United States Environmental Protection Agency

Office of Environmental Information
Washington, DC 20460

EPA/240/B-07/001
March 2007

Systematic Planning: A Case Study of Particulate Matter Ambient Air Monitoring

EPA QA/CS-2

Quality

FOREWORD

This document shows the use of the Data Quality Objectives (DQO) Process in the form of a case study involving particulate matter ambient air monitoring. The U.S. Environmental Protection Agency (EPA) has developed the DQO Process for project managers and planners to help them collect the appropriate type, quantity, and quality of data needed to support Agency actions.

Systematic Planning Using the Data Quality Objectives Process: A Case Study of Particulate Matter Ambient Air Monitoring is one of a series of quality management documents that the EPA Quality Staff has prepared to assist users in implementing the Agency-wide Quality System. Other related documents include:

EPA QA/G-4 *Systematic Planning using the Data Quality Objectives Process*

EPA QA/G-5 *Guidance for Quality Assurance Project Plans*

EPA QA/G-9R *Data Quality Assessment: A Reviewer's Guide*

EPA QA/G-9S *Data Quality Assessment: Statistical Methods for Practitioners*

This document provides guidance to EPA program managers and planning teams as well as to the general public as appropriate. It does not impose legally binding requirements and may not apply to a particular situation based on the circumstances. EPA retains the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate.

This case study is one of the *U.S. Environmental Protection Agency Quality System Series* documents. These documents describe the EPA policies and procedures for planning, implementing, and assessing the effectiveness of the Quality System. These documents are updated periodically to incorporate new topics and revisions or refinements to existing procedures. Comments received on this version, will be considered for inclusion in subsequent versions. Please send your comments to:

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PREFACE

Systematic Planning: A Case Study of Particulate Matter Ambient Air Monitoring describes how the Data Quality Objectives (DQO) Process is applied in a decision-making situation. Through a detailed case study, this document shows how systematic planning, and the DQO Process in particular, leads to sound data collection techniques, selection of proper sampling methods, and the ability to analyze the collected data to make necessary decisions. As noted by this case study, systematic planning is conducted by a planning committee whose activities and discussion provide the basis for defining the problem, phrasing study questions to be addressed, and designing a method for obtaining and analyzing information to address these questions.

While this case study focuses primarily on the systematic planning process, it also addresses the implementation stage where data are collected according to an approved QA Project Plan, as well as how the collected data would be assessed relative to their intended use. It explains how the choice of statistical technique for data analysis was made as a result of discussions held between members of the planning committee and a consulting statistician.

The case study is intended for all EPA and extramural organizations that 1) have quality systems based on EPA policies and specifications, 2) may periodically assess these quality systems for compliance to the specifications, or 3) may be assessed by EPA. The use of the DQO Process is consistent with EPA Order 5360.1 A2 (issued May 5, 2000) which calls for the use of systematic planning in the collection of environmental data.

The techniques discussed in this case study are non-mandatory, and the case study is intended to help project managers and staff understand how the DQO Process should be applied in practical situations. The techniques discussed in the case study are appropriate for this particular situation but should not necessarily be used as a template or recommendation for the investigation of similar studies. The techniques discussed in this case study are real, although the location and identifying characteristics of the actual power plant have been obscured to protect its identity.

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LIST OF ACRONYMS USED IN THIS CASE STUDY

AQIA	Ambient Air Quality Impact Assessment
CFR	Code of Federal Regulations
DQA	Data Quality Assessment
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
NAAQS	National Ambient Air Quality Standard
NIST	National Institute of Standards and Technology
PM	Particulate Matter
PM_{10}	Particulate Matter less than 10 microns in diameter
$PM_{2.5}$	Particulate Matter less than 2.5 microns in diameter
PSD	Prevention of Significant Deterioration
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
SOP	Standard Operating Procedure
WINS	Well Impactor Ninety Six

SYSTEMATIC PLANNING: A CASE STUDY OF PARTICULATE MATTER AMBIENT AIR MONITORING

1.0 INTRODUCTION

This case study, *Systematic Planning: A Case Study of Particulate Matter Ambient Air Monitoring*, represents an investigation of ambient air particulate matter concentrations following the installation of upgrades to a large coal-fired power plant. Its purpose is to demonstrate the importance of a systematic planning process in the use of existing data as well as the collection of new data to address an environmental monitoring problem. This case study demonstrates how use of the iterative Data Quality Objectives (DQO) Process can ensure that data to be obtained for such a study will be of sufficient quality and quantity to address the study goal.

The Project Life Cycle consists of three project stages – planning, implementation, and assessment – each of which contains activities and tools that are applied or prepared on individual data collection projects to ensure that project objectives are achieved. These stages and their primary components are illustrated in Figure 1. (A fourth stage, reporting and the improvement process, is often added.) This case study illustrates how systematic planning can be effectively implemented on a project, emphasizing its iterative nature, and how the Project Life Cycle proceeds following its completion.

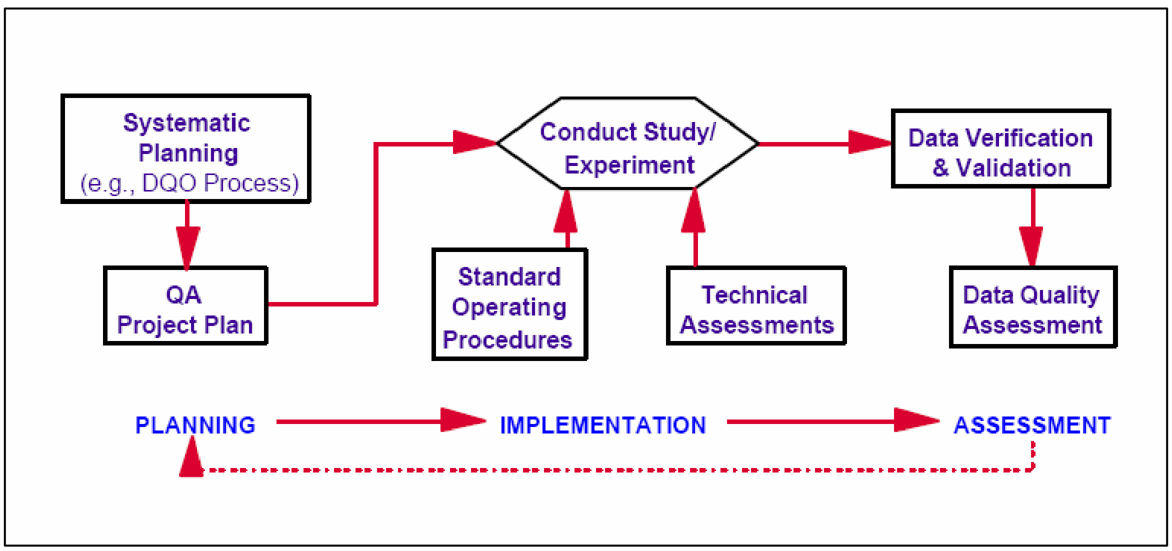

Figure 1. The Project Life Cycle

The monitoring project described in this case study will generate data that must demonstrate a known and appropriate level of quality due to its intended use in supporting conclusions on public health risk. Thus, the systematic planning process will adhere to EPA's Information Quality Guidelines (as detailed in *Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by the Environmental Protection Agency* (U.S. EPA 2002a) in ensuring that the data to be collected will meet basic quality standards on objectivity, utility, and integrity. The systematic planning process also allows for collected environmental information to achieve the following General Assessment

Factors, which EPA's Science Policy Council published in *A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information* (U.S. EPA 2003):

- Soundness: The extent to which the scientific and technical procedures, measures, methods, or models employed to generate the information are reasonable for, and consistent with, the intended application.
- Applicability and Utility: The extent to which the information is relevant for the intended use.
- Clarity and Completeness: The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations and analyses employed to generate the information are documented.
- Uncertainty and Variability: The extent to which the variability and uncertainty (quantitative and qualitative) in the information or the procedures, measures, methods, or models are evaluated and characterized.
- Evaluation and Review: The extent of independent verification, validation, and peer review of the information or of the procedures, measures, methods, or models.

This case study illustrates application of systematic planning using the DQO Process for a specific project.

1.1 Case Study Background

A large coal-fired power plant located just southwest of the small Midwestern city of Emmerton planned to expand its generating capacity by installing a new boiler. When this expansion was announced, the ambient air quality in Emmerton was considered to be in attainment with the 24-hour National Ambient Air Quality Standard (NAAQS) for particulate matter less than ten microns in diameter (PM_{10}). Therefore, the power plant owners, *A&B Inc.*, were required to obtain a *Prevention of Significant Deterioration (PSD) permit* from the State EPA before initiating the expansion.

A&B Inc. proposed that the power plant's expansion would increase the plant's coal combustion rate. Therefore, the expansion also included a new add-on pollution control device for reducing the plant's sulfur oxide and nitrogen oxide emissions. Nevertheless, the expansion still had the potential to yield a significant net emission increase of PM_{10} levels in Emmerton. For this reason, and as dictated by PSD regulations, *A&B Inc.* monitored pollutant levels that had the potential to increase in ambient air as a result of the expansion (including PM_{10}), and collected meteorological data, for a period of 12 months prior to submitting the PSD permit application (i.e., *pre-construction* monitoring).

The NAAQS primary 24-hour PM_{10} standard is 150 $\mu g/m^3$, and the allowable *PSD increment*, or the maximum amount that the ambient PM_{10} concentration could increase from the expansion without resulting in significant deterioration of air quality, was determined to be 15 $\mu g/m^3$. For its PSD permit application, *A&B Inc.* conducted an *ambient air quality impact assessment (AQIA)* to demonstrate that allowable emission increases following the proposed upgrade would not cause or contribute to violations of the NAAQS or the PSD increment. The AQIA used the pre-construction monitoring data and an applicable air quality dispersion model (specified in US EPA's Guideline on Air Quality Models) to calculate the *post-construction* ambient PM_{10} concentration, or the expected average concentration that would occur following the proposed expansion.

Based on the pre-construction monitoring data, the estimated average 24-hour pre-construction ambient PM_{10} concentration was 80 $\mu g/m^3$. The air quality dispersion model calculated that average 24-hour ambient PM_{10} concentration would increase by 9 $\mu g/m^3$ following the expansion. Therefore, the AQIA estimated a post-construction average ambient air concentration of 89 $\mu g/m^3$. Because this average concentration was less than the NAAQS PM_{10} standard (150 $\mu g/m^3$), and the size of the expected average increase (9 $\mu g/m^3$) was less than the allowable PSD increment (15 $\mu g/m^3$), the State EPA continued processing *A&B Inc.'s* PSD permit application and published a draft permit approval action for public comment. The draft permit received by the plant specifies allowable emission rates (e.g., lbs/hour) for each emission source within the facility that would be affected by the expansion. The draft permit requires that the plant demonstrate adherence to these rates through stack testing, but does not require the plant to conduct post-construction ambient air monitoring to confirm conformance with the NAAQS and the allowable PSD increment. Although the permit does not specify the PSD increment nor the NAAQS for ambient air, it is implied that compliance with these ambient air standards will occur if the plant achieves the permitted emission rates.

