Quality Assurance Project Plan

Project 20 – 005
Using Satellite Observations to Quantify Surface $PM_{2.5}$ Impacts from Biomass Burning Smoke

Prepared for
Texas Air Quality Research Program (AQRP)
The University of Texas at Austin

Prepared by

Matthew J. Alvarado
Atmospheric and Environmental Research, Inc.

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Version 1

Atmospheric and Environmental Research, Inc. has prepared this Quality Assurance Project Plan (QAPP) following EPA guidelines for a Quality Assurance (QA) Category III Project: Research Model Development and Application and for a Quality Assurance (QA) Category III Project: Secondary Data Projects. It is submitted to the Texas Air Quality Research Program (AQRP) as required in the Work Plan requirements.

QAPP Requirements: Project Description and Objectives; Organization and Responsibilities; Scientific Approach; Quality Metrics; Data Analysis, Interpretation, and Management; Model Design; Model Coding; Model Calibration; Model, Verification; Model Evaluation; Model Documentation; Reporting.

QA Requirements: Technical Systems Audits - Not Required for the Project
Audits of Data Quality – 10% Required
Report of Findings – Required in Final Report

Approvals Sheet

This document is a Category III Quality Assurance Project Plan for the "Using Satellite Observations to Quantify Surface $PM_{2.5}$ Impacts from Biomass Burning Smoke" project. The Principal Investigator for the project is Matthew J. Alvarado.

Electronic Approvals:

This QAPP was approved electronically on 06/15/2020 by

Elena McDonald-Buller
Project Manager, Texas Air Quality Research Program
The University of Texas at Austin

This QAPP was approved electronically on 6/19/2020 by

Vincent M. Torres
Quality Assurance Project Plan Manager, Texas Air Quality Research Program
The University of Texas at Austin

This QAPP was approved electronically on 05/11/2020 by

Matthew J. Alvarado
Principal Investigator, Atmospheric and Environmental Research, Inc.

QAPP Distribution List

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David Allen, Director
Elena McDonald-Buller, Project Manager
Vincent M. Torres, Quality Assurance Project Plan Manager

Texas Commission on Environmental Quality (TCEQ)
Fernando Mercado, Project Liaison

Atmospheric and Environmental Research, Inc. (AER)
Matthew J. Alvarado, Principal Investigator

1. Project Description and Objectives

In this project, we will evaluate the ability of existing near-real-time (NRT) remote sensing smoke products to identify regions impacted by smoke using additional polar satellite observations that are sensitive to smoke, specifically observations of carbon monoxide (CO) and ammonia (NH_3) from Cross-track Infrared Sounder (CrIS) and Atmospheric Infrared Sounder (AIRS) and aerosol absorption Angstrom exponent (AAE) (a proxy for brown carbon) from Ozone Monitoring Instrument (OMI) (Task 1). We will also evaluate two methods for estimating the height of the plumes detected by the Hazard Mapping System (HMS) and other smoke products: the plume height estimates from the Moderate Resolution Imaging Spectroradiometer Multi-Angle Implementation of Atmospheric Correction (MODIS MAIAC) algorithm and a new method based on the observed transport direction of the smoke plumes (Task 2). Finally, we will test different statistical and model-based approaches to estimate the impact of the observed smoke aerosol optical depth (AOD) on surface Particulate Matter ($PM_{2.5}$) (Task 3).

The objectives of this project are:

1. **To compare different methods for identifying smoke plumes from National Oceanic and Atmospheric Administration (NOAA) and National Aeronautics and Space Administration (NASA)remote sensing imagery;**
2. **To investigate different remote sensing techniques to estimate the height and vertical profiles of these smoke plumes; and**
3. **To investigate new statistical and machine learning methods to relate the smoke AOD observations to surface $PM_{2.5}$ concentrations.**

Our three project tasks are designed to answer our three key science questions:

1. How consistent are the different methods for identifying the extent of smoke plumes?
2. How well can the height of the smoke plumes over Texas observed in current smoke products be constrained?
3. How well can the surface $PM_{2.5}$ impacts of smoke in Texas be constrained using current remote sensing products?

