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40 Code of Federal Regulations (CFR) Part 58 Technical Systems Audit (TSA) of Clean Air Status and Trends Network (CASTNET) Program Ozone Monitoring Process

Final Report

by

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Summary

This document reports the audit findings made by RTI International (RTI) after conducting a Technical Systems Audit (TSA) on the ozone collection process and ozone data and data management operated by Air Resources Specialists, Inc. (ARS) for Clean Air Status and Trends Network (CASTNET) program. ARS is responsible for overseeing the operations of the CASTNET sites located at the National parks and operated by the National Park Service (NPS) staff. A TSA was conducted to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data. The TSA consisted of an onsite visit to a NPS air monitoring site (Mammoth Cave National Park, KY – MAC426), a virtual audit of the Ozone Calibration Laboratory processes at the ARS facility in Ft. Collins, Colorado (CO), and a remote review of ozone data collection and data management.

RTI prepared two questionnaires based on US Environmental Protection Agency (EPA) guidance, *Conducting Technical Systems Audits of Ambient Air Monitoring Programs (EPA-454/B-17-004) November 2017*, 40 Code of Federal Regulations (CFR) Part 58 and Appendix H of the *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, (EPA-454/B-17-001) January 2017* (*QA Handbook*). The first questionnaire covered the onsite visit to the field site and the review of the Ozone Calibration Laboratory processes. The second questionnaire discussed activities related to the data review and data management for ozone data. Prior to the TSA, RTI submitted the questionnaires to the ARS staff to be interviewed and the CASTNET Program Manager, Mr. Kemp Howell, and the CASTNET Quality Assurance (QA) Manager, Mr. Marcus Stewart. The questionnaires were finalized by the RTI auditors following the audit process and included responses from the ARS staff. The questionnaires are attached as Appendices A and C.

The RTI audit team consisted of Dr. Prakash Doraiswamy and Mr. Andrew Dart. Dr. Doraiswamy was responsible for overseeing the auditing activities as well as leading the data management review. Mr. Dart performed the onsite review of the field site and participated in the virtual review of Ozone Calibration Laboratory processes along with Dr. Doraiswamy. RTI staff conducted interviews with the ARS staff on various aspects of the air monitoring program including such areas as network design, field operations, laboratory operations, data handling, and quality assurance and quality control (QA/QC) procedures. Mr. Dart visited the MAC426 site and reviewed the onsite procedures. Dr. Doraiswamy and Mr. Dart conducted the virtual review of the ozone calibration laboratory processes and conducted interviews with ARS staff regarding the review and handling of ozone data, the data validation and correction procedures, data processing, and internal and final reporting. Dr. Doraiswamy performed the data review and data management audit. He reviewed the ozone raw data records from the MAC426 site and compared the data posted to CASTNET website, the NPS website, and the US EPA Air Quality System (AQS) database. He also performed a review of the overall ozone data management system and QA/QC checks from the site through ARS to these databases.

For the CASTNET program, the activities at the field sites and supporting laboratories are overseen and performed by two organizations. Wood Environment and Infrastructure Solutions, Inc. (Wood) is responsible for the sample collection activities at the US EPA field sites, providing filter pack and ozone support to the site operators, filter pack laboratory analyses support and data review / management / reporting for all of the CASTNET sites (US EPA and NPS), data reporting for ozone from the US EPA sites to AQS and filter pack results from all CASTNET sites to the CASTNET website. ARS is responsible for overseeing and providing support to the ozone collection operations at the NPS sites, data reporting to AQS and NPS websites, and assisting site operators with logistical support in the filter packs collection that are sent to the Wood Laboratory in Newberry, Florida (FL).

Findings

The findings listed below were based on a small sample set (one field site visit, a virtual review of the Ozone Calibration Laboratory processes, and a review of the ozone data stream from the MAC426 site) overseen by ARS. Continual review of the entire network should be conducted to verify if the findings are an anomaly or consistent throughout the entire CASTNET network.

During the audit of the CASTNET ozone process (field (NPS-governed sites), calibration laboratory, and data management reviews) performed by ARS, RTI was extremely impressed with several aspects of the program such as:

- ARS management structure that oversees the CASTNET program is precise and well organized. The ARS support staff are knowledgeable, experienced, cooperative, and supportive.
- Supportive communication link between ARS (Ozone Calibration Laboratory and Information Management Center (IMC)) with the site operators is advantageous and valuable means of communication.
- Knowledgeable, reliable, and conscientious field team with NPS (Mr. Johnathan Jernigan).
- Use of consistent and current state of art instrumentation (Thermo 49i, ESC data loggers, and mass flow controllers),
- Multiple calibration and verification checks conducted within the measurement system at the field sites and five levels of validation of data from field to reporting databases,
- Use of electronic means to maintain and store field information and provide instructions to the site operators in the forms of the QAPP, SOPs, checklists, and field notations on the DataView software system,
- Use of database program with e-mail prompts to track and schedule recertification of field equipment, and
- The levels of NIST-traceable standards used in the program (Level II transfer standards, Level III onsite standard, and Level IV site analyzer).