During the public comment period for the draft permit approval action, an environmental citizens' group voiced concern to the State EPA regarding the planned upgrades to the power plant. The group was concerned that the results of dispersion modeling were not sufficiently accurate to be able to state with high confidence that the health of Emmerton's citizens would be protected following the upgrades. This would imply that the PSD provisions on performing an acceptable AQIA, which would demonstrate that allowable post-upgrade emission increases would not cause or contribute to violations of the NAAQS or the PSD increment, were not satisfied. The health concern was elevated by the U.S. EPA's recent revisions to its NAAQS for particulate matter (*Code of Federal Regulations, 40 [CFR] Part 50*) that would apply to particles from industrial sources. As the proposed NAAQS revisions were based on the U.S. EPA's review of the scientific literature relating to the health risks associated with exposure to particulate matter pollution, the citizens' group was particularly concerned that the power plant upgrades would put Emmerton's more vulnerable citizens, including the elderly and asthmatic children, at risk for respiratory health effects. The citizens' group urged that *A&B Inc.* should be required by its PSD permit to conduct post-construction monitoring of PM_{10} to:

- Assist in determining the impact of the plant upgrades on local air quality,
- Verify that the area in which Emmerton is located will remain in attainment for PM_{10} NAAQS upon *A&B Inc.'s* implementation of the upgrades and that the allowable increment will not be exceeded, and
- Verify the accuracy and correctness of the assumptions and methods applied in the plant's AQIA.

Upon learning of the concerns raised by the citizens' group, *A&B Inc.* agreed that once the facility expansion was completed and brought online, they would continue monitoring PM_{10}

concentrations to demonstrate that ambient air levels remained within acceptable levels following the expansion. They agreed to organize a planning committee to develop a post-construction monitoring program. The draft PSD permit was subsequently approved.

1.2 Site History and Description

During coal combustion, a number of gaseous pollutants (sulfur oxides, nitrogen oxides, and others) are produced. In addition to gaseous pollutants, fly ash (soot) particulate emissions are generated. Coal-fired power plants utilize filters and electrostatic precipitators to trap particles produced during coal combustion with good efficiency. However, those particles that are not retained at the power plant are emitted to the air and, when in sufficient concentration, can lead to reduced visibility and a potential human health risk. Secondary particulate matter can also be formed in power plant plumes from the reactions of sulfur and nitrogen oxides in the atmosphere to produce aerosol particles, made of sulfur and nitrate salts.

A&B Inc.'s power plant is located approximately 10 miles southwest of Emmerton's city limits. *A&B Inc.* conducted pre-construction PM_{10} monitoring just south of Emmerton according to EPA's *Reference Method for Determination of Particulate Matter as* PM_{10} *in the Atmosphere* (40 CFR Part 50, Appendix M), and the sampling location was determined according to guidelines established in EPA's *Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)* (U.S. EPA1987). For pre-construction monitoring, *A&B Inc.* arranged to locate the monitoring equipment on the grounds of a nearby private golf course. Given the historical predominant wind direction in Emmerton (southwest), any emissions by the power plant would be expected to impact ambient air quality at this location. The location also had the logistical features (e.g., shelter, power, easy access for operators) needed to perform the pre-construction monitoring of PM_{10} and meteorological parameters.

2.0 PRELIMINARY ACTIVITIES PRIOR TO FIRST MEETING

As the first step in designing its post-construction monitoring effort, *A&B Inc.* determined that it would utilize EPA's systematic planning seven-step DQO Process (Figure 2) to produce a cost effective monitoring design that fully addressed the public concerns. *A&B Inc.* decided to form a planning committee and charged it with implementing the DQO Process. Information on the practical implementation of the DQO Process was obtained from *Systematic Planning: A Case Study for Hazardous Waste Site Investigations* (EPA QA/CS-1)

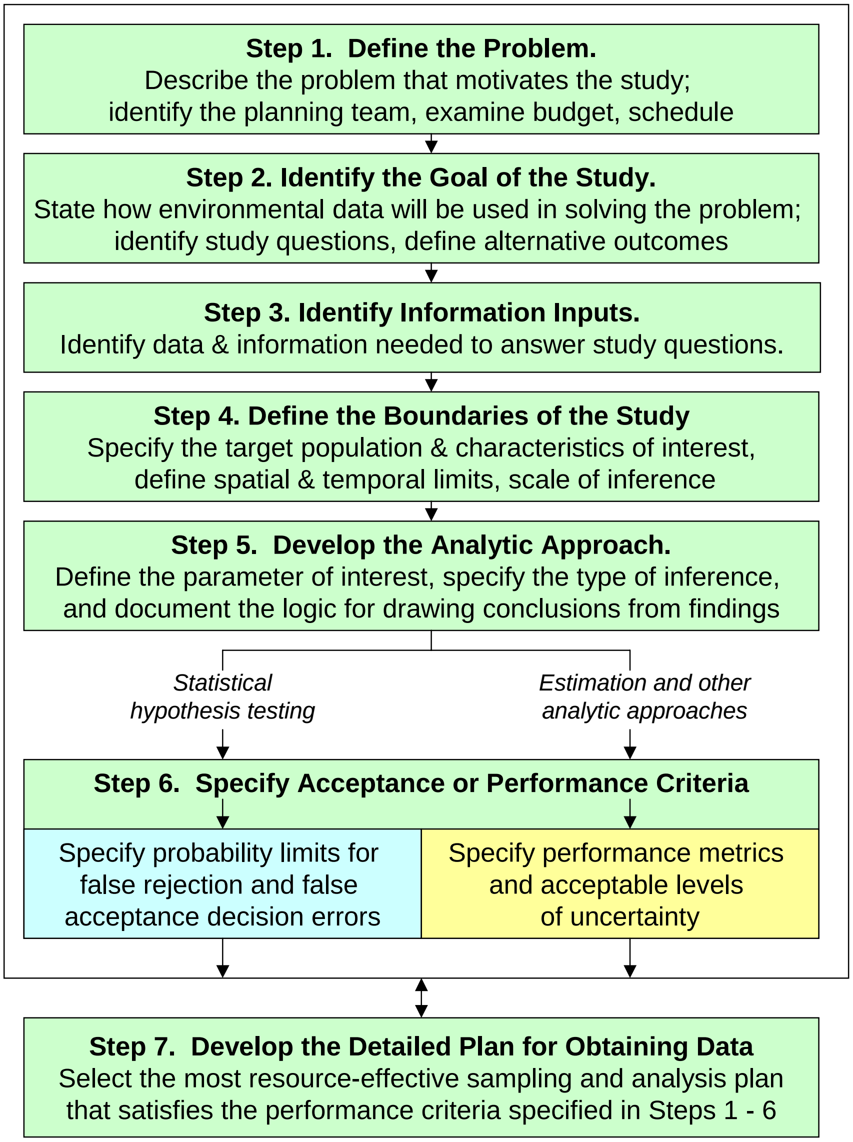

Figure 2. The Data Quality Objectives (DQO) Process

The chief environmental engineer for the Emmerton plant was assigned the duty of identifying and recruiting members of the planning committee and chairing the committee meetings. Along with getting the commitment of committee members to participate, he conducted several preparatory steps prior to the first meeting. He also identified other stakeholders who might have an interest in the work of the planning committee and would be either available for consultation or routinely updated on the committee's progress. *A&B Inc.* hired an environmental consulting firm to provide technical expertise in designing and executing the monitoring program and to prepare review documents.

The following sections review the types of preparations that the plant's chief environmental engineer made for the planning committee's initial meeting. These activities contribute toward Step 1 of the DQO Process.

2.1 Preliminary Documentation

The chief environmental engineer for the Emmerton plant prepared a packet of preliminary documentation that was mailed to each member of the planning committee to review prior to the first meeting. This packet included:

- A brief owner-supplied background narrative on the history of the plant, the need for plant upgrades, the types of upgrades that were planned, and the expected impact of these upgrades on emission sources;
- A conceptual model (including exposure scenarios) of particulate matter in ambient air within the vicinity of Emmerton that is associated with plant emissions;
- Selected information gathered in the process of obtaining and holding the PSD permit for construction (including an overview of the types of pre-construction ambient air data collected and the results of air dispersion modeling);
- The State EPA's published PSD permit approval action;
- A summary of written comments received during the public comment period in response to the State EPA's permit approval action (including those submitted by the environmental citizens' group);
- A draft narrative describing the purpose and goals of the monitoring study;
- An overview of the DQO Process; and
- A draft of the problem statement, which the chief environmental engineer prepared under Step 1 of the DQO Process. This statement read as follows:

  A&B Inc. recently expanded its coal-burning power plant near the town of Emmerton to better meet the needs of its customers. The plant received a PSD permit from the State EPA that specified allowable emission rates following expansion. As the expansion would increase the plant's coal combustion rate, several members of the general public raised the concern about the lack of post-construction monitoring in the permit process that could confirm whether the plant continued to operate within the limits on PM_{10} emissions established in the permit. Thus, it is necessary to address this concern by verifying particulate matter concentrations through post-construction emissions monitoring.

2.2 Identification of Key Participants

A&B Inc. hired a consulting firm to conduct the study and designated one of its experts in air particulate matter monitoring to be the principal investigator. The chief environmental engineer determined that the planning committee should also include a regulator from the district office of the State EPA who was knowledgeable in air quality regulations, and a member of the environmental citizens' group whose concerns led to performing the study. The citizens' group selected the leader of a local environmental organization to be its representative on the committee. In addition, the consulting firm would provide an individual to take notes at each meeting. Thus, the planning committee tasked to conduct the DQO Process consisted of the following:

- *A&B Inc.*'s chief environmental engineer (committee chair);
- The study's principal investigator (an employee of the environmental consulting firm);
- A regulator from the district office of the State EPA;
- A local environmental organization leader, representing the environmental citizens' group.

The chair and principal investigator were also given the freedom to bring other members of their organizations to participate in meetings as needed, such as a statistician, field sampling technician, quality assurance specialist, and meteorologist.