2. Organization and Responsibilities

2.1. Key Personnel and Tasks

This section identifies the roles and responsibilities of those individuals participating in the project. The individuals responsible for maintaining and updating the QAPP are also identified.

A project organization chart is provided in Figure 1.

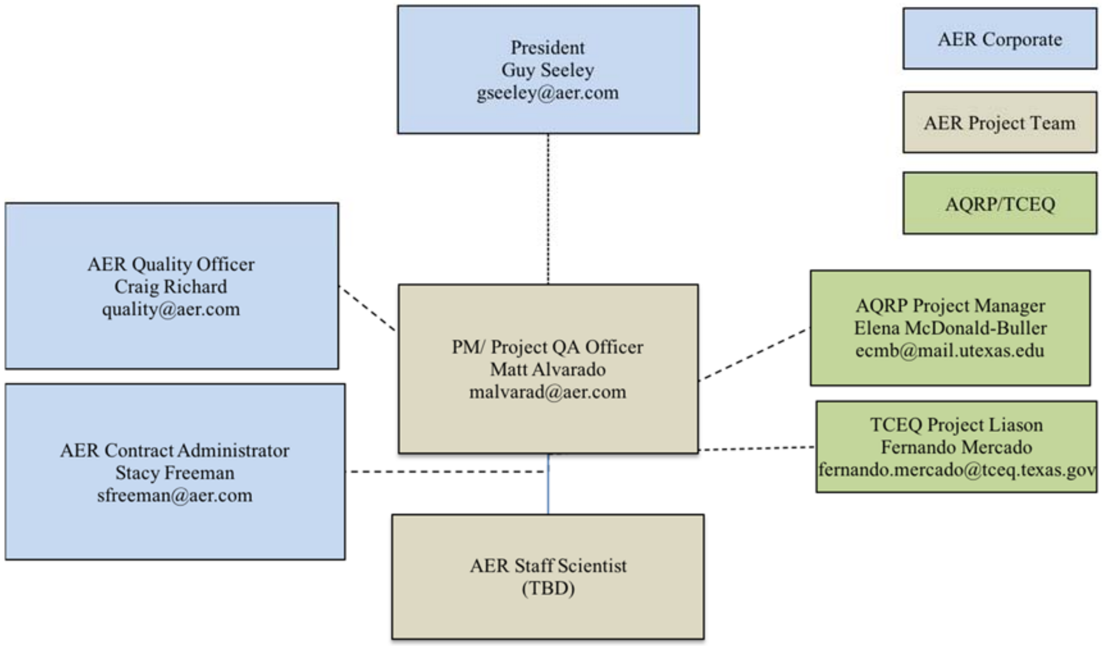

Figure 1. AER organization chart for AQRP Project 20-005. Persons with direct charging authority to the project are indicated in brown; persons serving in a corporate capacity are indicated in blue. AQRP Project Manager and TCEQ Project Liaison are shown in green. Solid blue lines indicate the reporting for this project only, while dotted lines indicate AER's corporate hierarchy. Dashed lines are used to connect the PM to AER administrative support and the TCEQ project manager.

The Project Manager (PM), Matt Alvarado, is also the Project Quality Assurance Officer and will have responsibility for maintaining and updating this QAPP via communication with the AQRP Project Manager Elena McDonald-Buller. Updates to this document will be coordinated with the AER Quality Officer, Craig Richard, who serves independently in this role from the project.

The technical individuals shown in Figure 1 (brown boxes) will share responsibility for evaluating existing data obtained for this project that isn't already covered by other TCEQ-accepted QAPPs. These evaluations, if required, will be documented and controlled per AER's established Quality Management System (QMS).

Below we provide a summary description of the key people, their responsibilities, and contact information:

Elena McDonald-Buller, AQRP Project Manager (ecmb@mail.utexas.edu) is the key AQRP contact for all technical communications, submittal of preliminary deliverables, and other tasks related to the production of deliverables prescribed in the contract.

