 normalized design values.

The analysis shown in Figure 5 prioritizes the locations that should be evaluated to potentially establish a monitor. In this evaluation, the primary objective is to find a sufficient number of feasible locations with predicted peak and/or relatively high SO_2 concentrations where a permanent monitoring site might be located. However, the site selection process also needs to account for the frequency in which a receptor sees daily maximum concentrations. In order to assess the frequency of occurrence of concentration maxima at a given receptor, an analysis was performed on the top 200 receptors in AERMOD where the MAXDAILY option was used to output the maximum 1-hour concentration for each receptor for each day. This output was used to determine the number of days for which each receptor was the overall highest 1-hour concentration for the day for the 3 modeled years and is presented in Figure 6.

The receptor with the overall highest NDV, circled in Figures 3, 4, and 5, is also the receptor with the most days where it had the highest 1-hour concentration for the day (153 days) and is circled in Figure 6. Therefore, that receptor has the highest NDV and most often has the highest 1-hour concentration of all receptors. The receptors with the next highest frequency of having the daily 1-hour maximum concentrations are just to the east of the SO_2 source and also to the north-northeast, across the river. Those receptors just to the east of the SO_2 source also happen to have relatively high NDV (see Figures 3, 4, and 5). However, the two receptors across the bay which had a relatively high number of 1-hour daily maxima do not have NDVs within the top 100 of all NDVs. As such, while frequently having 1-hour daily maxima, the sites across the river likely do not have relatively high concentrations on those days when they have the 1-hour daily maximum concentration among all receptors.

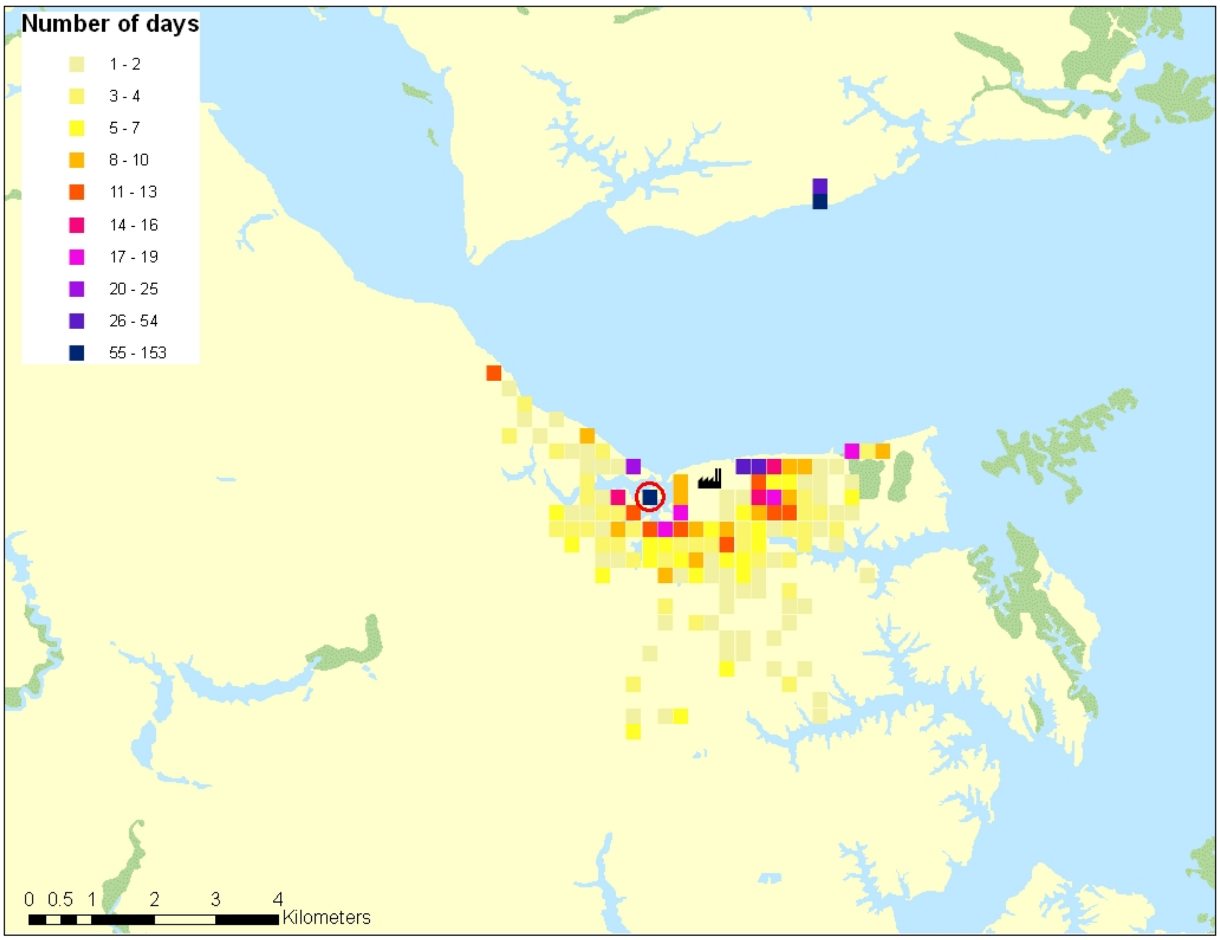

Figure 6. Cumulative number of days that an individual receptor had the 1-hour daily maximum concentration among all receptors. Darker colors indicate an increasing number of days that a receptor had the 1-hour daily maximum concentration.