2.3 Identification of Other Interested Parties

In addition to determining membership on the planning committee, the study's principal investigator suggested that a list of potential stakeholders and other interested parties be identified prior to initiation of the planning committee meetings. These stakeholders would not be involved in the meetings to develop DQOs, but they would be given the opportunity to review and comment on the final study plan. The organizations identified as potential stakeholders and interested parties included:

- Emmerton public officials (mayor and town council), as well as officials from several neighboring towns that are downwind of the power plant;
- County health department officials (to coordinate communication with the public from a health perspective);
- Members of the Emmerton Senior Citizens' Organization; and
- Health or environment reporters from Emmerton's newspaper and from media in neighboring cities.

2.4 Schedule of Meetings

Based on the principal investigator's past experience in implementing the DQO Process on similar studies, it was expected that the planning committee would have to meet three or four times to plan the study, with the meetings to be held in a conference room at the Emmerton power plant. The committee chair cleared the date for the first meeting with each of the committee's members and provided the following agenda to the members for the first meeting:

1:00 Introduction of committee members
1:15 Background Material for Study
1:45 DQO Step 1: Define the Problem
2:30 DQO Step 2: Identify the Goals of the Study
3:15 Break
3:30 DQO Step 3: Identify Information Inputs
4:00 DQO Step 4: Define the Boundaries of the Study
4:30 Review of progress
4:45 Identify needs for next meeting
5:00 Adjourn

In providing the preliminary documentation packet to the planning committee members, the chair of the committee suggested that the members be prepared to share their own ideas on study goals and important issues that the committee should consider within this first meeting.

3.0 FIRST MEETING OF PLANNING COMMITTEE

The first meeting of the planning committee for the post-construction PM_{10} monitoring study of the Emmerton power plant focused on initial execution of the first four steps of the DQO Process (Figure 2):

Step 1: Define the Problem
Step 2: Identify the Goal of the Study
Step 3: Identify Information Inputs
Step 4: Define the Boundaries of the Study

The following sections document the discussions that were held in this first meeting and the outputs from each of these four steps.

3.1 Step 1: Define the Problem

The primary focus of Step 1 is to assemble the planning committee, to prepare a problem statement, and to examine available resources for investigating this problem.

The committee chair was able to begin work under Step 1 prior to the first committee meeting. For instance, he compiled the list of planning team members and identified roles for each member, including who would be making certain types of decisions. He also prepared drafts of a conceptual model of particulate matter in ambient air within the vicinity of the plant and of a draft problem statement associated with the monitoring program (Section 2.1) and included them with the preliminary documentation given to the committee members for their review before the first meeting. Therefore, discussion on Step 1 focused on agreeing on a problem statement among the members, determining the scope of the study, and determining initial information on the program's potential cost, duration, and technical needs. This discussion featured the following:

- As the plant's chief environmental engineer, the committee chair presented the budget allocated to the study by the plant's owner: $250,000.

- The principal investigator provided information on line-item costs associated with conducting a monitoring study, including samplers, sample filters, sample collection, laboratory analysis, and data analysis. While she was prepared to discuss various monitoring options depending on the direction the committee was willing to take, her presentation focused on stack testing to address the committee chair's initial draft problem statement on measuring post-construction emissions (Section 2.1). The principal investigator pointed out that stack testing would be less costly for the plant to perform compared to other types of sampling, thereby allowing them to collect additional data.

- The citizens' group representative asked whether it was possible to expand the study beyond measuring particulate matter to also measuring other toxic chemicals that may exist within the power plant's exhaust. Others argued that this was beyond the scope of what *A&B Inc.* had originally agreed to do and would require an additional commitment of resources (including cost) from the company.

- On the basis of the discussions held, the committee chair decided to proceed to Step 2 of the DQO Process with the originally proposed problem statement (Section 2.1), after supplementing it with the following statement:

  The study is to involve stack testing that would be conducted over a one year period within a total budget of $250,000.

3.2 Step 2: Identify the Goal of the Study

In Step 2, the committee uses the problem statement to identify a principal study question and a statement of the study goals, and then considers potential alternative actions that may be made upon answering this question and their implications. This leads to making either a decision statement or an estimation statement, whichever is relevant to the particular problem.

To initiate Step 2 of the DQO Process, the committee chair proposed the following as the principal study question:

Using the results of stack testing as input to an air dispersion model, are post-construction ambient PM levels projected to be higher than the values that are calculated by the air dispersion model under the allowable PM emission rates?

As this and other follow-up study questions and study goals began to be discussed, a couple of committee members began raising questions on whether stack testing would really be addressing what citizens wished to learn from the collected data: that whether post-construction ambient air levels in the vicinity of the power plant (where most of Emmerton's citizens lived) were not appreciably different from pre-construction levels, and in particular, were within the standards set to protect public health. This led to a debate, led by the environmental citizens' group representative, on whether the committee was, in fact, addressing the right question. After all, the plant's requirement to collect pre-construction ambient air samples yielded concentration data against which post-construction levels could be compared. It soon became evident that performing stack testing to verify that the emission rate limits specified in the PSD permit were being achieved was not sufficient to fully address citizens' concerns that levels in ambient air had been negatively affected. Thus, the committee decided that it needed to go back to Step 1 of the DQO Process to redefine the problem they were trying to address.

3.3 Step 1 Revision: Define the Problem

The committee determined that the post-construction monitoring program needed to perform ambient air monitoring, similar to (and perhaps at the same location from) the pre-construction ambient air monitoring that the plant performed as part of its PSD permit application. Therefore, they asked the principal investigator to resume her presentation on costs associated with conducting a monitoring study, but she should now focus on the information she prepared relating to ambient air monitoring. For example, she addressed the ramifications of using fixed versus mobile ambient air samplers on the study costs, as well as how costs associated with sample filters, sample collection, laboratory analysis, and data analysis for ambient air sampling may change from the stack testing approach. Her presentation implied that under a $250,000 budget, several hundred ambient air samples could be collected using the same sampler that was used to collect pre-construction ambient air samples, allowing the study to extend longer than one year if necessary. If a new sampler were purchased and used, the number of samples that could be collected within the available budget would be reduced to roughly 150.

In the ensuing discussion, the committee realized that the amount of time spent to collect a fixed number of samples, whether it is one or two years, would have a somewhat minimal effect on overall study costs. Rather, costs would be dominated most heavily by the number of samples and number and location of samplers. While most group members preferred to limit the monitoring effort to one year, the citizens' group representative lobbied to extend the study for more than one year, as a one-year study would not be able to account for annual variation in weather. While the committee agreed that a two-year sampling program could address some of that concern, extending the sampling to two full years would likely not be acceptable to stakeholders and others in the general public who were anxiously awaiting the outcome of the monitoring study. The committee chair also noted that *A&B Inc.* still had an agreement in place with the golf course that served as the location for pre-construction monitoring, allowing them to use the same location for post-construction ambient air sampling, but the agreement would need to be extended if the study were to extend for two years. There was also discussion about whether meteorological variability that occurs within a single year would be a sufficient surrogate for year-to-year variation, although no conclusion in that regard was reached.

Given the discussion and the principal investigator's presentation, the planning committee worked together to revise the problem statement, in order to have it centered on performing ambient air monitoring rather than stack testing, and giving some flexibility to extend sampling to beyond a year if necessary. The result, agreeable to all on the committee, was the following:

> *A&B Inc recently expanded its coal-burning power plant near the town of Emmerton to better meet the needs of its customers. The plant received a PSD permit from the State EPA prior to construction. As the expansion would increase the plant's coal combustion rate, several members of the general public raised the concern about the lack of post-construction monitoring in the permit process that could confirm whether the increase in actual PM_{10} emissions from the expanded operation would result in unhealthy ambient concentrations. Thus, it is necessary to address this concern by verifying particulate matter concentrations through post-construction monitoring. The study is to be conducted in one year, if possible, extending to no more than two years, and within a total budget of $250,000.*

Before moving on to Step 2, the committee chair initiated a brief discussion on whether additional expertise needed to be represented on the committee in order to complete the DQO Process. The study's principal investigator noted that her consulting firm employed experts in air sample collection and handling, air transport modelers, and statisticians to provide assistance in addressing areas where their expertise was needed. They would be called upon to provide background reference material and participate in discussions when needed.

3.4 <u>Step 2 Revision</u>: Identify the Goal of the Study

Working with the revised problem statement, the committee members prepared a list of specific questions that the study should be designed to answer. Two initial questions that members suggested were the following:

- Are ambient PM levels higher than those considered safe by EPA?
- Are ambient PM levels higher after construction than before construction?

This led to drafting the following primary study question:

- Can it be verified that the allowable emissions from the power plant's upgrades result in post-construction ambient particulate matter concentrations that are within acceptable levels?

After further discussion, however, the statement "*within acceptable levels*" was considered too vague. The committee made this question more specific and unanimously adopted it as the primary study question:

Can it be verified that the allowable emissions from the power plant's upgrades result in post-construction ambient particulate matter concentrations that are within regulatory levels defined as protective of human health?

Considering the possible answers to this question, the committee identified the possible alternative actions that could be taken based on the findings of this study:

- If the answer to this question is "Yes", then the study would conclude that PM levels are within safe levels (as represented by the allowable PSD increment and the NAAQS). This result would be reported to public health officials, other stakeholders, and the general public through a press release to the local media.

- If the answer to this question is "No", then the study would conclude that the air dispersion modeling, which was used in the permit application process to estimate the impact that the upgrades may have on ambient air quality based upon the allowable particulate matter emission rates, was not sufficiently accurate to ensure with high confidence that the health of the citizens of Emmerton would be protected. The results would be forwarded to the State EPA for further review, and they would determine an appropriate course of action.

The problem statement and study questions led the committee to establish the following primary study goal:

Determine whether levels of particulate matter (PM) in post-construction ambient air samples are considered hazardous to the health of the population of Emmerton and its surroundings, and therefore, require the plant owner to take additional action to reduce emissions of particulate matter from the plant. Specific questions to be addressed are

- *Are ambient PM concentrations greater than levels defined by the U.S. EPA (through NAAQS standards) and the State EPA as being "safe" (i.e., protective of human health)?*
- *Are ambient PM levels measured after construction higher than those measured before construction, as well as what was expected by dispersion modeling?*

PM concentrations in air samples will be collected once the upgrade is brought online, and these concentrations will provide the scientific information that is necessary to answer these questions.

