Quality Assurance Project Plan

Project 17-032

Spatial Mapping of Ozone Formation near San Antonio

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

Prepared by

Ezra Wood
Department of Chemistry, Drexel University

12/05/2016
Version #3

Ezra Wood / Drexel University has prepared this QAPP following EPA guidelines for a Quality Assurance (QA) Category III Project: Measurement. 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, 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 Project 16-032, "Spatial Mapping of Ozone Formation near San Antonio". The Principal Investigator for the project is Ezra Wood.

Electronic Approvals:

This QAPP was approved electronically on 12/06/2016 by Gary McGaughey, The University of Texas at Austin.

Gary McGaughey
Project Manager, Texas Air Quality Research Program

This QAPP was approved electronically on 09/28/2016 by Vincent M. Torres, The University of Texas at Austin.

Vincent M. Torres
Quality Assurance Project Plan Manager, Texas Air Quality Research Program

This QAPP was approved electronically on 09/29/2016 by Ezra Wood, The University of Texas at Austin.

Ezra Wood
Principal Investigator, Drexel University

QAPP Distribution List

Texas Air Quality Research Program

David Allen, Director

Gary McGaughey, Project Manager

Texas Commission on Environmental Quality

Mark Estes, Project Liaison

Drexel University

Ezra Wood, Principal Investigator

Contents

1. PROJECT DESCRIPTION AND OBJECTIVES

1.1 Description of Environmental system to be evaluated.
Ozone is the main component of smog and has adverse effects on human health and vegetation. Unlike primary pollutants like carbon monoxide or black carbon, ozone is formed by photochemical reactions involving volatile organic compound (VOCs) and nitrogen oxides (NOx). In contrast to Houston and Dallas, little is known about ozone formation in San Antonio.

The rate at which ozone is formed is effectively equal to the rate at which NO is converted to NO_2 by reaction with peroxy radicals (e.g., $C_3H_7O_2$, which is formed by the photo-oxidation of propane, and HO_2):

$$P(O_3) = k_{HO2+NO}[HO_2][NO] + k_{RO2+NO}[RO_2][NO] \qquad \text{Eq. 1}$$

"RO_2" represents all organic peroxy radicals (e.g., CH_3O_2, $C_2H_5O_2$, etc.)

Due to the various radical termination steps such as formation of H_2O_2 and HNO_3, the value of $P(O_3)$ does not always simply increase with increased concentrations of VOCs or NOx. Ozone production is said to be "NOx-limited" if, due to low NO concentrations, peroxy radicals react with themselves rather than with NO. Conversely, ozone formation is "VOC-limited" (or "NOx-saturated") if HOx radicals (OH, RO_2, HO_2) are mainly lost via reactions with NO$_x$. Knowing in which chemical regime an air mass resides is crucial for designing effective ozone abatement strategies, since reducing NOx emissions can lead to undesirable *increases* in ozone formation rates if the air is in a VOC-limited state. This is the case in southern California, evident by the higher ozone observed on weekends when there is reduced NOx emissions due to lower diesel truck traffic ([Pollack et al., 2012](#)).

To address ozone air quality problems, regulators need to know the following:
- Which VOCs act as the "fuel" for ozone formation and from which emission sources?
- What are the absolute ozone production rates in ppb/hr?
- How much ozone is produced locally and how much is transported from upwind?
- Does ozone formation occur under NOx-limited or VOC-limited chemical conditions?

By measuring total peroxy radicals and NO and evaluating Eq. 1 above, the absolute rates of ozone formation in the greater San Antonio area will be quantified aboard a mobile measurement platform (the Aerodyne mobile laboratory) and "mapped" in this project.