A.3 <u>Model Conclusions</u>

In this example (and any other case where monitoring is elected to characterize air quality pursuant to the anticipated data requirements rule), at least one monitor would be expected to be sited and operated. The primary target for our example network design would be to first find a location at or very near the receptor having both the highest NDV and frequency of 1-hour daily maxima, which is just west of the SO_2 source. Additional monitors could also be considered in the area on the east side of the facility and possibly across the river to the north. The area to the east of the facility has relatively high NDVs in a different cardinal direction (i.e., a different wind direction) from the SO_2 source compared to the first potential site. The receptor locations on the north side of the river, while not having as high NDVs as areas immediately around the source, do appear to see some plume impacts on a higher frequency. This is not to say that one or both of these possible additional areas to the east and north should or would end up being feasible or otherwise warranted monitoring locations, but typical logistical issues not withstanding (i.e., access, power, safety concerns, etc.), their consideration would be encouraged. The EPA encourages state, local, and tribal air agencies to evaluate potential sites in this way, using the available model predictions, potential for population exposure, and other logistical metrics in laying out a rationale of why a certain number sites should be implemented.

In general, the example analyses presented here provides a potential template for using modeling to inform monitoring site placement. Following this procedure will provide state, local, and tribal air agencies with information to begin evaluating specific areas to determine where SO_2 monitors might be placed to characterize air quality around an SO_2 source. Further, there will be an expectation that due diligence will be carried out to get as close as possible to the location or locations anticipated to have the peak or otherwise highest NDVs available to them. The EPA expects state, local, and tribal air agencies to provide a rationale based on the available data on whether these monitoring sites are appropriate. As noted above in Section 3.1, the EPA recognizes that increasing the number of monitoring sites around a single facility can present resource and logistical burdens. However, the benefits of considering multiple monitor sites include increased spatial representation, increased population exposure coverage, and the potential to increasingly capture and characterize some portion of the emissions from the identified SO_2 source. Even in situations where the measured concentrations at any given monitor are not the peak values that would be driving the design values in the area, the characterization of SO_2 concentrations around the SO_2 source are enhanced, furthering the understanding of exposures and dispersion in that area. These data will allow for a more complete understanding of the likely SO_2 concentration gradients in an area, increased understanding of the frequency at which certain locations see SO_2 concentration maxima, and increased detail and confidence in any NAAQS determination activity.

Appendix B: Detailed Discussion of Pressure Driven Channeling

Pressure driven channeling depends upon the location of proximate atmospheric high and low pressure centers and the direction of winds above the ridge line relative to the orientation of the valley axis. Winds in the free troposphere (i.e., that are above ridge lines and the boundary layer in our case) generally flow along lines of equal pressure. Such winds are referred to as geostrophic winds in meteorological terms. Geostrophic winds result from a balance between the pressure gradient force, which moves air from a high pressure center to a low pressure center, and the Coriolis force, which deflects atmospheric motion (with stronger apparent deflection occurring with increasing speeds and at higher latitudes) to the right in the Northern hemisphere and to the left in the Southern hemisphere. As such, geostrophic winds generally flow along lines of equal pressure with the high pressure center on the right and the low pressure on the left, relative to the air's forward motion.

The in-valley pressure gradient that causes pressure driven channeling is maximized when geostrophic winds (above the ridge line) are blowing perpendicular to the valley axis, and when the air mass is stable or of neutral buoyancy (Whiteman and Doran, 1993; Birdwell, 2011). In this case, with no thermally driven or vertically coupled influences, pressure driven air flow is from the end of the valley nearest the high pressure towards the end of the valley nearer the low pressure center. As geostrophic winds approach the valley axis at increasingly parallel angles, the pressure gradient lessens even though pressure driven channeling still occurs.

Up to this point, we have been using geostrophic wind to help describe how pressure driven channeling works. However, in reality, truly geostrophic winds are not always present, and such wind in the free atmosphere is actually ageostrophic. Other forces acting on air flow such as friction and centrifugal forces can change the actual trajectories of winds in an area making what was geostrophic flow become ageostrophic. When ageostrophic winds are flowing above a ridgeline, there can be cases where pressure driven flows in valleys can be nearly opposite in direction to the winds aloft (sometimes referred to as a counter flow). For example, if a valley axis is oriented north-south, and a high pressure exists to the north and low pressure to the south, geostrophic flow would be easterly (towards the west) and perpendicular to the valley axis, and pressure driven channeling would be strong from north to south. If we changed this example by having an ageostrophic wind which was increasingly veering from easterly to southerly (shifting from being towards the west to be more towards the north), we would develop a counter flow situation, as the pressure driven channeling is still from the high pressure in the north to low pressure in the south, as air is constrained to travel down the axis of the valley.

A further consideration is that valleys are typically not straight, and may have multiple bends, curves, or even split. As such, pressure driven channeling can vary in magnitude along the entire length of a valley and connecting valleys, as the orientation of a valley axis changes from one segment, bend, or curve to the next one with respect to the position of proximate pressure centers and the winds aloft (Kossman and Sturman, 2003). If a valley is segmented, curved, or split, pressure driven channeling within valley segments can lead to areas of convergence or divergence within the valley at inflection points in the valley axis (Birdwell, 2011).

In all cases where pressure driven channeling is present, it will be enhanced when an air mass is stable and there is little or no thermally driven or vertically coupled flow from the winds aloft, which is believed to allow air flows of different trajectories at different heights to move over each other with less exchange in momentum (Monti et al., 2002; Birdwell, 2011).