Before the committee chair could move to Step 3 of the DQO Process, the principal investigator and State EPA regulator noted that simply having the study questions and the study goal refer to "particulate matter" in ambient air was too vague. A discussion ensued as to whether only fine particular matter less than 2.5 microns in diameter ($PM_{2.5}$) should be measured, versus PM_{10} (i.e., total particulate matter less than 10 microns in diameter). The citizens' group representative suggested that the type of particular matter known to have the greater link to adverse health effects should be measured. The principal investigator noted that permit levels were expressed relative to PM_{10}, which includes $PM_{2.5}$, and there is evidence from several studies of a link between PM_{10} and various respiratory problems in sensitive subpopulations. Thus, the committee decided that the study should focus on measuring PM_{10}, and therefore, references to "PM" in the above study questions and the study goal were revised to "PM_{10}".

3.5 Step 3: Identify Information Inputs

Given the study goals and questions prepared under Step 2, the committee now begins to identify the different types of information that are needed to answer these questions and whether appropriate sampling and analytical methods are available to obtain this information.

Based on the decision to focus ambient air monitoring on measuring PM_{10} levels, the committee identified the following necessary information inputs:

- To determine whether PM_{10} concentrations are greater than "safe" levels, action levels specified as "safe" by the U.S. EPA and State EPA would be needed. The study's principal investigator noted that the NAAQS 24-hour standard of 150 $\mu g/m^3$ for PM_{10} is the appropriate standard to adopt as the action level, because it represents a level set by the U.S. EPA to provide protection of public health. The State EPA regulator noted that the state has accepted this national level.

- To determine if PM_{10} levels are higher after construction than before construction, it would be necessary to obtain PM_{10} concentration data collected before the construction. These data were collected as required by the PSD permit and are maintained by the plant's owner. Therefore, the plant's chief environmental engineer agreed to provide the environmental consulting firm with the pre-construction monitoring data.

- Post-construction PM_{10} concentration data obviously do not exist, and therefore, would need to be newly collected under this study. The committee decided that the study will follow the U.S. EPA requirements for monitoring of PM_{10} concentrations (*40 CFR Part 58*). The principal investigator was charged with reviewing these requirements and providing the committee with recommendations for sampling and analysis approaches at the next meeting.

- A discussion was held among committee members on the need for generating and interpreting predictions from air transport models, because modeling had been used within the AIQA to generate allowable emission levels. If such prediction data were needed, there would be an implicit need to collect meteorological data for use as input to the model. The committee concluded that computer modeling would not be needed to generate information to address the study goals and questions.

- The committee discussed the extent to which measured PM_{10} ambient concentrations could possibly be affected by emissions from other sources in the area. The principal investigator noted that pre-construction monitoring data were used as input to the modeling that evaluated allowable PM_{10} emission rates for the plant's upgrades. Any contributing sources to ambient PM_{10} levels would be assumed to impact both pre- and post-construction levels. Therefore, expected effects associated with the plant's permit levels, which were assessed based on pre-construction ambient air levels and the allowable emission rates associated with the upgrades, would already have been adjusted for other PM_{10} sources. Thus, any observed increases in PM_{10} concentrations at the sampling location (i.e., the golf course site) should be the exclusive result of the plant's modification. It was suggested, however, that meteorological data would assist in the analysis and interpretation of the PM_{10} concentration data should any questions arise about the source of PM_{10} present in ambient air at the monitoring site.

3.6 Step 4: Define the Boundaries of the Study

In addressing Step 4, the committee addresses how the target population should be defined, along with determining the geographic (spatial) and temporal boundaries associated with the population, and whether any practical constraints exist to collecting data.

- The committee began by discussing the consequences of using only the single sampler that the plant used in pre-construction monitoring. Using this sampler for the post-construction monitoring would facilitate the interpretation of comparisons between pre- and post-construction measurements. However, committee members noted that a single sampler provides limited spatial coverage and questioned how the representativeness of the site to other locations in Emmerton would be assessed. In response, the principal investigator noted that variations in wind direction will occur at the fixed location, which would simulate greater spatial coverage. Also, the committee reviewed the plan and results from the pre-construction monitoring analysis distributed by the committee chair, which included the State's detailed assessment of the representativeness of the single site for that analysis. Based on this information, the committee members tentatively agreed to the use of a single sampler, pending further consideration of the benefits and limitations of using a fixed-location sampler versus a mobile sampler.

- The committee defined the target population to consist of all possible air samples that could be collected from the sampler's location (at the nearby golf course) during the period of time that the post-construction monitoring study will cover.

- The committee specified in the problem statement that the study should be completed in less than two years, and within a budget not exceeding $250,000. The principal investigator will determine how this budget should be divided among several tasks within the study, such as project management, planning, field sampling, laboratory analysis, and data analysis.

- Some committee members raised questions about whether the quality of the pre-construction sampling data would be sufficient to allow comparisons to be made to post-construction. The plant's chief environmental engineer (committee chair) will investigate the quality criteria that were placed on the pre-construction data and the extent to which these criteria were achieved, and will share this information with the committee in the next meeting

The output prepared under Step 4 in this first meeting was as follows:

The target population consists of all possible samples that might be collected during post-construction from the sampling location used for the pre-construction monitoring. The spatial boundaries of the study consist of the single location, which represents all points the same distance from the source within the cone defined by the prevailing winds. The temporal boundaries of the study are from the end of construction until the end of the post-construction monitoring program.

3.7 Identifying Information Needed for Subsequent Steps

Prior to adjourning the first meeting, the committee chair set a date for the second meeting that would work in the schedule of all members of the committee. The chair then listed a series of action items for committee members that will provide additional important information for use in the next meeting. These action items were as follows:

- The principal investigator will explore alternative sampling and analysis methods for use in the post-construction monitoring study.

- In order to better determine whether a mobile sampler would be feasible to consider as an alternative to a fixed-location sampler, the principal investigator will provide some initial estimates for the number of samples that could be collected within a budget of $250,000, first assuming a single fixed sampler is used, and then assuming a mobile sampler is used.

- Steps 6 and 7 of the DQO Process will require some expertise in statistical sampling design. Thus, upon request by the committee chair, the principal investigator will arrange to have a statistician assigned to the planning activities. This statistician will review the outcome of the first meeting and will plan to participate in the second meeting.

- The State EPA representative will provide additional information on regulatory guidelines concerning PM_{10}.

- The plant's chief environmental engineer (committee chair) will provide information (e.g., quality criteria, summary) on the pre-construction monitoring data.

- The committee chair, with the assistance of the principal investigator's firm, will compile notes of the first meeting and propose an agenda for the second meeting within seven days of the first meeting. Each committee member will review the notes for accuracy.

4.0 INTERIM ASSIGNMENTS PRIOR TO THE SECOND MEETING

The action items resulting from the first meeting (Section 3.7) required certain committee members to do some additional research work and to gather information that all members would review and discuss in the second meeting. For example, minutes of the first meeting would be prepared, distributed, and reviewed prior to the second meeting. Other assignments given to specific committee members and performed before the start of the second meeting are discussed in the following sections.

4.1 Reviewing Sampling and Analysis Methods

The principal investigator was asked to review the PM_{10} sampling and analysis methods used for pre-construction monitoring and to determine if post-construction monitoring should involve the same or a different method. Ambient air monitoring requirements for criteria pollutants, including PM_{10}, are available in *40 CFR Part 58*; the method provides for the measurement of the mass concentration of PM_{10}. Particles are inertially size-selected by a specially shaped inlet and collected on a filter over the 24-hour sampling period. The filter is weighed, and the net mass gain due to the collected PM is used to calculate the PM_{10} concentration. The filters could then be saved for subsequent physical or chemical analysis. The committee had already agreed that it would be appropriate to follow the methods and requirements that *A&B Inc*. used for the pre-construction monitoring.

4.2 Determining Numbers of Samples for a Fixed Cost, Considering a Fixed Sampler Versus a Mobile Sampler

The principal investigator was also asked to provide initial estimates of the number of samples that could be collected for a cost of $250,000 under two scenarios:

- Using the sampler that collected pre-construction monitoring samples, at the same (fixed) location as in the pre-construction monitoring; and
- Using a mobile air sampler.

Upon gathering information on laboratory analysis costs, equipment costs, and operating costs, she concluded that for a fixed cost of $250,000, approximately 500 samples could be collected using the fixed sampler, and approximately 100 samples could be collected using the mobile sampler. The number of samples is lower for the mobile sampler due to the cost required to obtain the sampler and the higher operational cost associated with moving the sampler.

4.3 Investigating Use of Existing Data

The plant's chief environmental engineer was asked to provide a summary of the pre-construction PM_{10} data that *A&B Inc.* collected during the permitting process. He gathered this information from the data summaries that were included in the permitting report that *A&B Inc.* supplied to EPA in support of the plant upgrade. These summaries included:

- the starting and ending sampling dates;
- the number of samples collected during that period;
- the minimum, maximum, median, and mean PM_{10} concentrations;
- the standard deviation of the PM_{10} concentrations; and
- a plot of the PM_{10} concentrations over time that shows trends and any unusual measurements.

In addition, the chief environmental engineer was asked to provide information on the quality assessment of the pre-construction data and its analysis, including all quality assurance requirements and summaries. The committee members would use this information to determine whether the pre-construction data were of sufficient quality to warrant the data's use in the post-construction investigation. Also, in his capacity as committee chair, the chief environmental engineer considered an initial list of possible alternatives to propose to the committee if the quality assessment led the committee to conclude that the pre-construction data should not be accepted for use in this investigation.

4.4 Identifying Regulatory Guidelines

The regulator from the State EPA was asked to provide details on State regulations concerning PM_{10}. He worked with staff in his office to obtain information on the State Implementation Plan for PM_{10} and found that it was in agreement with the national regulatory standard promulgated by the U.S. EPA.

5.0 SECOND MEETING OF PLANNING COMMITTEE

The second meeting of the planning committee was held about two weeks after the first meeting. The first item on the agenda was to review and refine the outcome of Steps 1 through 4 of the DQO Process (as determined from the first meeting). Then, the agenda featured initial discussion on Steps 5 through 7 (Figure 2):

Step 5: Develop the analytic approach
Step 6: Specify acceptance or performance criteria
Step 7: Develop the detailed plan for obtaining data

The participants of the second meeting included all of the original planning committee members, along with a statistician from the principal investigator's environmental consulting firm who had reviewed the committee's work to date and was prepared to address statistical-related issues that were expected to be encountered in Steps 6 and 7.

5.1 Discussion of the Findings of Interim Assignments

The first item on the agenda of the second meeting was to review the findings of the interim assignments made in the first meeting. This was done by revisiting each of Steps 2 through 4 of the DQO Process to determine if the additional information should lead to making revisions or more specifics to the outcome of these steps. The following subsections highlight the discussions and outcome of this review.