1.2 Purpose of the project and specific project objective(s).
The purpose of the project is to provide useful data and analysis for policymakers regarding ozone formation in San Antonio. This project will quantify how much ozone is produced locally within the urban core and determine whether ozone

formation is NOx-limited or VOC-limited in San Antonio and in upwind regions. Detailed objectives are to answer the following science questions:

- What are the rates of instantaneous ozone production ($P(O_3)$) upwind, within the urban core, and downwind of San Antonio? How much ozone is produced locally and how much is transported? During what times of day and where (upwind/downwind) is $P(O_3)$ NOx-limited vs. VOC-limited?
These questions will be addressed with mobile measurements of total peroxy radicals and NO, which will be used with equation 1 ($P(O_3) = k_{HO2+NO}[HO_2][NO] + k_{RO2+NO}[RO_2][NO]$) to calculate the rates of ozone formation ($P(O_3)$). The NOx-limited or VOC-limited nature will be investigated by the relationship between $P(O_3)$ and [NO] and will complement separate analyses using radical budgets and indicator species by collaborators at Aerodyne.

- What is the role of alkanes in O_3 formation? Alkanes comprise the majority of emissions from oil and gas activities but not urban or biogenic emissions. *The role of alkanes in San Antonio ozone formation will be probed with both local and integrated markers:*
A. $P(O_3)$ resulting just from alkyl peroxy radicals (formed by the first generation oxidation of alkanes) will be determined using novel measurements of alkyl peroxy radicals. These measurements will be performed by Drexel, using the ECHAMP sensor and the Nafion-based sampling scrubber (see section 5.1)
B. Measurements of total hydroxy and alkyl nitrates will be used to infer the overall alkyl nitrate branching ratio. Higher values imply an important role of RONO_2 as a radical termination step and would likely implicate large (C5-C10) alkanes due to their known high RONO_2 branching ratios. These measurements will be made by Drexel using the thermal dissociation – CAPS technique (see section 5.1)

2. ORGANIZATION AND RESPONSIBILITIES
2.1 Project personnel and responsibilities
The Primary Investigator of this project is Ezra Wood, Associate Professor of Chemistry at Drexel University. Dr. Wood will direct all aspects of the project, mentor the postdoctoral researcher to be hired, and execute the quality assurance (QA) processing of the data.

A postdoctoral researcher will be recruited and hired by January 2016 who will work 25% time on this project. This postdoc will conduct much of the day-to-day operation of the peroxy radical sensor following successful training in its use. If a postdoc cannot be hired, a co-op student will be hired instead who will work 100% on the project for six months.

2.2 Project schedule and key milestones.
The project is divided into six Tasks as described in the Scope of Work. The timing of these tasks along with key outcomes or milestones are described below. Further

information on these tasks is described in the Scope of Work and elsewhere in this document.

Task 4.1: Recruit post-doc (September 2016 – January 2016)
The primary milestone from this task is the successful recruitment of either a post-doc or co-op student.

Task 4.2: Laboratory preparation (February 2017 – April 2017)
The outcome of this task will be successful integration of field-ready instruments into the Aerodyne mobile laboratory.

Task 4.3: Field deployment (May 2017 – June 2017)
The outcome of this task will be the raw data collected during the field deployment planned for late spring 2017 in and around San Antonio.

Task 4.4: Follow-up laboratory work (June 2017 – August 2017)
The outcome of this task is a fuller understanding of the performance of the instruments during the field deployment.

Task 4.5: Data work-up and analysis (August 2017)
The deliverable resulting from this task will be the quality-assured dataset and the project final report which summarizes the preliminary analysis performed.

Task 4.6. Project Reporting and Presentation (September 2016 – August 2017)
This ongoing Task will generate the following Deliverables: Abstract, monthly technical reports, monthly financial status reports, quarterly reports, draft final report, final report, attendance and presentation at AQRP data workshop, submissions of presentations and manuscripts, project data and associated metadata.

3. SCIENTIFIC APPROACH

Experimental design.
The Drexel ECHAMP (Ethane CHemical AMPlifier) peroxy radical sensor will be integrated into the Aerodyne Mobile Laboratory (AML) and quantify concentrations of peroxy radicals ($HO_2 + RO_2$) during driving routes in the greater San Antonio area. Nitric oxide (NO) concentrations will be separately quantified using a Thermo chemiluminescence sensor. This method of quantifying NO is not included in the TCEQ list of NELAP-recognized fields of accreditation. The rate of gross ozone production will be quantified by the following equation:

$$P(O_3) = k_{eff}[HO_2 + \Sigma RO_2][NO]$$

Where $P(O_3)$ is the production rate of ozone (ppb/hr), k_{eff} is the average rate constant for the reaction of HO_2 and individual RO_2 species with NO.