Fernando Mercado, TCEQ Project Liaison (Fernando.mercado@tceq.texas.gov) is the key AQRP contact for all technical communications, submittal of preliminary deliverables, and other tasks related to the production of deliverables prescribed in the contract.

Matthew Alvarado, AER Project Manager and Project Quality Assurance Officer (malvarad@aer.com. 781-761-2330)**,** will be responsible for directing this project's day-to-day activities. He will also maintain overall responsibility for the successful completion of the project. He will lead all project tasks and prepare the final report.

A Staff Scientist (TBD) from AER's Atmospheric Composition and Air Quality Section will assist Dr. Alvarado with all project tasks.

Craig Richard, AER QA Officer (quality@aer.com, 781-761-2288), will provide independent quality assurance to the project. He is familiar with all aspects of AER's quality control standards, procedures and policies.

Stacy Freeman, AER Contract Administrator (sfreeman@aer.com, 781-761-2242), will manage all non-technical aspects of the project, including generation and submission of invoices.

2.2. Schedule and Milestones

The proposed schedule and milestones for this project is shown in Table 1 below. As necessary, AER will propose revised milestone dates. AER will commence work upon receipt of the Notice to Proceed.

Table 1. Project Schedule and Milestones

2020	
Q2	Compare existing smoke products over Texas and nearby areas (Task 1).
Q3	Evaluate existing smoke products using OMI Brown Carbon estimates (Task 1).
	Evaluate existing smoke products using CrIS and AIRS CO and NH_3 retrievals (Task 1).
	Evaluate MAIAC smoke plume height product over Texas using MISR and CALIPSO data (Task 2).
Q4	Use MAIAC product to estimate heights for smoke plumes observed by GOES (Task 2).
	Develop HYSPLIT-based estimates of plume heights based on GOES smoke transport observations (Task 2).
	Evaluate HYSPLIT-based estimates of plume heights using MISR and CALIPSO data (Task 2).
	Gap-fill smoke AOD observations from MODIS and GOES (Task 3).
2021	
Q1	Develop and evaluate different methods for converting AOD to surface $PM_{2.5}$ concentrations (Task 3).
	Develop models separately for smoke and non-smoke days to estimate smoke impact on total $PM_{2.5}$ (Task 3).
Q2	Determine if height estimates from Task 2 improve the predictions of surface $PM_{2.5}$ impacts (Task 3).
Q3	Preparation and submittal of draft final report on August 2, 2021. Write final report and draft presentation to AQRP workshop.

3. Scientific Approach

The following datasets will be used in this project.

3.1. NOAA HMS Fire and Smoke Product

To make the HMS Fire and Smoke product, National Environmental Satellite, Data, and Information Service (NESDIS) satellite analysts manually generate a daily operational list of fire locations and outline areas of smoke. These analysts compare automated fire detections to the infrared satellite images used to produce them to ensure each fire exists (Ruminski *et al.*, 2006; Schroeder *et al.*, 2008; Brey *et al.*, 2018). Small fires are more difficult to detect and are underreported (*e.g.*, Hu *et al.*, 2016). False fire detections are removed, and fires that were not automatically detected are added manually.

After identifying fire locations, HMS analysts use imagery from multiple NOAA and NASA satellites to identify the geographic extent of smoke plumes (Rolph *et al.*, 2009; Ruminski *et al.*, 2006). Smoke detection is done primarily with visible-band geostationary Geostationary Operational Environmental Satellite R-series (GOES-R) imagery, which has high temporal coverage (typically every 15 min), occasionally assisted by GOES infrared imagery and polar orbiting satellite imagery (Ruminski *et al.*, 2006). Due to the frequent interference by cloud cover, the number and extent of smoke plumes reported in the HMS represents a conservative estimate. No information about the height or vertical profile of smoke plumes is provided.