5.1.1 Step 2 Revision: Identify the Goal of the Study

- The State EPA regulator proposed that there should be less of an emphasis on comparing post-construction PM_{10} concentrations, to be collected in this new study, with the existing pre-construction monitoring levels. Rather, the study should focus on determining whether post-construction levels were below a specified level, such as a health-based level. Upon further consideration and discussion, the committee agreed to this change in focus.

- A follow-on discussion addressed whether the primary interest should be 1) verifying that post-construction PM_{10} concentrations meet health-based levels, or 2) the level implied by the permit (i.e., the PSD increment) was not exceeded. The State EPA regulator noted that the PSD increment was lower (i.e., more stringent) than the NAAQS. The citizens' group representative thus argued for considering the PSD increment as the threshold to which post-construction PM_{10} concentrations would be compared. However, the remainder of the committee argued that ambient air samples should be collected assuming comparison to PSD.

- The specific PM_{10} measurement techniques had not been specified in the first meeting. The principal investigator suggested that 24-hour ambient air samples should be collected and analyzed, because the NAAQS assumes a 24-hour sampling period. This would result in daily average PM_{10} concentrations being measured and reported from post-construction monitoring. The committee was in agreement.

Based on these discussions, the committee chair proposed the following revision to the primary goals statement, which was approved by the committee:

Determine whether levels of particulate matter (PM_{10}) in 24-hour post-construction ambient air samples exceed the levels dictated by PSD regulations and used to establish emission limits in the permit, and therefore, require the plant owner to take additional action to determine if the emissions of particulate matter from the plant are contributing to a violation of the NAAQS in ambient air. The specific question to be addressed is:

- *Are PM_{10} concentrations greater than the levels defined in PSD regulations?*

5.1.2 <u>Step 3 Revision</u>: Identify Information Inputs

- With the revision made to the study's primary goal in Step 2, the committee requested additional information on the AQIA used to establish the allowable PM_{10} emission limits for the upgrade. The committee chair noted that the AQIA was based on:

  - the estimated average 24-hour PM_{10} ambient air concentration observed by pre-construction monitoring (80 $\mu g/m^3$);
  - the plant's estimate of the post-construction PM_{10} emission rate;
  - the expected post-construction average 24-hour PM_{10} ambient air concentration, as calculated by dispersion modeling during the permit process (89 $\mu g/m^3$),
  - the maximum PM_{10} level in ambient air considered to be protective of human health (the NAAQS primary 24-hour PM_{10} standard of 150 $\mu g/m^3$), and
  - the allowable PSD increment associated with the upgrade (15 $\mu g/m^3$).

- The chief environmental engineer for the power plant presented information on the pre-construction data summary and quality assessment. He noted that the AQIA depended on the pre-construction data solely through its average (80 $\mu g/m^3$). The committee determined that this average was based upon data of sufficient quality to be used in this effort, and the entire pre-construction database would not be required.

- In reviewing the results of Step 3 from the first meeting, the committee concluded that computer simulation modeling would be unnecessary to address the primary study goals and questions. However, meteorological data may still be useful to acquire, particularly in helping to interpret the PM_{10} concentration data to be collected, such as explaining extreme measurements or apparent outliers. The meteorological data could also be compared between pre- and post-construction monitoring periods to determine the extent to which data collected within the two periods are comparable. Several meteorological parameters that could be of importance were average wind direction and speed, total precipitation, and average temperature.

5.1.3 Step 4 Revision: Define the Boundaries of the Study

- The principal investigator proposed that because the AQIA utilized data from pre-construction monitoring, and the threshold to which post-construction monitoring data would be compared would depend in part on the outcome of pre-construction monitoring, the post-construction data should be collected in as similar a manner as possible to the pre-construction data. In particular, she recommended that the monitoring study use the same fixed pre-construction location for post-construction monitoring. The committee chair noted that the plant owner had made prior arrangements with the owner of the site (the golf course) to continue ambient air monitoring from this site for the foreseeable future.

- While the committee agreed to conduct post-construction ambient air monitoring at the golf course site, the debate continued on whether monitoring should be performed at other sites as well. In particular, some committee members raised the concern of a lack of spatial variability in the data if monitoring occurred only at a single site. The principal investigator noted that a single site would be much easier to manage within the study's available budget, and in particular, fewer samples could be collected if multiple sites were considered, in part due to the additional labor and expense associated with maintaining multiple samplers and multiple sites. Furthermore, the principal investigator and her statistician noted that spatial variability would be represented within the sample results by variability attributable to meteorological conditions (i.e., wind speed and direction). Recognizing that a sampling approach that featured the single golf course site would be most cost effective, the committee agreed to proceed with this approach.

- The committee reviewed the definition of the target population that was drafted in the last meeting. While actual post-construction sampling would only occur over a finite period of time, the committee did not want to limit the target population to only those samples that could be collected during the study. Thus, the definition of the target population was slightly revised to be all ambient air samples that could be collected at the site under those conditions that exist over the duration of post-construction monitoring (i.e., 12 to 24 months), for as long as those conditions remain in effect (i.e., until the various contributors to PM_{10} in ambient air at this site change in some way, such as the addition of a PM_{10} source or a change in emission rates from existing sources).

From these discussions, the revised output from Step 4 was as follows:

The target population consists of all possible 24-hour ambient air samples that might be collected from the sampling location used for pre-construction monitoring, during the period of time in which conditions that can affect PM_{10} levels in ambient air are unchanged from those present during the first 12-24 months following construction. The spatial boundaries of the study consist of the single location, which represents all points the same distance from the source within the cone defined by the prevailing winds. The temporal boundaries of the study are from the end of construction until the end of the post-construction monitoring program.

5.2 Step 5: Develop the Analytic Approach

In developing Step 5, the committee addresses the methods that will be used to draw conclusions from the study results that address the specific objectives of the study, including specifying the population parameters that will be examined and creating a decision rule or estimator based on the population parameters and the data collected.

At this point in the second meeting, the committee shifted from reviewing and revising the outputs from the first meeting to addressing the final three steps of the DQO Process. In addressing Step 5, the committee accomplished the following:

- The principal investigator presented the findings of her review of PM_{10} sampling and analysis methods to be used. She noted that the methods used by *A&B Inc*. for pre-construction monitoring met the requirements described in *40 CFR Part 58*, and therefore, the same approaches should be used in this study. She also discussed methods for characterizing the chemical make-up of the particles in the samples, for use in verifying that the PM_{10} in the collected sample filters actually originated from plant emissions. The committee agreed that additional research into chemical analysis of the collected PM_{10}, focusing on fingerprinting coal combustion sources, should be investigated only if the results could show that the PSD increment was exceeded more than once per year.

- A discussion on the appropriate population parameters to consider began by noting that the study would be measuring average 24-hour post-construction PM_{10} concentrations in ambient air. Some committee members were unclear on exactly how the average concentration could be used to verify the assumptions used in the AQIA, and ultimately, to determine the appropriate action that the plant may need to take. The State EPA regulator explained that the draft permit – like all similar PSD permits for PM_{10} that are issued in situations such as this – specifies that the plant would be in compliance with the 24-hour PSD increment, as indicated by the air dispersion model results, as long as the 24-hour post-construction PM_{10} concentration in ambient air did not exceed the increment more than once per year.

- As a result of this explanation on how to determine compliance with the 24-hour PM_{10} PSD increment, the citizens' group representative suggested that the parameter of interest should not be the average concentration, but instead, the observed proportion of days in a given year during the monitoring period that the daily average concentration exceeded the PSD increment. Of interest would be whether or not this observed proportion exceeds 1/365 = 0.00274 (i.e., the maximum proportion of days in a year that the PSD increment could allowably be exceeded). The statistician pointed out that this approach would require that 24-hour samples be collected over a large number of days, such as daily for one to two years.

- The committee members agreed that the proportion of days exceeding the PSD increment would be an appropriate measure for determining compliance. They asked the statistician whether a decision on compliance could be made by performing a statistical hypothesis test rather than simply noting whether or not the observed proportion of days exceeds 0.00274. The statistician suggested an approach that was based on calculating *tolerance intervals*, or confidence intervals placed on percentiles of a probability distribution. He suggested that a tolerance interval could be calculated for the (1-0.00274) x 100 = 99.726th percentile of the distribution of 24-hour PM_{10} sample concentrations at the fixed site. The average pre-construction PM_{10} concentration (80 $\mu g/m^3$) would be subtracted from the upper bound of this tolerance interval, as calculated from the actual sample results.

    - If this result is less than the PSD increment, then it would be reasonable to expect (with a specified degree of statistical confidence) that under current post-construction conditions, daily average PM_{10} levels in ambient air would exceed the PSD increment no more than one day per year, on average.
    - If this result exceeds the PSD increment, then under current post-construction conditions, daily average PM_{10} levels in ambient air are expected to exceed the PSD increment more than one day per year, on average, implying that sufficient evidence exists that the assumptions used for the AQIA did not accurately represent the upgrades to the power plant.

    The committee agreed that the parameter of interest would be the 99.726th percentile of the distribution of 24-hour PM_{10} concentrations, and that a decision rule would be based on calculated tolerance intervals for this percentile.

As a result of the suggestions and discussion made in support of Step 5, the committee prepared the following statement:

The parameter of interest is the 99.726th percentile of the distribution of 24-hour post-construction PM_{10} concentrations. The type of statistical inference to be used to address the study questions is a tolerance interval associated with this percentile. If the upper bound on this tolerance interval calculated from the actual monitoring data, minus the average pre-construction PM_{10} concentration, exceeds the PSD increment, then decide that the AQIA did not accurately represent the upgrades to the power. If the upper bound is less than the PSD increment, then decide that the plant is in compliance with the PSD regulations.

5.3 <u>Step 6</u>: Specify Acceptance or Performance Criteria

In this step, the committee will establish "performance or acceptance criteria" that the post-construction monitoring data need to achieve in order to achieve their intended use in the approach specified within Step 5. The committee now accepts the fact that that the collected data will represent one of many possible outcomes from the (infinite) target population, and as a result, must understand the various types of "random error" (or uncertainty) to which the data will be subject, such as errors due to sampling and analysis techniques. As some degree of error is inevitable in this process, the committee needs to agree upon how much random error is "acceptable," relative to the extent that this error may lead to making erroneous conclusions upon analysis and interpretation of the collected data.

