Quality Assurance Project Plan

Project 16 – 008
High Background Ozone Events in the Houston-Galveston-Brazoria Area: Causes, Effects, and Case Studies of Central American Fires

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

Prepared by

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Version 4

The University of Houston has prepared this QAPP following EPA guidelines for a Quality Assurance (QA) Category IV Project: Research Model Development and Application. 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, Model Selection, Model Calibration, Model Verification, Model Evaluation, Model Documentation, Reporting, and References.

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 "High Background Ozone Events in the Houston-Galveston-Brazoria Area: Causes, Effects, and Case Studies of Central American Fires" project. The Principal Investigator for the project is Yuxuan Wang and the Co-PI is Robert Talbot.

Electronic Approvals:

This QAPP was approved electronically on 8/26/2016 by Elena McDonald-Buller, The University of Texas at Austin.

Elena McDonald-Buller
Project Manager, Texas Air Quality Research Program

This QAPP was approved electronically on 8/29/2016 by Vincent M. Torres, The University of Texas at Austin.

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This QAPP was approved electronically on 8/25/2016 by Yuxuan Wang, The University of Houston.

Yuxuan Wang
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QAPP Distribution List

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1.0 Project Description and Objectives

1.1 Project Objectives

A significant fraction of surface ozone in Texas comes from regional background originating from outside of Texas, with an estimated range of 20 ~ 50 ppbv (Zhang et al., 2011; McDonald-Buller et al., 2011; Fiore et al., 2014). Background ozone is expected to vary substantially from day to day as a result of meteorological variability and emissions (e.g., wildfires, and lightning). There are only a few case studies of high background ozone events in Texas, mostly focusing on short periods of aircraft campaigns (e.g., Langford et al., 2009) and single episodes (e.g., Morris et al., 2006). Background ozone contributes more than 50% to the HGB MDA8 ozone and explains 63-83% of the MDA8 ozone variability during the ozone season (Berlin et al., 2013). Given this substantial contribution, it is important to identify extreme events of high background ozone over the HGB area over a longer time period, plus characterize common features and drivers of these events, and understand their effects on ozone exceedance. This project is directed at addressing these questions.

Episodic emissions such as wildfires are important drivers of short-term enhancement in background ozone (Morris et al., 2006). Internationally, Mexico and Central America is a large fire region of unique importance to Texas air quality and its background ozone (Wang et al., 2006; Alvarez, 2009). The Central America fire season peaks in spring (Apr-May), coincident with the start of the ozone season in Texas. The transport of Central American wildfire emissions into Texas is largely steered by the Bermuda High (Wang et al., 2009), the same large-scale circulation pattern controlling the maritime background ozone into the HGB area (Wang et al., 2015). The implication of this linkage on HGB background ozone has not been investigated in prior analyses. Here we hypothesize that wildfire emissions originating from Central America can cause significant perturbations to chemical composition of the otherwise clean maritime air masses flowing into the HGB area, resulting in short-term enhancements in background ozone. The project will test this hypothesis by quantifying the contribution of Central American fires to background ozone in the HGB area.

The project aims to improve the current understanding of the causes and effects of high background ozone events in the HGB area. The specific objectives are:

1) To identify days/events of high background ozone in the HGB region and characterize meteorological conditions and emission anomalies for those cases;
2) To distinguish the effect of high background ozone versus local ozone production on daily MDA8 ozone concentration and exceedances; and
3) To quantify the contribution of wildfire emissions from Central America on background ozone in Texas and the HGB area.

To achieve these objectives, the GEOS-Chem global chemical transport model and its nested-grid version will be applied to simulate the effects of Central American fires on high background ozone events over the HGB region. The time periods that this project will be focused on are from April to October (ozone season) over the period 2000 to 2015 when routine surface measurements of ozone, aircraft, and satellite remote sensing data are available and well maintained.