3.2. GOES-R Aerosol Detection (Smoke and Dust) Algorithm

The GOES-R aerosol detection algorithm detects smoke and dust contaminated pixels using images taken by the Advanced Baseline Imager (ABI) flown on the GOES-R series NOAA operational geostationary meteorological satellites (NOAA/NESDIS/STAR, 2018). The algorithm provides an initial estimate of the presence or absence of smoke or dust within each ABI pixel. The smoke and dust detection algorithm is based on the fact that smoke/dust exhibits features of spectral dependence and contrast over both the visible and infrared spectrum that are different from clouds, surface, and clear-sky atmosphere (NOAA/NESDIS/STAR, 2018). The GOES-R smoke and dust algorithm has been tested for different scenarios such as wildfires and dust storms against MODIS and CALIPSO observations.

3.3. NOAA Automated Smoke Detection and Tracking Algorithm (ASDTA)

The ASDTA product provides smoke-specific GOES AOD maps at a 30-minute interval to provide observational support for verification of NOAA Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) smoke ($PM_{2.5}$) forecasts. Automated Smoke Detection and Tracking Algorithm (ASDTA) uses a source apportionment technique to fuse GOES observations of fire hot spots and GOES AOD maps at a 30-minute interval (Zeng and Kondragunta, 2010). Plume direction and extent from all observed fire sources are first determined, then AOD values not associated with the fires are dropped. A pattern recognition technique is used for plumes transported long distances from fire sources. ASDTA provides wind speed and direction associated with the plumes; however, the vertical location of the plumes is not provided.

3.4. Smoke Extent Data

We will use polar satellite observations of the trace gases CO and NH_3 from the Cross-Track Infrared Sounder (CrIS; Shephard and Cady-Pereira, 2015) as an additional indicator of the presence of smoke. Both CO and NH_3 are emitted in large quantities by biomass burning (*e.g.*, Akagi *et al.*, 2011; Alvarado *et al.*, 2011), and daily observations of NH_3 and CO from CrIS can be used to determine the extent of smoke transport.

We will also use data from the polar-orbiting Ozone Monitoring Instrument (OMI) to identify areas that have large concentrations of brown carbon (BrC) aerosols, which are emitted by biomass burning. OMI provides absorption aerosol optical depth (AAOD) at five wavelengths between 342.5 nm and 483.5 nm once a day around 13:30 local solar time. These wavelengths can be used to calculate an AAE in the UV. High values of this UV AAE imply the presence of BrC aerosols from biomass burning smoke: for example, Wang *et al.* (2016) found that $AAE_{388/440\ nm}$ for BrC is generally ~4 worldwide, with a smaller value in Europe (< 2), compared to ~1 for black carbon aerosols from both biomass burning and anthropogenic sources.

3.5. Smoke Height Data

We will explore two different methods to provide height information for the smoke plumes identified in the NRT smoke products. First, Collection 6 of the MODIS Multi-Angle Implementation of Atmospheric Correction (MAIAC, Lyapustin *et al.*, 2011, 2019) algorithm provides an estimated injection height of smoke plumes over land under certain conditions (*i.e.*, thick smoke near clear-sky pixels). We will develop a technique that takes the twice-daily heights from the MAIAC product and extrapolates them in time to provide estimates of smoke height for the NRT products.

Second, we will take advantage of the plume wind speed and direction provided by the ASDTA product (Section 1.2.3) to estimate the height of the smoke plumes. As the wind speed and direction at any location will depend on height, the ASDTA plume wind speed and direction estimates could be matched to modeled vertical profiles of horizontal winds to provide an estimate of the height at which most of the smoke transport is occurring. We will explore two ways of performing this matching: directly comparing the wind speed and direction fields from the NOAA high resolution rapid refresh (HRRR) smoke forecasts (Ahmadov *et al.*, 2017) and performing HYSPLIT simulations at fire locations with different injection heights to determine which height is most spatially consistent with the observed transport direction and speed, using the methods used by Stein *et al.* (2009). MISR and CALIPO data will also be used to evaluate these wind direction height estimates.