In beginning efforts under Step 6, the principal investigator and her statistician explained the concept of acceptance and performance criteria. As noted in the U.S. EPA's *Systematic Planning using the Data Quality Objectives Process* (EPA QA/G-4) (U.S. EPA 2006a), *performance criteria* represent the full set of specifications that are needed to design a data or information collection effort such that, when implemented, will generate *newly-collected* data that are of sufficient quality and quantity to address the project's goals (determined from Step 2). *Acceptance criteria* are specifications intended to evaluate the adequacy of one or more *existing* sources of information or data as being acceptable to support the project's intended use. As this study will be collecting new post-construction ambient air monitoring data, the committee will focus on establishing performance criteria that these new data will need to achieve in order to be used to determine compliance with the established PSD increment. These criteria are then adopted as the study's Data Quality Objectives (DQOs).

The discussion to initiate Step 6 featured the following:

- Given that the committee agreed in Step 5 to take the tolerance interval approach to determining compliance, the committee's next task was to determine the level of confidence that they would be willing to accept in ensuring that the tolerance interval correctly contained the 99.726th percentile of the distribution. The citizens' group representative argued vehemently for 100% confidence. However, the statistician convinced him that 100% confidence was impossible to achieve, due to inherent variability present in the sampling and measurement process. Furthermore, the statistician warned that extremely high confidence levels (e.g., 99.5%) would require very large numbers of samples. After further discussion, the committee agreed that a confidence level of 95% would serve as a reasonable value for this performance criterion, as this level is routinely used in similar efforts.

- The statistician pointed out that the DQO Guidance also required a second performance criterion on the width of the tolerance interval, which is an indicator of the degree of acceptable uncertainty in estimating the 99.726th percentile. The citizens' group representative demanded that it be as short as possible – perhaps on the order of 10 $\mu g/m^3$ – so that a clear idea of the ambient PM_{10} levels would be available. The statistician requested that the discussion of tolerance interval width be tabled because he needed more time to research the appropriate methodology before making recommendations. The committee agreed and asked the statistician to provide additional guidance at the next meeting regarding methods for calculating tolerance intervals and their associated performance criteria.

Thus, the committee chair determined that Step 6 could not be completed in this meeting, and appropriate action items would be assigned to provide additional information that is needed to complete this step in the next meeting.

5.4 Step 7: Develop the Detailed Plan for Obtaining Data

In this final step of the DQO Process, the committee will decide upon a sampling and analysis design that will generate the post-construction data that will achieve the performance criteria developed in Steps 1 through 6 and can be implemented within the available budget.

The committee realized that the sampling design requires a specification of the sample size, which is pending upon finalizing the performance criteria in Step 6. Thus, various design alternatives, and selection of the final design, cannot be reviewed and agreed upon until the next meeting. However, based on discussions in prior steps, the committee did agree on several features of the sampling plan:

- 24-hour ambient air samples would be collected to obtain daily average PM_{10} concentrations;
- The same sampler used in the pre-construction monitoring would be used, and it would continue to be located at the golf course;
- Samples will be collected daily for at least one year, but no more than two years.

Rather than wait until the next meeting to clarify performance criteria, the statistician was asked, with the help of the principal investigator, to provide some candidate sample designs for the committee to consider at the next meeting. If none were acceptable to the committee, then further guidance could be given to the environmental consulting firm on preparing other options, and another meeting would be required to approve the final design.

5.5 Identifying Areas for Further Review and Additional Information Needs

Prior to adjourning the second meeting, the committee chair set a date for the third meeting that would work in the schedule of all members of the committee. The chair then established the following action items for committee members, to be completed by the next meeting, that will provide additional important information for use in that meeting:

- All members will review the current outputs from each step of the DQO Process and determine the need for further revision.

- The statistician will provide more details on the tolerance interval approach, including methodology and related performance criteria.

- The statistician and principal investigator will prepare candidate sample designs based on the use of a 95% tolerance interval.

- The principal investigator would report on costs associated with sampling and analysis.

- The committee chair, with the assistance of the principal investigator’s firm, will compile notes of the second meeting and propose an agenda for the third meeting within seven days of the second meeting. Each committee member will review the notes for accuracy.

6.0 INTERIM ASSIGNMENTS PRIOR TO THE THIRD MEETING

Between the second and third meetings of the planning committee, selected committee members investigated the topics introduced in the sections that follow.

6.1 Performance Criteria for Tolerance Intervals

As requested by the committee, the statistician researched procedures for calculating tolerance intervals, as well as proper interpretation of tolerance intervals, in order to determine how appropriate performance criteria can be established, and therefore, how sample sizes would be determined based on these criteria. He determined that in this situation, the following two performance criteria were relevant:

- The tolerance interval should contain the true 99.726th percentile of the distribution with high probability; and

- The tolerance interval should contain a specified percentage (to be determined) of the distribution that is higher than the 99.726th percentile of the distribution with low probability. For example, the probability that the tolerance interval actually contains the 99.9th percentile should be small.

The first performance criterion ensures that the goal of containing the specified percentage is achieved, while the second criterion specifies that the goal need not be exceeded by an unusually large margin. In other words, the sampling design must specify that a sufficient number of samples will be collected to allow the first performance criterion to be met, but the sample size should not be so unnecessarily large as to overshoot this goal by a large margin.

The planning committee would be tasked with concurring on versions of the above performance criteria in which numeric probabilities are specified rather than simply “high” and “low.” If the collected data satisfy the criteria established by the committee, then the plant would be considered to have demonstrated compliance with the PSD increment.

6.2 Options for Sample Sizes

In estimating the number of samples required to achieve the performance criteria given above, the statistician considered a series of different values for the probabilities specified within these criteria, then calculated the sample sizes required for each set. For example, the statistician considered the following specific performance criteria, which he planned to propose to the committee:

- There should be a 95% chance that the collected data will (correctly) demonstrate that 99.726% of the population falls below the upper bound of the tolerance interval.

- There should be a 5% chance that the collected data will demonstrate that 99.9% of the population falls below the upper bound of the tolerance interval.

His statistical analysis concluded that 588 samples would be required to meet both of these performance criteria. For the sample sizes calculated by the statistician, the principal investigator estimated the associated sampling and analysis costs, which she planned to present at the next meeting. She noted that in many cases, including the example above, the projected costs exceeded the budgeted amount for the study. After discussions with representatives of the plant owners, it was decided that an initial recommendation to reduce sample sizes may be to increase the probability underlined in the second criterion.

7.0 THIRD MEETING OF PLANNING COMMITTEE

The goal of the third meeting was for the planning committee to arrive at a final set of DQOs and a final sampling design. The statistician also attended this meeting to provide input on statistical issues. The agenda called for a review of outputs for all seven steps of the DQO Process. The sections that follow document the discussions that were held, with the final outputs from each step given at the end.

7.1 Discussion of the Findings of Interim Assignments

7.1.1 Finalizing Steps 1 through 4

The committee began this meeting by reviewing the most recent outputs from Steps 1 through 4 and accepting these outputs as written. Thus, there was no need to further consider these steps, and their outputs could be considered final.

7.1.2 Step 5 Revision: Develop the Analytic Approach

There was additional discussion about the analytic approach that was adopted in the previous meeting within Step 5. Given the 99.726th percentile was adopted as the primary parameter of interest, some committee members had some questions about the calculation of a tolerance interval for this percentile, including whether alternative methods may be available that are more straightforward or "mainstream." The committee chair tabled the discussion until after the statistician presented his information on the tolerance interval methodology. At that time, it would be determined whether iteration back to Step 5 would be needed to redefine the analytic approach.

7.1.3 Example Performance Criteria, Corresponding Sample Size, and Budget Implications

- The statistician presented the example performance criteria introduced in Section 6.2 to illustrate the application of tolerance interval method to the problem. This example was as follows:

  - There should be a 95% chance (0.95 probability) that the collected data will (correctly) demonstrate that 99.726% of the population falls below the upper bound of the tolerance interval.

  - There should be a 5% chance (0.05 probability) that the collected data will demonstrate that 99.9% of the population falls below the upper bound of the tolerance interval.

  His presentation included a detailed discussion of the two performance criteria and justification for their relevance. Using this example as a basis for discussion, the committee was able to better understand the underlying principles of the tolerance interval methodology, but the citizens' group representative continued to voice concern about whether the general public would understand this approach.

- The statistician noted that in order to meet these two example performance criteria, the sampling design would need to specify a minimum of 588 samples to collect.

- The principal investigator gave a report on expected rates associated with sampling and analysis. Labor costs for field technicians could range from $40 to $70 per hour, sample filters would cost about $40/filter for the sampler used by the plant to conduct pre-construction monitoring, and laboratory analysis costs associated with these filters (including labor) were approximately $65/sample.

- The principal investigator noted that under these assumed rates, collecting enough samples to yield 588 valid 24-hour averages would require more budget than what was available for the study. Thus, she pointed out that above example performance criteria would need to be revised to be less stringent, so that fewer samples would be required, and therefore, the study could be completed within budget. The citizens' group representative argued that the confidence level of 95% in the first criterion should not be made less stringent, in order to sufficiently protect human health.

7.2 Specific Sample Collection Design and Alternatives

- As part of his interim assignment, the statistician calculated minimum sample sizes for different sets of values for the two percentages underlined in the example criteria given above. He summarized these sample sizes in Table 1 and presented this table to the committee. Note that the sample size for the example criteria (588) is specified in the row labeled 0.05 and the column labeled 0.95.

Table 1. Relationship Between Tolerance Interval Performance Criteria and Minimum Sample Size

Probabilities within the Second Performance Criterion[2]	Probabilities within the First Performance Criterion[1]					
	0.75	**0.80**	**0.85**	**0.90**	**0.95**	**0.99**
0.25	100	127	162	213	301	506
0.20	125	155	194	249	343	561
0.15	158	191	234	295	397	629
0.10	205	243	291	357	469	719
0.05	285	330	385	462	588	865
0.01	472	539	599	694	846	>1000

[1] Probability of correctly concluding that 99.726% of the population falls below the upper bound of the tolerance interval.

[2] Probability of concluding that 99.9% of the population falls below the upper bound of the tolerance interval.

- The committee reviewed and evaluated the different sample sizes in Table 1, considering which sample sizes would lead to performance criteria that could be considered acceptable, and could also be collected within the available budget (based upon the cost estimates which the principal investigator provided earlier in the meeting). The committee chair reminded the committee that in an earlier meeting they agreed that the monitoring program needed to be less than two years in duration, with a one-year duration being preferable, to ensure that results could be reported back to the public within an acceptable period of time.