Data will be collected during drives in the AML over periods of several hours across a range of geographic areas that will be recorded with the AML's on-board GPS system.
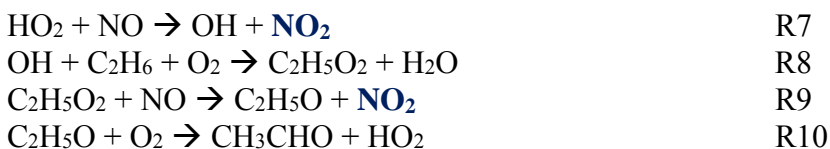
4. SAMPLING PROCEDURES

The ECHAMP sensor is an in situ sensor – ambient air is drawn in to the instrument using a vacuum pump, and the peroxy radical concentrations are analyzed in near real-time. As such, there are no samples to collect or transport back to a laboratory. Air will be sampled into a well-characterized inlet system following successful deployments of the ECHAMP sensor in Bloomington, IN during July 2015 and Pellston, MI during July 2016. Air will be sampled at a flow rate of over 5 standard liters per minute into tubing made of a fluoropolymer (e.g., Teflon or glass coated with halocarbon wax). Sampling losses are quantified based on laboratory tests of sampling losses of radicals and by comparison of the radical signal recorded while sampling a calibration source with the inlet system and with a shorter, minimal system.

5. MEASUREMENT PROCEDURES

5.1. ECHAMP and TD-CAPS methods.

ECHAMP (*Ethane CHemical AMPlifier)* is a newly developed peroxy radical detection method based on the "chemical amplification" (a.k.a. "CHAMP" or "PERCA") technique which has been used with variable success for several decades (Cantrell et al., 1996, Green et al., 2006, Wood and Charest, 2014). Ambient air is drawn into two FEP (Teflon) reaction tubes and mixed with high concentrations of ethane (C_2H_6) and nitric oxide (NO). These reagents participate in the following radical propagation reactions with the sampled peroxy radicals:

|	
$HO_2 + NO \rightarrow OH + \mathbf{NO_2}$	R7
$OH + C_2H_6 + O_2 \rightarrow C_2H_5O_2 + H_2O$	R8
$C_2H_5O_2 + NO \rightarrow C_2H_5O + \mathbf{NO_2}$	R9
$C_2H_5O + O_2 \rightarrow CH_3CHO + HO_2$	R10

The HO_2 produced by reaction 10 can then react with NO again (reaction 7). For each completion of the chain represented by the four reactions above, two NO_2 molecules are produced. Due to radical termination steps (not shown) the effective amplification factor is 15 at a relative humidity of 50%, meaning that for each HO_2 sampled, 15 NO_2 molecules are produced. This NO_2 amplification product is then detected by cavity attenuated phase shift spectroscopy (CAPS) – a highly sensitive NO_2 detection method (Kebabian et al., 2008). Two reaction chambers are required – at any given point in time, one is in "amplification mode" while the other is in a background mode.

For the measurement of alkyl peroxy radicals, air will be sampled through Nafion tubing, which selectively removes compounds with –OH groups (i.e., HO_2 and hydroxy-alkyl

peroxy radicals) while passing alkyl peroxy radicals (e.g., $C_2H_5O_2$). Since alkyl peroxy radicals are primarily formed by the OH oxidation of alkanes and hydroxy-alkyl peroxy radicals are primarily formed by the OH oxidation of alkenes and aromatic VOCs, this measurement will complement measurements of speciated VOCs and enable the quantification of the instantaneous ozone production rate that is attributable to first-generation oxidation of alkanes.