4. Quality Metrics

No project-specific quality requirements exist for the information that will be used in this project. All data used in this project will be filtered using the quality flags (provided as an integral part of each dataset listed in Section 3 by the same source as the dataset itself) as directed by the respective user's guides. The processing and analysis scripts used in this project will be inspected by a team member not involved in their creation for accuracy. All automated calculations and at least 10% of manual calculations will be inspected for correctness, and if errors are found all calculations will be re-examined. This meets the requirement of Level III QAPPs that 10% of the data must be inspected. The results of these quality evaluations will be documented in the final report.

As the quality of the information, including secondary data, will not be evaluated by EPA, we will add a disclaimer to any project deliverable to indicate that the quality of the information, including secondary data, has not been evaluated by EPA for this specific application. The wording of this disclaimer will be:

> *Disclaimer: The information contained in this report or deliverable has not been evaluated by EPA for this specific application, i.e. the identification of brown carbon aerosols and biomass burning smoke.*

5. Data Analysis, Interpretation, and Management

5.1. Reporting Requirements

No data reduction procedures specific to the project will be required. The data reporting requirements will include thorough documentation of all raw and processed data sets, scripts, and other codes and algorithms used in processing the data. The final report will include a discussion of the data sources and thorough instructions on using scripts to obtain and analyze the data used.

5.2. Validation Procedures

As stated above, the processing and analysis scripts used in this project will be inspected by a team member not involved in their creation for accuracy. All automated calculations and at least 10% of manual calculations and the data produced by these calculations will be inspected for correctness, and if errors are found all calculations will be examined. This meets the requirement of Level III QAPPs that 10% of the data must be inspected. The results of these quality evaluations will be documented in the final report.

5.3. Technology Assessment

We will evaluate the smoke detections from HMS, GOES-R, and ASDTA with the smoke detections from the CrIS and OMI satellites. Our evaluation will focus on periods when fires were present within Texas, as well as times where smoke is known to have been transported to Texas urban areas from fires in the rest of the US and Mexico (*e.g.*, Wang and Talbot, 2017). These evaluations will use the figure of merit in space (FMS) evaluation metric, defined as the intersection over the union of the observed and calculated smoke plumes:

$$FMS(\%) = \left(\frac{A_I \cap A_J}{A_I \cup A_J}\right) \times 100$$

where A_I and A_J are the areas of the smoke detections by methods I and J, respectively, as defined by a specified contour value. FMS has been frequently used to evaluate smoke forecasts using satellite observations (*e.g.,* Rolph *et al.*, 2009; Stein *et al.*, 2009). Note, however, that while this evaluation will allow us to assess the consistency of these products, none of the products provide a "truth" dataset to use as a reference.

6. Model Design

In this project, we will develop statistical models for relating the methods for relating the observed smoke AOD to the surface $PM_{2.5}$ impacts. We will start with a two-stage statistical approach (Zhang *et al.*, 2019). The first stage of the approach will use a linear mixed effect model (Lee *et al.*, 2011). In these models, the fixed-effect term explains the average effect of the relationship between the independent variables and $PM_{2.5}$ concentrations during the whole study period. The random effect explains, for each day, the variation in this relationship. Both the fixed and random effect slopes are assumed to be the same for all sites. In addition to the presence or absence of smoke and the observed GOES AOD, meteorological variables (*e.g.*, temperature, RH, PBL height), the estimated smoke plume heights from Task 2, and other variables will be tested as predictors for the smoke AOD/$PM_{2.5}$ relationship. The second stage will use geographically weighted regression (GWR, van Donkelaar *et al.*, 2015) to develop site-specific corrections for the smoke AOD/$PM_{2.5}$ relationship, using geographic variables (*e.g.*, % urban cover nearby, population density) as predictors. We will explore training two separate statistical models, one for smoke-influenced days and one for days without observed smoke and use the difference between these model predictions on smoky days to estimate the impact of smoke on surface $PM_{2.5}$.