- The citizens' group representative reminded the committee of concerns about being able to account for variations in weather from year to year and noted that the problem statement offered the possibility of extending the sampling into a second year. The committee agreed that up to 18 months of sampling would be acceptable in keeping the study to within a two-year time frame, as the laboratory can still analyze the collected samples, the collected data could be statistically analyzed, and a final report prepared, within this time frame. This would also allow for some year-to-year variability due to weather to be addressed. If daily sampling occurred seven days per week, an 18-month sampling period would yield approximately 550 samples. She also reiterated her objection to any confidence levels within the first performance criterion being below 95%, and therefore, would only support sample sizes selected from one of the last two columns of Table 1.

- The principal investigator noted, however, that overtime costs associated with sampling on weekends and holidays may not be acceptable within the study budget, and therefore, it may be necessary to limit sampling only to business days (e.g., 5 days per week). If this occurred, only about 380 samples could be collected in an 18-month period.

- The principal investigator also mentioned that it was unlikely that 100% of the samples would yield valid results, due to various problems that could occur with air sampling and sample collection and analysis. In fact, only about 75% of collected samples were predicted to yield valid data. Thus, the maximum number of valid data points that could be obtained in an 18-month period was about 285 if sampling occurred only on business days, and about 400 if sampling occurred seven days per week.

- Given the principal investigator's presentation on sampling and analysis costs, the committee determined that the study budget could afford paying the extra labor cost associated with daily sampling for seven days per week (i.e., including sampling on weekends and holidays) in order to accelerate the sampling period.

- The principal investigator noted that she had held discussions with representatives of the plant owners in advance of the meeting, and they appeared to be willing to increase the percentage specified in the second performance criterion in order to meet the budget.

7.3 Completion of Steps 6 and 7: Selection of Final Sample Design

Using the tolerance interval methodology, the committee decided that 24-hour ambient air samples would be collected using the same sampler that was used for pre-construction monitoring. According to Table 1, the committee noted that approximately 400 data points would be needed to achieve the following performance criteria:

- *There should be a 95% chance that the collected data will (correctly) conclude that 99.726% of the population falls below the upper bound of the tolerance interval; and*
- *There should be a 15% chance that the collected data will conclude that 99.9% of the population falls below the upper bound of the tolerance interval*

(Note that these criteria differ from the example criteria specified by the statistician only in the percentage given in the second criterion, which increased from 5% to 15%.) Upon further discussion, all members of the committee agreed that these appeared to be acceptable performance criteria. At that time, while the committee members took a break, the committee chair and principal investigator held a brief conference call with representatives of the plant's owner to present the pros and cons associated with these criteria and to determine if they would be acceptable. The plant's owner agreed that, given the endorsement of the planning committee and the ability to meet the original specified budget, these criteria would be acceptable.

If daily monitoring were to occur seven days per week, and assuming that 25% of samples would yield results that were unusable or invalid, then it would take 18 months to collect enough daily samples to yield 400 valid data points (i.e., 550 samples would be collected and this would correspond to the 397 valid samples needed to satisfy the 15% criterion). Given the principal investigator's presentation of sampling and analytical costs, the costs associated with collecting and analyzing 550 samples were approximately $95,000, which was within the portion of the allocated budget. Therefore, the committee agreed that taking 550 samples over an 18-month time frame, expected to yield a minimum of 400 valid sample points, would be acceptable from both a time and cost standpoint.

7.4 Review of Final DQOs

Upon the conclusion of the systematic planning process, the planning committee released the final set of outputs on the DQO Process that is provided in Table 2.

As noted in Section 1 and throughout this particular case study, efforts to complete the DQO Process can often involve iterating between its various steps, where information gathered in later steps of the process leads to revisiting earlier steps and revising their output. Figure 3 illustrates the degree of iteration in the DQO Process that occurred by the planning committee in this case study. The freedom to iterate among steps as needed is one feature of the flexibility that is inherent in the DQO Process.

Table 2. DQOs for the Post-Construction Monitoring Study of PM_{10} Concentrations in Ambient Air in the Vicinity of the Emmerton Power Plant

DQO Step	Statement
1. Define the Problem	*The power plant in Emmerton is planning an expansion and is going through the permitting process to operate the updated facility. During a public hearing, a citizens' action group voiced concern that the permitting process does not require post-construction monitoring to verify that the plant's emissions do not result in unacceptably high ambient concentrations of particulate matter. The plant owner, A&B Inc., has agreed to conduct post-construction monitoring of ambient particulate matter (specifically, PM_{10}) concentrations to assuage the group's concerns that unhealthy levels of ambient PM_{10} within city limits may result upon implementing the plant upgrades. Daily monitoring data will be needed that can be used to isolate the effect of plant emissions on ambient PM_{10} concentrations.* *The planning committee for the study consists of the following individuals:* • *the chief environmental engineer from the power plant (chair);* • *an expert in air sampling from a firm hired by A&B Inc. to perform post-construction monitoring (principal investigator);* • *an environmental regulator from the State EPA District Office; and* • *a local environmental organization leader, representing the environmental citizens' group.* *A&B Inc., has set a total budget for the monitoring program at $250,000. Initial estimates are that the monitoring program will last between one and two years, with an additional 6 months for data compilation, analysis, and reporting.*
2. Identify the Goal of the Study	*The environmental data to be collected consists of PM_{10} concentrations in air samples collected on a daily basis. These concentrations will be examined to determine if they are too high compared to regulatory levels. The primary question of interest is whether the power plant is operating within the requirements of the PSD regulations after completion of construction (specifically regarding PM_{10} concentration). The data will be used to determine how the ambient PM_{10} levels compare to the NAAQS or PSD increment. Possible outcomes of the study are 1) that requirements of the PSD regulations are being met (meaning no further action is needed) or 2) that they are not being met (meaning that the ambient air quality impact assessment that provided justification for the allowable PM_{10} emission rates must be re-evaluated).*
3. Identify Information Inputs	• *Daily PM_{10} concentrations after construction (new data).* • *Pre-construction PM_{10} concentration used for the permitting process (to be provided by the plant's owner).* • *EPA-published NAAQS standard for PM_{10}.* • *Permitted PSD increment (provided by State EPA District Office).* • *Allowable PSD increment for PM_{10} concentration.* • *Expected post-construction performance (in terms of PM_{10} concentration predicted by the dispersion model during the permitting process)* • *Daily meteorological measurement data (new data).*
4. Define the Boundaries of the Study	*The target population is the set of all possible 24-hour air samples obtained at the fixed (pre-construction) sampling location, and the characteristic of interest for the air samples is their PM_{10} concentrations. The study is bounded spatially to the area from which the air samples are collected. Temporal restrictions for the historical data are to the period during which data were collected for the permitting process. While the monitoring program will operate for 18 months, the temporal boundaries for the inference will be to the entire length of time that the power plant will be operating under the post-construction conditions.*

Table 2. (cont.)

DQO Step	Statement
5. Develop the Analytic Approach	*The parameter of interest is the 99.762 percentile of the estimated distribution of post-construction PM_{10} concentrations minus the average pre-construction PM_{10} concentration. The type of inference is an upper tolerance bound (i.e., an upper confidence bound on the percentile of interest). If the upper tolerance bound exceeds the PSD increment, then decide that the air quality impact assessment conducted as part of the PSD permitting process may not have adequately represented the PM_{10} emissions from the plant's upgrades; if the upper tolerance bound is less than the PSD increment, then decide that the plant is likely in compliance with the PSD regulations.*
6. Specify Acceptance or Performance Criteria	*A tolerance interval is defined to be a confidence interval that contains a fixed percentage of the population of observations. In this study, the fixed percentage is 99.726% (1-1/365) and the population is all 24-hour PM_{10} concentrations. Often, there is also interest in controlling the probability that a higher percentage is also covered. For example, in this study we will control the probability that the tolerance bound covers more than 99.9% of the population of 24-hour PM_{10} concentrations. Thus, the performance criteria for this study are* • *95% likelihood that 99.726% of all 24-hour PM_{10} concentrations are less than the PSD increment; and* • *less than 15% chance that 99.9% of all 24-hour PM_{10} concentrations are less than the PSD increment.*
7. Develop the Detailed Plan for Obtaining Data	• *Total number of valid data points required to meet the performance criteria: 397;* • *One location (same as the pre-construction monitoring location);* • *18-month sampling duration (to allow for seasonal yearly differences);* • *Collection of samples 7 days per week;* • *Expected data completeness target of 75% (i.e., 75% usable data)* • *Total number of samples to be collected: 550*

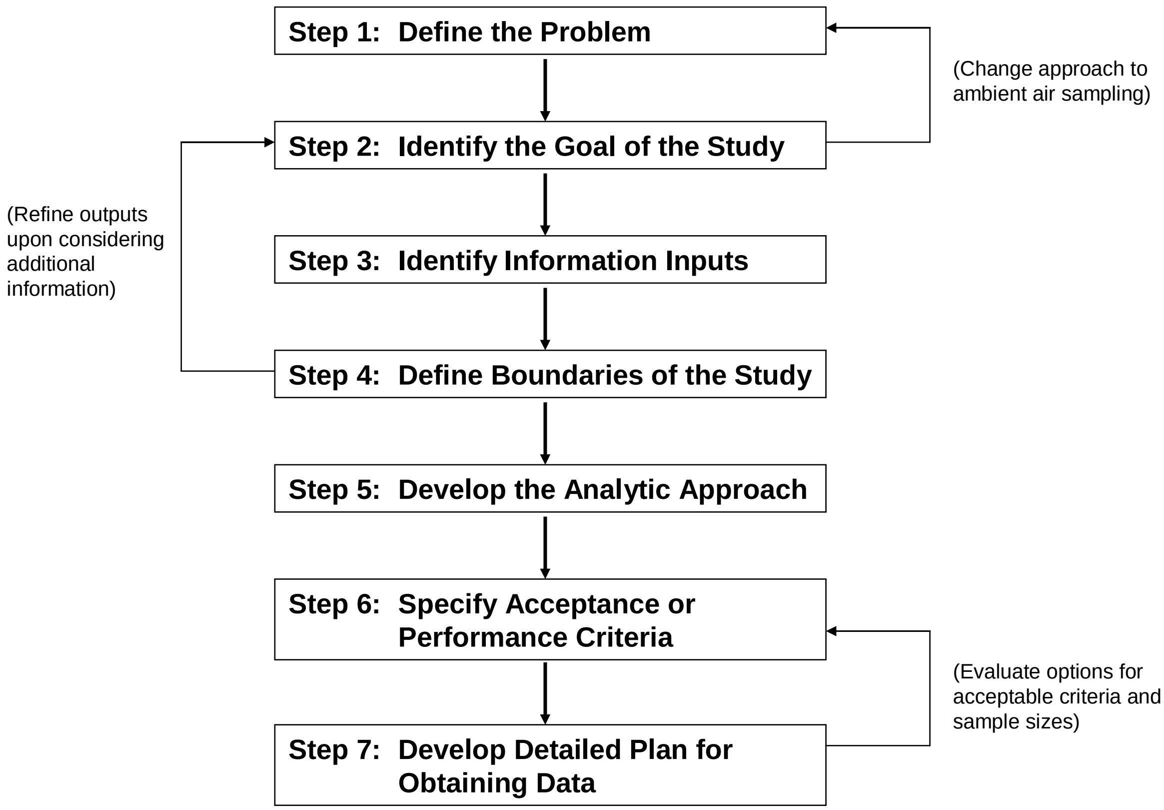

Figure 3: Iteration of Steps Within the DQO Process for the PM_{10} Ambient Air Monitoring Situation