Total hydroxy alkyl nitrates and alkyl nitrates "$RONO_2$" will be quantified by the Drexel thermal dissociation – CAPS sensor (TD-CAPS). Air is sampled into a quartz tube resistively heated to 300° C, causing $RONO_2$ compounds to thermally dissociate:

$RONO_2$ + heat $\rightarrow$ RO + NO_2
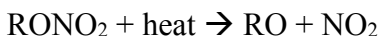
The NO_2 formed is then quantified by a dedicated CAPS sensor (i.e., separate from the two CAPS sensors used for the ECHAMP measurement). Since ambient NO_2 and that produced by the decomposition of less thermally labile compounds like peroxy acyl nitrates ("PANs", RO_2NO_2) are also detected by the CAPS sensor, air is also sampled through an unheated tube and through a tube set to a temperature at which PANs decompose but alkyl nitrates do not, and the alkyl nitrate concentration determined by difference:

$[RONO_2] = [NO_2]_{300° C: NO2 + RO2NO2 + RONO2} - [NO_2]_{180° C: NO2 + RO2NO2}$

In practice, the sampled air will alternate between the three tubes (set at ambient, 180° C, and 300° C) and be sampled by the same CAPS sensor.

5.2. Calibration procedures.
The primary method by which the ECHAMP sensor is calibrated is the water photolysis method (Dusanter et al., 2008), which is a well-established method used by almost all HOx measurement groups in the world. This is typically performed once per day, at changing times of day to ensure no artifact arises from differences in ambient temperature. Humidified air is exposed to 184.9 nm UV radiation from a mercury lamp, creating a 50/50 mixture of OH and HO_2:

H_2O + UV $\rightarrow$ H + OH
H + O_2 + M$\rightarrow$ HO_2 + M
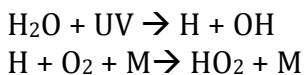
A VOC (e.g., propane) is added to the humidified air to convert all the OH into the corresponding organic peroxy radical (e.g., propyl peroxy radical):

OH + C_3H_8 + O_2 $\rightarrow$ $C_3H_7O_2$ + H_2O
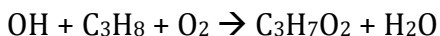
The UV radiation also causes photolysis of O_2, producing O_3:
$3O_2$ + UV $\rightarrow$ $2O_3$

The HO_2 + RO_2 concentration is then calculated by the following equation:

$$[HO_2] + [RO_2] = \frac{[O_3][H_2O]\sigma_{H2O}\varphi_{H2O}}{[O_2]\sigma_{O2}\varphi_{H2O}}$$

where the σ and Φ values are the absorption cross sections and photolysis quantum yields for H_2O and O_2 at 184.9 nm.

A second calibration used less frequently (once per week) due to the time required (~ two hours) is a methyl iodide (CH_3I) photolysis method. The latter is similar to the method described by Liu and Zhang (2014): CH_3I is photolyzed by UV radiation at 254 nm from a mercury lamp:

CH_3I + 254 nm $\rightarrow$ CH_3 + I
CH_3 + O_2 + M $\rightarrow$ CH_3O_2 + M
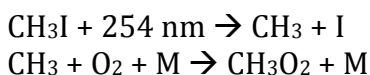
The CH_3O_2 concentration is quantified by reaction with excess NO and detection of the NO_2 formed. For each CH_3O_2 present, 2 NO_2 molecules are formed:

CH_3O_2 + NO $\rightarrow$ CH_3O + NO_2
CH_3O + O_2 $\rightarrow$ HCHO + HO_2
HO_2 + NO $\rightarrow$ OH + NO_2
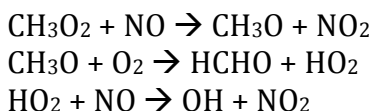
The CAPS sensors are calibrated to NO_2 as well as described in section 6. The correct dissociation temperatures for the quartz tubes for the TD-CAPS sensor is determined both by sampling from a cylinder of compressed n-propyl nitrate, and also by scanning the temperature of the inlet while sampling outdoor air and observing the NO_2 detected.

6. QUALITY METRICS (QA/QC CHECKS)

QC metrics are listed below:
A. The CAPS NO_2 sensors must be calibrated to NO_2. This is accomplished by having the instrument sample ozone prepared by UV photolysis of zero air, quantifying the ozone concentration using a standard UV-absorbance ozone instrument, and simultaneously recording the NO_2 signal from the CAPS sensor. The ozone is quantitatively converted into NO_2 by the reaction NO + O_3 $\rightarrow$ NO_2 + O_2. This NO_2 calibration is performed once per week, consistent with the negligible calibration drift observed over years of operation of these instruments.