In addition, we will test one model-based approach where output from a chemical transport model is used to estimate the relationship between AOD and surface $PM_{2.5}$ (*e.g.*, van Donkelaar *et al.*, 2015) and the modeled surface $PM_{2.5}$ estimate is scaled up to match the observed AOD. We will use the predictions from the 3-km resolution HRRR WRF-Chem smoke forecasts (Ahmadov *et al.*, 2017) to estimate the vertical profile of the smoke plumes. The AOD for these profiles will be calculated using the smoke aerosol model from the GOES AOD retrievals.

7. Model Coding

The models described in Section 6 will be derived using the R software language, and R scripts used in deriving and applying the generated models will be supplied to TCEQ at the end of the project. All other software developed in this project will be in R, Python, Perl, or Microsoft Excel®, depending on which is most useful for each part of the task, and will be supplied to TCEQ along with the Final Report.

8. Model Calibration

Model calibration is defined as "adjusting model parameters within physically defensible ranges until the resulting predictions give the best possible or desired degree of fit to the observed data." The parameters of the statistical models will be determined using the R software environment. Different combinations of predictor variables will be evaluated as part of the model development. The most physically meaningful and statistically important variables will be selected using standard, non-automated methods, such as "backward one variable deletion" based on the F statistic (Venables and Ripley, 2002). Model residuals will be analyzed as well to determine the importance of different meteorological variables. Highly correlated variables will be excluded from the process, and only variables that are statistically significant will be retained. The predictive power of the models will be measured by the square of the Pearson correlation statistic (R^2). All predictor variables and relationships will be reviewed to ensure that in our expert judgment the models represent plausible causal relationships between the predictor variables and surface $PM_{2.5}$, rather than chance correlations.

9. Model Verification

Model verification is defined as "comparing the predictions of a calibrated model with data that were not used in the model development and calibration." One of the dangers of using statistical models is the possibility of "over-fitting" the models, where the model has enough free parameters that its fit to the training set is much better than its performance in forecasting. To evaluate this, 30% of the original data set will be set aside to use for model verification purposes. AER will use this verification data set to explore the potential errors from over-fitting as part of our evaluation.

Best-fit lines for plots of the observed (x-axis) and hind-cast (y-axis) total and smoke $PM_{2.5}$ values will be computed via ordinary least squares regression. Statistics such as the OLS slope, the Pearson linear correlation coefficient (r) and the mean (μ) and standard deviation (σ) of the residuals will also be used to evaluate the quantitative model performance.

10. Model Evaluation

10.1. Evaluation techniques

The predictive power of the statistical models will be evaluated as described in Section 8, while the performance of the models in predicting 'unseen' data will be assessed as described in Section 9. In addition, AER personnel will use their expert judgment to evaluate the performance of the models. The causal nature of the relationships captured by the models will be evaluated against our conceptual understanding of the relationships between AOD and surface $PM_{2.5}$. Any identified significant predictors without such conceptual causal relationships will be identified, and separate models that do not include the questionable predictors will be produced. The residuals of the models will be examined, and any days with extreme residuals will be flagged for further analysis.

10.2. Peer Review and Reconciliation with User Requirements

The information collected from the exercises described in Sections 8, 9, and 10.1 will be used to make a final, overall assessment of the model and data usability that will be included in the final report. This assessment will address the following questions:

- Do the relationships described in the developed models make physical sense given our conceptual models of smoke transport, AOD, and surface $PM_{2.5}$?
- Are these relationships consistent with the scientific literature?
- Under what conditions are the models expected to be valid? What conditions give exceptionally large residuals?
- What are the bias and error characteristics of the models?

11. Model Documentation

As part of the Final Report, AER will prepare and deliver a technical memo describing the developed models for converting AOD to surface PM2.5 estimates as well as a User's Guide for the models. This documentation will include:

- The final model description, hardware and software requirements, including programming language, model portability, memory requirements, required hardware/software for application, and data standards for information storage and retrieval
- The equations on which the model is based
- The underlying assumptions used in the model development
- Flow charts of model inputs, processing, and outputs
- Descriptions of the software routines
- Data base description
- A copy of the source code
- Explanation of error messages
- Parameter values and sources

- Restrictions on model application, including assumptions, parameter values and sources, boundary and initial conditions, validation/calibration of the model, output and interpretation of model runs;
- Limiting conditions on model applications, with details on where the model is or is not suited
- Actual input data (type and format) used
- Overview of the immediate (non-manipulated or post-processed) results of the model runs
- Output of model runs and interpretation
- User's guide (electronic or paper)
- Instructions for preparing data files
- Example problems complete with input and output
- A report of the model calibration, validation, and evaluation.