1.2 Project Data and Model

Secondary data used in the project include: (1) daily HGB background ozone estimates from the TCEQ (Estes et al., 2014) which cover the period from 2000 to 2013; (2) CAMSs data of MDA8 ozone over the HGB region which will be downloaded in ASCII format from the EPA AirData website (https://www3.epa.gov/airquality/airdata/) with additional data at supplementary sites from the TCEQ; (3) meteorological data from the National Centers for Environmental Prediction (NCEP) North America Regional Reanalysis (spatial resolution of ~32 km); and (4) Fire INventory from NCAR (FINN) compiled by Wiedinmyer et al. (2011) that provides daily, 1 km resolution, global estimates of the trace gas and particle emissions from open burning of biomass. Those data will be used to identify high background ozone and MDA8 ozone days and other relevant 'event days' such as heat waves, stagnation, cold fronts and Central America fire events.

The GEOS-Chem global chemical transport model and its nested-grid version over North America will be used to simulate the periods of selected case studies of Central American fires. The case studies will include previously identified large events of Central American fires that adversely affected air quality in Texas, including late Apr – May 2003 (Levinson and Waple, 2004; Wang et al., 2006), Apr 2011 (Saide et al., 2015), Apr 2013, and Apr 2015 (http://www.nasa.gov/ mission_pages/fires/main/world/20130412-centralamerica.html; http://www.nasa.gov/image-feature/fires-in-the-yucatan-peninsula-april-2015). The GEOS-Chem model will be driven by the GEOS-5 assimilated meteorology and uses the FINN inventory for biomass burning emissions. Long-range transport of gaseous emissions (NO_x, VOCs, and CO) from Central American fires will be simulated and perturbations of these fire events to background ozone concentrations in Texas will be quantified through the difference in model results with and without fire emissions in Central America.

2.0 Organization and Responsibilities

2.1 Project Personnel

The project will be directed by a collaborative team of two PIs: Dr. Yuxuan Wang (PI) and Dr. Robert Talbot (Co-PI) at the University of Houston (UH). The PIs will be supported by a group of graduate students and undergraduate students in the Department of Earth and Atmospheric Sciences at UH. Both PIs and their graduate students will be involved collaboratively in all the tasks and reporting. Specifically, Dr. Wang and her team will lead the analyses of meteorological conditions (Task 2) and GEOS-Chem modeling (Task 3); Dr. Talbot and his team will lead the analysis of ozone and meteorological data to identify different types of events (Task 1) and their respective effects on HGB ozone exceedances (Task 4). Project participants and their responsibilities are listed in Table 1.

Table 1. Project participants and key responsibilities

Participant	Project Responsibility
Dr. Yuxuan Wang	Principal investigator (PI). Overseeing all aspects of this project and quality assurance; supervising PhD graduate students and undergraduate research assistants to work on Task 2 and 3; project reporting and presentation; responsible for quality assurance (QA) of the project deliverables.
Dr. Robert Talbot	Co-PI. Supervising PhD graduate students and undergraduate research assistants to work on Task 1 and 4; project reporting and presentation; responsible for quality assurance (QA) of the project deliverables.
Sally Sing-Chun Wang	PhD. student working with Dr. Wang on Task 2 and 3.
Ruixue Lei	PhD. student working with Dr. Talbot on Task 1 and 4.
Ph.D. Student (TBD)	PhD student working with Dr. Wang on analysis of GEOS-Chem model outputs.
Undergraduate student (TBD)	Undergraduate research assistants working with Dr. Wang and Dr. Talbot on compilation of ozone monitoring data.
Undergraduate student (TBD)	Undergraduate research assistants working with Dr. Wang and Dr. Talbot on compilation of meteorological data.
Undergraduate students (TBD)	Undergraduate research assistants working with Dr. Wang and Dr. Talbot on analysis of fire data and model outputs.