B. All flow rates from the flow controllers and into the reaction chambers are measured with two separate BIOS flow meters to ensure consistency in flow rates between the two reaction channels.

As required by this category of QAPP, an audit of 10% of the data quality will be performed. Calibration data is analyzed as it is performed, but 10% of the raw

calibration data (both H_2O photolysis and CH_3I photolysis methods) will be audited by analyzing all steps of the procedure. Additionally, at least 10% of the flow rate measurements will be audited post-campaign. Typically, all data work-up and calibrations are reviewed after the campaign to ensure no errors were made during analysis during the field measurements. A report of the results of the Data Quality Audit will be included in the final report.

7. DATA ANALYSIS, INTERPRETATION, AND MANAGEMENT

7.1 Data processing
The calculation of peroxy radical concentrations from the raw data is accomplished using the following steps, all of which are executed using Matlab software: 1. The difference between the raw one-second NO_2 data from each of the two ECHAMP CAPS sensors are calculated. 2. Data from the first 15 seconds of each 45 second "valve state" (when one reaction channel is in amplification mode and the other in background mode) are expunged. 3. The remaining NO_2 difference values in ppt are averaged over the remaining 30 seconds. 4. Consecutive 30-second average values are averaged with each other, as described in detail in Wood and Charest (2014). 5. The resulting values from step 4 (in 1.5 minute increments) are divided by an RH-dependent amplification factor based on separate in-field calibrations and the relative humidity measured by the inlet system's RH probe.

NO data from the chemiluminescence sensor will be corrected to account for instrument baseline drifts (quantified by hourly measurements of "zero air") and the instrument calibration (quantified by bi-weekly calibrations of the instrument with a standard NO cylinder diluted with dry or humid synthetic air using mass flow controllers).

7.2 Data validation procedures.
The MATLAB code used to calculate the peroxy radical concentrations generates graphs of the partially analyzed data at each of the steps described above. These are visually inspected to ensure correct synchronization of the solenoid valve timing and the averaging routine.

7.3 Data analysis.
The ozone production rates $P(O_3)$ in ppb/hr in the air masses intercepted will be calculated by the following equation:
$$P(O_3) = k_{eff}[HO_2 + \Sigma RO_2][NO]$$

where k_{eff} is the average rate constant for the reaction of HO_2 and individual RO_2 species with NO, $[HO_2 + \Sigma RO_2]$ is the measurement of total peroxy radicals by the ECHAMP instrument, and [NO] is the concentration of NO measured by the chemiluminescence sensor. This numeric data will be presented graphically on geographic maps using the location data from the Aerodyne Mobile Lab's GPS system.

The NOx-limited or VOC-limited nature of ozone production will be assessed in two ways – the first will be performed by Drexel, the second by Aerodyne in collaboration with Drexel:

1. By inspection of the graph of $P(O_3)$ vs. [NO]. This graph will generally show a positive slope at low NO values when $P(O_3)$ is NOx-limited and increases with [NO], and a negative slope at "high" NO values when $P(O_3)$ is VOC-limited. At the transition point the slope is zero. This analysis is most successful when other determining factors are controlled for, especially VOC reactivity ($\Sigma k_{OH+VOC_i}[VOC_i]$) and HOx production rate, which is calculated using measurements of radical precursor concentrations (O_3, H_2O, oxygenated VOCs, HONO, alkenes) and measured or modeled photolysis rate constants (e.g., "j_{HCHO}")

2. By quantification of the budget of HOx radical production and removal. The total HOx formation rate will be calculated as described in #1 above. Since these short-lived radicals are safely assumed to be steady state, the production rate is equal to the loss rate, i.e., $P(HOx) = L(HOx)$. The Loss rate is mainly determined by the following reactions:

$OH + NO_2 + M \rightarrow HNO_3 + M$	R11
$RO_2 + NO + M \rightarrow RONO_2 + M$	R12
$HO_2 + HO_2 \rightarrow H_2O_2 + O_2$	R13
$RO_2 + HO_2 + M \rightarrow ROOH + M$	R14
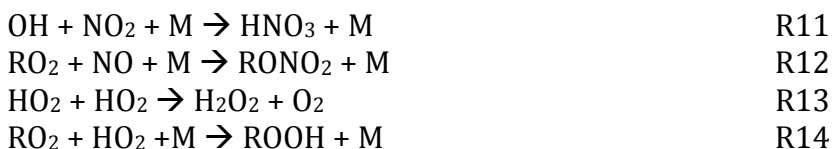
Under NOx-limited conditions, "HOx-NOx" reactions (R11 and R12, though mainly R11) are the main HOx removal reactions. Under VOC-limited (low NOx) conditions, R12 and R13 are the main HOx removal reactions. Although OH will not be directly measured, NO, NO_2, and the sum of HO_2 and RO_2 will be quantified, allowing the rates of the above reactions to be constrained.

7.3.1 Statistics and experimental uncertainties.
The uncertainty (accuracy) at the two sigma level of the peroxy radical data is expected to be in the range of 20 to 25%, and the NO uncertainty is expected to be 5%. By standard propagation of errors this leads to an uncertainty in the calculated ozone production rates of 21% to 25%.

7.4 Data storage requirements.
The peroxy radical and NO measurements generate a raw data every second (including NO_2 concentrations, cell pressures and temperatures, flow rates, etc.). Total data storage required from a month-long deployment in Michigan during summer 2016 was 1 GB and we estimate that the San Antonio deployment would produce approximately the same volume of data. This is easily stored on USB storage devices ("thumb drives"), on computer hard drives (both internal and external), and on a secure cloud back-up service. The PI will retain all data, results of

measurements and reports, whether in electronic or hard copy format, for a minimum of five years.

8. REPORTING

8.1 Project deliverables

A description of the specific reports to be submitted by the PI 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.

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

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.

8.2 Expected final product(s) prepared for the project.
We expect that the final products resulting from this project will be the final project report (due 8/31/2017) and at least one journal article that describes the most noteworthy results from this project. The most likely target journals are *Environmental Chemistry and Technology*, *Atmospheric Chemistry and Physics*, and *Journal of the Air and Waste Management Association*. These will be prepared and submitted following the Publication/Publicity Guidelines included in Attachment G of the Subaward.

9. REFERENCES

Cantrell, C. A., R. E. Shetter, and J. G. Calvert (1996), Dual-Inlet chemical amplifier for atmospheric peroxy radical measurements, *Analytical Chemistry*, *68*(23), 4194-4199.

Green, T. J., C. E. Reeves, Z. L. Fleming, N. Brough, A. R. Rickard, B. J. Bandy, P. S. Monks, and S. A. Penkett (2006), An improved dual channel PERCA instrument for atmospheric measurements of peroxy radicals, *Journal of Environmental Monitoring*, *8*(5), 530.

Dusanter, S., Vimal, D., and Stevens, P. S. 2008. "Technical note: Measuring tropospheric OH and HO_2 by laser-induced fluorescence at low pressure. A comparison of calibration techniques". *Atmospheric Chemistry and Physics*, 8, 321-340

Liu, Y. and Zhang, J. 2014. "Atmospheric Peroxy Radical Measurements Using Dual-Channel Chemical Amplification Cavity Ringdown Spectroscopy". *Analytical Chemistry*, dx.doi.org/10.1021/ac5004689

Pollack, I., Ryerson, T., Trainer, M., Parrish, D., Andrews, A., Atlas, E., Blake, D., Brown, S., Commane, R. & Daube, B. 2012. "Airborne and ground‐based observations of a weekend effect in ozone, precursors, and oxidation products in the California South Coast Air Basin." *Journal of Geophysical Research: Atmosphere*s, 117.

Wood, E. C. & Charest, J. 2014. "Chemical Amplification – Cavity Attenuated Phase Shift Spectrometer Measurements of Peroxy Radicals". *Analytical Chemistry,* 86**,** 10266-10273.