12. Reporting

12.1. Deliverables

The deliverables for the project are listed in the Scope of Work and reproduced below. The PM Matthew Alvarado is responsible for evaluating the quality of all deliverables prior to delivery.

AQRP requires certain reports to be submitted on a timely basis and at regular intervals. A description of the specific reports to be submitted and their due dates are outlined below. One report per project will be submitted (collaborators will not submit separate reports), with the exception of the Financial Status Reports (FSRs). The lead PI will submit the reports, unless that responsibility is otherwise delegated with the approval of the Project Manager. All reports will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources. Report templates and accessibility guidelines found on the AQRP website at http://aqrp.ceer.utexas.edu/ will be followed.

Abstract: At the beginning of the project, an Abstract will be submitted to the Project Manager for use on the AQRP website. The Abstract will provide a brief description of the planned project activities, and will be written for a non-technical audience.

Abstract Due Date: Friday, July 31, 2020

Quarterly Reports: Each Quarterly Report will provide a summary of the project status for each reporting period. It will be submitted to the Project Manager as a Microsoft Word file. It will not exceed 2 pages and will be text only. No cover page is required. This document will be inserted into an AQRP compiled report to the TCEQ.

Quarterly Report Due Dates:

Report	Period Covered	Due Date
Quarterly Report #1	May, June, July 2020	Friday, July 31, 2020
Quarterly Report #2	August, September, October 2020	Friday, October 30, 2020
Quarterly Report #3	November, December 2020, January 2021	Friday, January 29, 2021
Quarterly Report #4	February, March, April 2021	Friday, April 30, 2021
Quarterly Report #5	May, June, July 2021	Friday, July 30, 2021
Quarterly Report #6	August, September, October 2021	Friday, October 29, 2021

Monthly Technical Reports (MTRs): Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison in Microsoft Word format using the AQRP FY20-21 MTR Template found on the AQRP website.

MTR Due Dates:

Report	Period Covered	Due Date
Technical Report #1	Project Start - June 30, 2020	Wednesday, June 10, 2020
Technical Report #2	July 1 - 31, 2020	Friday, July 10, 2020
Technical Report #3	August 1 - 31, 2020	Monday, August 10, 2020
Technical Report #4	September 1 - 30 2020	Thursday, September 10, 2020
Technical Report #5	October 1 - 31, 2020	Friday, October 9, 2020
Technical Report #6	November 1 - 30, 2020	Tuesday, November 10, 2020
Technical Report #7	December 1 - 31, 2020	Thursday, December 10, 2020
Technical Report #8	January 1 - 31, 2021	Friday, January 8, 2021
Technical Report #9	February 1 - 28, 2021	Wednesday, February 10, 2021
Technical Report #10	March 1 - 31, 2021	Wednesday, March 10, 2021

Technical Report #11	April 1 - 30, 2021	Friday, April 9, 2021
Technical Report #12	May 1 - 31, 2021	Monday, May 10, 2021
Technical Report #13	June 1 - 30, 2021	Thursday, June 10, 2021
Technical Report #14	July 1 - 31, 2021	Friday, July 9, 2021

DUE TO PROJECT MANAGER

Financial Status Reports (FSRs): Financial Status Reports will be submitted monthly to the AQRP Grant Manager (RoseAnna Goewey) by each institution on the project using the AQRP 20-21 FSR Template found on the AQRP website.