2.2 Project Schedule

The overall schedule of the project is presented in Table 2. The key milestones of the project are listed below:

- Nov 30 2016 - **Deliverable 1**: Monthly reports describing selected background ozone and MDA8 ozone 'event days' and meteorological 'event days'.
- Mar 1 2017 - **Deliverable 2**: Monthly reports describing meteorological conditions causing high background ozone days and exceptional background ozone events in the HGB area; statistics of the occurrences of those conditions by month, season, and year; and quantitative analyses of background ozone characteristics under different types of meteorological events.
- May 15 2017 - **Deliverable 3**: Distribution maps of anomalous fire emissions during high background ozone days; Monthly reports describing emissions and meteorological conditions for each of the case studies of large fire events from Central America; and GEOS-Chem simulation results of the selected case studies of Central American fires on background ozone in Texas and the HGB area; and manuscripts in draft for publication in high-impact journals.
- Aug 1 2017 - **Deliverable 4**: Monthly reports presenting quantitative estimates of the effects of background ozone versus local production on ozone exceedance cases in the HGB area; and the dependence of such effects as meteorology, and fire

emissions; and publication of the manuscripts presenting project results in high-impact journals.

Table 2. Project schedule by tasks.

Task **Months**	**2016 9-10**	**2016 11-12**	**2017 1-2**	**2017 3-4**	**2017 5-6**	**2017 7-8**
Task 1. Identify high background ozone days and other events						
Task 2. Characterize meteorological conditions during high background ozone cases						
Task 3. Analyze case studies of Central American fires on HGB background ozone						
Task 4. Quantify the effect of background ozone on ozone exceedances						
Task 5. Project reporting and presentation						

3.0 Model Selection

The key objective of this project is to quantify the contribution of fire emissions from Central America on background ozone in Texas and the HGB area. To achieve this objective, a 3-D chemical transport model with scales larger than the US continent is required so as to simulate the long-range transport of pollutants from Central America to the US. Additionally, since the origin of background ozone in Texas can be hemispheric and global, the project requires a model that is capable of simulating the world beyond the targeted domain of interests. To meet those requirements, a global 3-D chemical transport model is the ideal candidate.

The key attributes of the candidate model include the following:

- Its ability of simulating long-range transport of pollutants has been recognized;
- It has a deterministic structure;
- It has a coupled ozone-aerosol chemical mechanism;
- It is driven by meteorological fields that are specific to the simulation periods rather than climatological mean conditions;
- Its domain is at least hemispheric or with dynamic boundary conditions provided by a global model;
- It is 3-dimensional and has the spatial resolution finer than 100 km over the targeted region (Texas and Central America);
- It can simulate the study period from 2000 to present;
- Its dynamic time step is less than 30 min so as to capture the dynamics of transport associated with turbulence and convection.

Based on those attributes, the GEOS-Chem 3-D global chemical transport model and its nested-grid version over North America (NA) (www.geos-chem.org) are selected. No other global chemical transport models (CTM) were considered for three reasons. First, the GEOS-Chem CTM has arguably the largest user base among all the global CTMs and the state-of-the-art tropospheric chemistry. Second, the regulatory models of TCEQ use chemical boundary conditions from the GEOS-Chem global CTM. Third, the GEOS-Chem global CTM has the nested-grid simulation capability, which offers a finer-resolution simulation over the US (0.5^{o} latitude x 0.667^{o} longitude) than other global CTMs with a typical resolution of 1^{o} latitude x 1^{o} longitude.

The GEOS-Chem model includes a detailed NOx-Ox-hydrocarbon-aerosol-bromine tropospheric chemistry mechanism and has a dynamic time step of less than 10 min. The GEOS-Chem model will be driven by the GEOS-5 assimilated meteorology and uses the FINN inventory for biomass burning emissions. The global version has a horizontal resolution of 2^{o} latitude x 2.5^{o} longitude and the NA-nested grid version has a horizontal resolution of 0.5^{o} latitude x 0.667^{o} longitude. The GEOS-Chem model has been used in several prior investigations of background ozone levels in the US (Fiore et al, 2002; Zhang et al., 2011). Its outputs also provide chemical boundary conditions for the regulatory models at TCEQ.