8.0 FROM PLANNING TO IMPLEMENTATION AND ASSESSMENT

As the planning committee completes the DQO Process, the project begins to move from the planning stage to the implementation stage (Figure 1). The DQO Process yields a set of specifications that are needed to support both the qualitative and quantitative components of the design for data collection. As such, they serve as the starting point for the QA Project Plan (QAPP), which is prepared and approved within the implementation stage. The systematic planning process also leads to Standard Operating Procedures (SOPs) which ensure conformance with required practices, reduction in error occurrences, and improved data comparability, credibility, and defensibility. As the implementation phase proceeds, the targeted data are collected according to the methods and procedures documented in the QA Project Plan and SOPs. Once all data are collected, the project enters the assessment stage, where the data are verified and validated for adherence to the QAPP and that the data are appropriate for their intended use. Then a Data Quality Assessment is performed to determine the extent to which the collected data meet the intended DQOs. This section addresses some of the methods that will occur on this PM_{10} *monitoring program to complete its planning, implementation, and assessment stages, and to make conclusions from the collected data.*

Upon completion of the DQO Process, the planning committee had completed its objective and no longer needed to meet formally. However, certain committee members, including the study's principal investigator from the environmental consulting firm, and *A&B Inc.*'s chief environmental engineer, continued as members of the project team assembled by *A&B Inc.* to complete the planning stage of the Project Life Cycle (Figure 1), and to conduct activities through the study's implementation and assessment stages. The remaining committee members showed an interest to serve as study consultants or as reviewers of the study findings. The following sections summarize the remaining activities on this study and the conclusions made from the collected data.

8.1 Completion of the Planning Stage

The project team was aware that several additional planning steps were required before data collection could begin. These steps included:

- Preparation of a <u>Quality Assurance Project Plan (QAPP)</u> and approval of this plan by project and State EPA officials before post-construction sampling and data collection begins. As noted in Figure 1 of Section 1, this follows the completion of systematic planning and serves to document its outcome (e.g., the DQO Process statements noted in Table 2). The QAPP describes the quality assurance procedures, quality control specifications, and other technical activities that must be implemented to ensure that the results of the project will meet the specifications that are represented in the DQOs. It integrates all technical and quality aspects of the project in order to provide a "blueprint" for obtaining the type and quality of data needed to address the principal study questions. Further information on the content of a QAPP was obtained from *Guidance for Quality Assurance Project Plans* (EPA QA/G-5) (U.S. EPA 2002b).

One duty of the principal investigator was to oversee QAPP preparation and approval. QAPP preparation was greatly facilitated by the review, discussion, and documentation that occurred within the planning committee while executing the DQO Process. As a result of these activities, information on several of the QAPP elements had been gathered earlier, and therefore, could be placed directly within the QAPP. The plant's chief environmental engineer assigned a QA Manager to the project, whose responsibilities were to ensure that the QA activities specified within the QAPP were being performed properly, to establish and follow up on any corrective action that may be required, to oversee performance reviews and audits, and to control the distribution of the proper version of the QAPP.

- Acquisition of Standard Operating Procedures (SOPs) for the sampling and analysis process. SOPs were already available from the principal investigator and the owner of the plant, who used them to conduct pre-construction monitoring. They were modeled after the specifications given in the EPA publication *Guidance for Preparing Standard Operating Procedures (EPA QA/G-6)* (U.S. 2001). The instruction manuals for all EPA Reference or equivalent methods were included in the SOPs. The monitoring consulting firm's field technicians were trained using these SOPs and instruction manuals. The Code of Federal Regulations was also consulted to review the specified method for PM_{10} -- CFR Title 40, Part 50, Appendix M, *Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere*.

- Selection of laboratories to supply and process 47 mm diameter Teflon filters in accordance with the guidance and SOPs supplied by the nationwide particulate matter (PM_{10}) monitoring network. The project team contracted with a public health laboratory on the basis of cost, its relative closeness to Emmerton, (to eliminate the expense associated with air shipment of samples), its experience in analyzing ambient air samples for PM_{10} that were collected from other sites in the area, and its ability to demonstrate successful adherence to quality assurance and quality control procedures required under the project.

- Training project personnel to service the PM_{10} sampler, including installation and calibration of the PM_{10} sampler and the electronic data acquisition and transmission systems, conducting performance audits, and operating the sampler. To save travel time and expenses, the monitoring consultants were asked to train two power plant employees in the operation of the sampler and in the process of handling and shipment of filter samples to the laboratory. Each trainee set up and operated the sampler three times while being observed by the trainer, completed field data sheets, and reviewed typical field data supplied by the laboratory.

- Creation of schedules for regular monitoring calibration and NIST standard traceability checks, to verify that the sampling system is operating within specified guidelines and standards. Checks of the ambient air sampler included pump speed, cleanliness of internal flow path surfaces, the handling and placement of the Teflon filter in its cassette, and the presence of oil in the Well Impactor Ninety Six (WINS) impactor well.

- Development of an implementation program for performance evaluation, which includes on-site visits to check accuracy of calibrations and operator knowledge of procedures. Supervised by the project's QA Manager, these evaluations include checks of the sampler, operation of the contracted public health laboratory, performance evaluation data, and chain-of-custody procedures.

8.2 Implementation Stage

Once planning activities were completed and the QAPP and SOPs were formally approved, the post-construction ambient air monitoring study moved into the implementation stage of the Project Life Cycle (Figure 1), where *A&B Inc.* collected samples and generated data according to specifications and procedures documented in the QAPP and in the SOPs. Several steps were involved in the sample collection and analysis process, including:

- Installing, calibrating, operating, and maintaining the PM_{10} ambient air sampler, collecting and replacing the filters each day, and shipping the filters to the laboratory for PM_{10} analysis.

- Performing chemical analysis of the filters to measure PM_{10} concentrations.

- Conducting technical assessments to verify field and laboratory adherence to QAPP specifications.

- Creating, populating, and maintaining a managed database containing the newly-collected sample measurements, sample identifiers, and other information used to assess the quality and utility of the measurements. The database was constructed in a format that would easily allow the data to be input to programs and functions associated with the statistical software that could be used for data analysis.

8.3 Assessment Stage

Once all samples were collected and analyzed and the data were stored in the project database, the project moved from the implementation to the assessment stage of the Project Life Cycle (Figure 1). In the assessment stage, the following two activities took place:

- Verifying and validating the data stored within the database, where the data were generated according to specifications noted in the QAPP and are appropriate and consistent for their intended use. EPA's *Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8)* (U.S. EPA 2002c) provided useful information on how to perform these activities. As part of this effort, a chemist employed by the power plant reviewed the data to verify that the measurements achieved the quality assurance criteria, including specifications on data quality indicators (e.g., precision, accuracy, representativeness, consistency, completeness, sensitivity) that are documented in the

QAPP. The project database also included selected validation functions to ensure quality of data entry and processing operations, including simple range and consistency checks and checks for data completeness within a given sampling record. Any specific data points (or batches of data) for which problems were identified through the validation procedure were either appropriately corrected or invalidated. Quality assurance validity flags, documented within the QAPP, were included as separate fields from the numerical data within the project database, with values for these flags being properly paired with the original data values.

- Performing statistical analyses on the daily average PM_{10} concentrations within the study database, as part of a data quality assessment (DQA) to determine the extent to which the collected data meet the DQOs that were generated during the DQO Process and are therefore suitable for use in addressing the study questions. (EPA's guidance document entitled, *Data Quality Assessment: A Reviewer's Guide (EPA QA/G-9R*) (U.S. EPA 2006b), provided general information on how to assess data quality criteria and performance specifications.) These data analyses began with a preliminary review that evaluated data assumptions, identified potential statistical outliers, calculated descriptive summary statistics (e.g., means, standard deviations, selected percentiles, ranges), and prepared graphical representations of the data. The analyses then proceeded to investigating the relationship between the newly-collected PM_{10} concentration data and meteorological data to determine the impact of climate-related factors on the concentration data, and ultimately, to calculating tolerance intervals on the 99.726th percentile of the 24-hour PM_{10} concentration data, using the techniques specified by a statistician, and determined whether the upper limit of the tolerance interval (after subtracting off the average pre-construction PM_{10} concentration) fell below the PSD increment. These analysis techniques used in the data quality assessment were documented in a separate statistical analysis report.

8.4 Conclusion

The study collected a total of 528 filter samples over the 18-month post-construction monitoring period, slightly less than the 550 samples that were targeted to be collected. (The number was reduced due to various field sampling problems that were encountered and an occasional mix-up in field workers successfully collecting and shipping the filters.) Of the 528 samples, 452 were deemed to yield valid analytical measurements for PM_{10} concentration. Thus, approximately 18% fewer sample measurements were available for statistical analysis, relative to the 550 measurements that were targeted. This percentage was below the 25% upper limit that was considered acceptable for completeness and therefore deemed satisfactory.

To draw the final study conclusion, the upper bound of the tolerance interval on the 99.726th percentile of the daily 24-hour monitoring data was calculated from the newly-collected PM_{10} data. Then, the average pre-construction PM_{10} concentration at the golf course site was subtracted from this upper bound value, resulting in 12.6 $\mu g/m^3$. This value was less than the allowable PSD increment of 15 $\mu g/m^3$. As a result, the study concluded that it was reasonable to expect (with 95% confidence) that under conditions represented by the 18-month post-construction monitoring period, daily average PM_{10} levels in ambient air would exceed the PSD increment no more than one day per year, on average. This implied that PM_{10} levels following the plant upgrades were, in fact, found to be within safe levels (as represented by the allowable PSD increment).

These findings, along with a summary of the study methods and the study data, were distributed to the original planning committee members and other members of the project team for review. Upon hearing back from these personnel, the plant's owners reported the study findings to public health officials and the general public through a press release to the local media.

9.0 REFERENCES

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