FSR Due Dates:

Report	Period Covered	Due Date
FSR #1	Project Start - June 30	Wednesday, July 15, 2020
FSR #2	July 1 - 31, 2020	Friday, August 14, 2020
FSR #3	August 1 - 31, 2020	Tuesday, September 15, 2020
FSR #4	September 1 - 30 2020	Thursday, October 15, 2020
FSR #5	October 1 - 31, 2020	Friday, November 13, 2020
FSR #6	November 1 - 31, 2020	Tuesday, December 15, 2020
FSR #7	December 1 - 31, 2020	Friday, January 15, 2021
FSR #8	January 1 - 31, 2021	Monday, February 15, 2021
FSR #9	February 1 - 28, 2021	Monday, March 15, 2021
FSR #10	March 1 - 31, 2021	Thursday, April 15, 2021
FSR #11	April 1 - 30, 2021	Friday, May 14, 2021

FSR #12	**May 1 - 31, 2021**	**Tuesday, June 15, 2021**
FSR #13	**June 1 - 30, 2021**	**Thursday, July 15, 2021**
FSR #14	**July 1 - 31, 2021**	**Friday, August 13, 2021**
FSR #15	**August 1 - 31, 2021**	**Wednesday, September 14, 2021**
FSR #16	**Final FSR**	**Friday, October 15, 2021**

DUE TO GRANT MANAGER

Draft Final Report: A Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will include an Executive Summary. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources. It will also include a report of the QA findings.

Draft Final Report Due Date: Monday, August 2, 2021

Final Report: A Final Report incorporating comments from the AQRP and TCEQ review of the Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources.

Final Report Due Date: Tuesday, August 31, 2021

Project Data: All project data including but not limited to QA/QC measurement data, metadata, databases, modeling inputs and outputs, etc., will be submitted to the AQRP Project Manager within 30 days of project completion (September 20, 2021). The data will be submitted in a format that will allow AQRP or TCEQ or other outside parties to utilize the information. It will also include a report of the QA findings.

AQRP Workshop: A representative from the project will present at the AQRP Workshop in the first half of August 2021.

Presentations and Publications/Posters: All data and other information developed under this project which is included in **published papers, symposia, presentations, press releases, websites and/or other publications** shall be submitted to the AQRP Project Manager and the TCEQ Liaison per the Publication/Publicity Guidelines included in Attachment G of the Subaward.

12.2. Final Report

AER will deliver a draft Final Report to the TCEQ Project Manager electronically (i.e., via file transfer protocol (FTP) or e-mail) in an accessible Microsoft Word® format no later than August 2, 2021. AER will deliver a Final Report to the TCEQ Project Manager electronically (i.e., via file transfer protocol (FTP) or e-mail) in an accessible Microsoft Word® format no later than August 31, 2021. The draft Final Report and Final Report will include the following components:

- An executive summary or abstract.
- A brief introduction that discusses background and objectives, including relationships to other studies if applicable.
- A discussion of the pertinent accomplishments, shortfalls, and limitations of the work completed under each Work Plan task.
- Recommendations, if any, for what should be considered next as a new study.

The Final Report will provide a comprehensive overview of activities undertaken and data collected and analyzed during the work. The Final Report will highlight major activities and key findings, provide pertinent analysis, describe encountered problems and associated corrective actions, and detail relevant statistics including data, parameter, or model completeness, accuracy and precision. All QA findings will also be included in the final report. The Final Report and any documents and electronic files will be updated based upon comments from TCEQ.

In preparing the report, AER will thoroughly document the technical literature cited and data sources used. AER will provide electronic copies of all data sets used to prepare the forecast models in comma separated value (*.csv) format along with separate files documenting variable definitions and explanations for any coding used in the data. The files will be saved in a compressed (*.zip) electronic file format and made available via AER's ftp site. AER shall also provide electronic copies of R scripts and other computer codes used to process and/or analyze the data used in this project as part of the Draft and Final Reports.

AER will deliver the Final Report to the TCEQ in electronic format. An electronic copy of the Final Report will be provided in MS Word® and in Adobe PDF via ftp download and/or e-mail.

13. References

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