4.0 Model Calibration

The GEOS-Chem global chemical transport model has a standard benchmarking procedure for each major code release, using observations compiled from surface monitoring network, aircraft campaigns, and satellite retrievals around the globe. During the benchmarking procedure, each module of the model, including transport, emission, chemistry, dry deposition, and wet deposition, is calibrated and best parameters are chosen based on the benchmarking results. For example, observed global distribution of radon is used to calibrate the transport process. This project will use the GEOS-Chem code version v10-01, the most recent public release of GEOS-Chem to date, which has gone through thorough the benchmarking procedure.

5.0 Model Verification

Since the goal of the project is to estimate the effects of Central American fires on Texas ozone, the objective of model verification is to use existing observations to verify the model's ability to simulate the overall features of ozone, its precursors, and aerosols related to fire emissions over Texas (receptor region) and Central America (source region) during April-May of the study period (2000-2015), the months when the Central America fires peak seasonally. The GEOS-Chem model will be verified by comparing the model prediction of aerosol optical depths (AOD), tropospheric columns of NO_2 (an ozone precursor), surface ozone and fine particulate matters ($PM_{2.5}$). The existing observations that will be used to verify the model include AOD across the Gulf of Mexico retrieved from satellite instruments, such as MODerate resolution Imaging

Spectroradiometer (MODIS), tropospheric NO_2 columns from Ozone Monitor Instrument (OMI), surface observations of ozone and $PM_{2.5}$ in the southern US (defined to include Texas and neighboring states) available from the EPA AirData (https://www3.epa.gov/airquality/airdata/), and additional data at supplementary sites in Texas from the TCEQ and UH, including the UH Moody tower site, surface ozone monitors not included in the EPA database, and ozonesonde profiles (http://physics.valpo.edu/ozone/). We will follow the quality assurance and quality control protocols of those data sources and document the data versions used in the project. For example, the MODIS AOD data will be screened by their retrieval quality flags and data completeness at surface sites will be checked before spatial and temporal aggregation. Those various datasets have different temporal and spatial coverage, e.g. 2000-present for MODIS AOD at a resolution of 10 km x 10 km, 2006-present for OMI NO_2 of 24 km x 13 km, and approximately 1990-present for EPA AirData. These observations will be mapped onto the GEOS-Chem grids for model verification. The model verification uses the same metrics described in the Model Evaluation section (Table 3) and will be conducted across the whole months of April-May of each year (2000-2015). By comparison, model evaluation (Section 6.0) will focus on the days of fire events.

In addition, model sensitivity simulations will be conducted to verify the capability of the model to capture the perturbations in atmospheric composition by Central American fires. In the sensitivity simulations, fire emissions from Central America in the FINN inventory will be turned off in each case study. Differences in model results between the sensitivity simulations and the corresponding standard model simulations (using the FINN inventory) will be quantified statistically (e.g. mean, median, range, and distribution). The existing data of observations described above will be used to compare with the results of the sensitivity simulations to verify the extent to which the FINN inventory, through GEOS-Chem's processing, can capture the signal of Central America fires contained in those observations. Since biomass burning emissions are highly variable, for a particular onshore transport pattern from the Gulf of Mexico, one can expect to have different wildfire signals for different days and different years. This variability will allow us to detect the signals of fires from Central America in each of the observational datasets. Inconsistencies will likely arise in the detection of those signals among the different datasets. We will address those inconsistencies taking into account different sensitivities between the observational platforms to detect fire emissions, e.g. surface-based versus satellite.

6.0 Model Evaluation

The GEOS-Chem model's performance in simulating surface ozone over the HGB region will be evaluated using CAMSs data of MDA8 ozone in this region. The focus will be on previously identified large events of Central American fires that adversely affected air quality in Texas (e.g. Apr – May 2003, Apr 2011, Apr 2013, and Apr 2015). Note that the CAMSs data over urban regions (such as HGB) are not used in the GEOS-Chem benchmarking procedure since the benchmark is oriented toward a global perspective rather than urban air quality. Interactive Data Language (IDL) programs will be used to visualize and extract the corresponding model outputs for the comparisons with the observational data. The model evaluation will use the performance metrics listed in Table 3. These particular metrics were selected because they are among the most commonly used standard statistical metrics to evaluate the simulated variability (e.g. correlation coefficient) and magnitudes in both absolute (MB, MAE) and relative terms (NMB). The RMSE gives more weights to model errors with larger absolute values than MAE, making it more appropriate to evaluate the model's ability to simulate the fire cases. GEOS-Chem has known positive bias in simulating surface ozone over coastal regions, and such bias will be quantified during the evaluation process and removed from subsequent analyses. If the model bias would not show pronounced temporal variability, it will be regarded as systematic that does not affect the simulated ozone enhancement due to Central American fires. If the model bias would exhibit a large day-to-day variability, we will use a simple regression analysis to correlate the model bias with meteorological parameters (such as winds, temperature, the Bermuda High indices) during the days without fires and apply such regression relationships to estimate the model bias during the fire cases on the daily basis. We have demonstrated the utility of such regression approach to reduce GEOS-Chem model bias over HGB in our prior AQRP project (14-016).

The metrics of model evaluation will be compared with published results of GEOS-Chem ozone simulation (e.g. Zhang et al., 2011). We will also invite a few members from the GEOS-Chem development team and users' community to review at least 10% of the modeling results; potential peer reviewers are Dr. Daniel Jacob at Harvard University and Dr. Lin Zhang at Peking University.

Table 3. Performance metrics of model evaluation.

Mean Bias (MB)	$MB = 1/N\sum_{i=1}^{N}(M_i - O_i)$
Mean Absolute Error (MAE)	$MAE = 1/N\sum_{i=1}^{N}\lvert M_i - O_i \rvert$
Normalized Mean Bias (NMB)	$NMB = \frac{\sum_{i=1}^{N}(M_i - O_i)}{\sum_{i=1}^{N}O_i} \times 100\%$
Correlation Coefficient (Corr. R)	$Corr.R = \frac{\sum_{i=1}^{N}(M_i - \overline{M})(O_i - \overline{O})}{\sqrt{\sum_{i=1}^{N}(M_i - \overline{M})^2}\sqrt{\sum_{i=1}^{N}(O_i - \overline{O})^2}}$
Root Mean Square Error (RMSE)	$RMSE = \sqrt{1/N\sum_{i=1}^{N}(M_i - O_i)^2}$

Note: M is the model output, O is the observation, N is the number of samples, and $\overline{M} = 1/N\sum_{i=1}^{N} M_i$, $\overline{O} = 1/N\sum_{i=1}^{N} O_i$.

7.0 Model Documentation

We will maintain documentation files for each model run that identifies model code versions, dates, analyses, and input and output files. Each input/output file used will be reviewed for quality assurance purposes using various visualization methods, including software animations and graphing, as well by quantitative filtering using selected filter criteria to identify anomalous data. The model documentation will include summaries of the input file values that were changed, the boundary conditions, and why the changes were made; the analysis of the output files, and any other important instructions required to replicate the each run.

8.0 Reporting

8.1 Deliverables

- **Deliverable 1**: Technical memo describing selected background ozone and MDA8 ozone ‘event days’ and meteorological ‘event days’.
- **Deliverable 2**: Technical memo describing meteorological conditions causing high background ozone days and exceptional background ozone events in the HGB area; statistics of the occurrences of those conditions by month, season, and year; and quantitative analyses of background ozone characteristics under different types of meteorological events.
- **Deliverable 3**: Distribution maps of anomalous fire emissions during high background ozone days; technical memo describing emissions and meteorological conditions for each of the case studies of large fire events from Central America; and GEOS-Chem simulation results of the selected case studies of Central American fires on background ozone in Texas and the HGB area; and manuscripts in draft for publication in high-impact journals.
- **Deliverable 4**: Technical memo presenting quantitative estimates of the effects of background ozone versus local production on ozone exceedance cases in the HGB area; and the dependence of such effects meteorology, and fire emissions; and publication of the manuscripts presenting project results in high-impact journals.

8.2 Reports

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: Wednesday, August 31, 2016

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
Aug2016 Quarterly Report	June, July, August 2016	Wednesday, August 31, 2016
Nov2016 Quarterly Report	September, October, November 2016	Wednesday, November 30, 2016
Feb2017 Quarterly Report	December 2016, January & February 2017	Tuesday, February 28, 2017
May2017 Quarterly Report	March, April, May 2017	Friday, May 31, 2017
Aug2017 Quarterly Report	June, July, August 2017	Thursday, August 31, 2017
Nov2017 Quarterly Report	September, October, November 2017	Thursday, November 30, 2017

Monthly Technical Reports (MTRs): Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison in Microsoft Word format using the AQRP FY16-17 MTR Template found on the AQRP website.

MTR Due Dates:

Report	Period Covered	Due Date
Aug2016 MTR	Project Start - August 31, 2016	Thursday, September 8, 2016
Sep2016 MTR	September 1 - 30, 2016	Monday, October 10, 2016
Oct2016 MTR	October 1 - 31, 2016	Tuesday, November 8, 2016
Nov2016 MTR	November 1 - 30 2016	Thursday, December 8, 2016
Dec2016 MTR	December 1 - 31, 2016	Monday, January 9, 2017

Jan2017 MTR	January 1 - 31, 2017	Wednesday, February 8, 2017
Feb2017 MTR	February 1 - 28, 2017	Wednesday, March 8, 2017
Mar2017 MTR	March 1 - 31, 2017	Monday, April 10, 2017
Apr2017 MTR	April 1 - 28, 2017	Monday, May 8, 2017
May2017 MTR	May 1 - 31, 2017	Thursday, June 8, 2017
Jun2017 MTR	June 1 - 30, 2017	Monday, July 10, 2017
Jul2017 MTR	July 1 - 31, 2017	Tuesday, August 8, 2017

Financial Status Reports (FSRs): Financial Status Reports will be submitted monthly to the AQRP Grant Manager (Maria Stanzione) by each institution on the project using the AQRP FY16-17 FSR Template found on the AQRP website.

FSR Due Dates:

Report	Period Covered	Due Date
Aug2016 FSR	Project Start - August 31	Thursday, September 15, 2016
Sep2016 FSR	September 1 - 30, 2016	Monday, October 17, 2016
Oct2016 FSR	October 1 - 31, 2016	Tuesday, November 15, 2016
Nov2016 FSR	November 1 - 30 2016	Thursday, December 15, 2016
Dec2016 FSR	December 1 - 31, 2016	Tuesday, January 17, 2017
Jan2017 FSR	January 1 - 31, 2017	Wednesday, February 15, 2017
Feb2017 FSR	February 1 - 28, 2017	Wednesday, March 15, 2017
Mar2017 FSR	March 1 - 31, 2017	Monday, April 17, 2017
Apr2017 FSR	April 1 - 28, 2017	Monday, May 15, 2017
May2017 FSR	May 1 - 31, 2017	Thursday, June 15, 2017
Jun2017 FSR	June 1 - 30, 2017	Monday, July 17, 2017
Jul2017 FSR	July 1 - 31, 2017	Tuesday, August 15, 2017
Aug2017 FSR	August 1 - 31, 2017	Friday, September 15, 2017
FINAL FSR	Final FSR	Monday, October 16, 2017

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: Tuesday, August 1, 2017

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: Thursday, August 31, 2017

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 29, 2017). 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. Dr. Yuxuan Wang at UH (PI) will retain all project data for a minimum period of five years.

AQRP Workshop: A representative from the project will present at the AQRP Workshop in the first half of August 2017.

9.0 References

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