In April-May 2017, RTI conducted a TSA of the ozone collection and reporting system overseen by ARS at one of the NPS site locations for the CASTNET program. At that time, RTI found four areas that ARS could improve to strengthen their program. Most of the 2017 findings have been remedied. For this TSA, RTI did have a few findings that should be addressed or clarified. The major deficiencies are listed below and are discussed in detail in this report.

- The QAPP organization chart refers to AMEC instead of Wood. The organization chart needs to be updated as part of the next revision cycle to correct the name to Wood. Additional staff changes in the data validation team and in the field specialists' team will also need to be made to the QAPP as part of the next revision cycle.
- Obsolete copies (hard copies) of field operation SOPs were found at the field site location. Outdated QAPP was found on the DataView system.
- The QAPP and some of the SOPs on the NPS website will need to be updated with the recent versions. Similarly, the SOPs in the CASTNET QAPP Appendix 3 will need to be updated with the recent revisions, where applicable.

Key Improvements since last TSA (April-May 2017)

1. The QAPP has been updated and revised. ARS has instituted a process where it is reviewed annually, and any changes are noted in a letter to the NPS. A complete update and revision of the QAPP is performed every 5 years.
2. A detailed organization chart is included in the QAPP.

Section 1: Introduction

For the Clean Air Status and Trends Network (CASTNET) program, the activities at the field sites and supporting laboratories are overseen and performed by two organizations. Wood Environment and Infrastructure Solutions, Inc. (Wood) and Air Resources Specialists, Inc. (ARS) are responsible for overseeing the US Environmental Protection Agency (EPA) and National Park Service (NPS) field sites, respectively. This technical systems audit (TSA) involves the audit of the ozone operations performed by ARS located in Ft. Collins, Colorado (CO). At these sites, ozone data is collected based on the requirements stated in 40 Code of Federal Regulations (CFR) Part 58.

RTI International (RTI) performed TSAs of the ozone collection process and data and data management operated by ARS. The TSA consisted of an onsite visit to a NPS site (Mammoth Cave National Park – MAC426), a virtual review of the Ozone Calibration Laboratory processes at the ARS facility in Ft. Collins, CO, and a remote review of ozone data collection and data management. This audit was focused on measuring ambient air quality (ozone) and reporting the data and other related information as stated in 40 CFR Part 58. The specific areas of monitoring criteria RTI reviewed and observed were:

1. Quality assurance procedures for monitor operation and data handling
2. Methodology used in monitoring stations
3. Operating schedule
4. Siting parameters for instruments or instrument probes
5. Minimum ambient air quality monitoring network requirements used to make decisions (network design requirements – number of sites and samplers used)
6. Air quality data reporting and requirements involved.

On February 9, 2021, Mr. Andrew Dart conducted the TSA at the MAC426 field site in the Mammoth Cave National Park, KY. At the site, Mr. Dart was able to discuss the field operations for the ozone collection process with the site operator, Mr. Johnathan Jernigan, and the ARS Field Specialist Mr. Dave Beichley. Mr. Beichley also conducted the 6-month calibration of the CASTNET ozone and meteorological system.

On February 17, 2021, Mr. Dart and Dr. Doraiswamy performed a virtual review of the Ozone Calibration Laboratory processes. RTI auditors discussed the operations and support provided by ARS to the field sites and operators and followed up on questions from the onsite visit. Dr. Doraiswamy talked to Ms. Jessica Ward, the ARS Information Management Section Manager on the data reviewing process and data management for the ozone collection process. The key ARS staff involved during the auditing process was:

- Mr. Mike Slate (ARS Field Operations Manager),
- Ms. Emily Vanden Hoek (ARS Quality Assurance Manager), and
- Ms. Jessica Ward (ARS Information Management Section Manager)

Sections 2, 3, 4, 5, 6, and 7 of this report discuss the general findings of the ARS's ozone collection process; network management; field operations at the MAC426 site; laboratory operations at the Ozone Calibration Laboratory; data management; and quality assurance/quality control (QA/QC) within the ozone collection process, respectively. The appendices are copies of the questionnaires and responses used during the audit, pictures of the MAC426 monitoring site taken during the site visit, a copy of the last 6-month audit of the MAC426 site, and a copy of the last National Performance Audit Program (NPAP) of the MAC426 site.

Section 2: General Program

In 2011, the U.S. EPA upgraded all ozone monitoring equipment at the EPA CASTNET monitoring sites to comply with the requirements stated in 40 CFR Part 58. Each CASTNET site that collects hourly ozone data must meet the additional audit requirements and comply with the data reporting deadlines set forth in the CFR. ARS is responsible for providing technical support to the site operators (subcontractors); maintaining the operation of all field equipment; collecting, analyzing, and reporting the ozone data; and developing an auditing program to meet the CFR requirements for all NPS CASTNET sites. ARS submits the real time NPS CASTNET hourly ozone data to the NPS websites daily. In addition, ARS submits the CASTNET ozone data to the US EPA's Air Quality System (AQS) database.

During the visits to the field site, the Ozone Calibration Laboratory review, and review of the ozone data and data management, the RTI auditors concluded that the requirements in the CFR were being met. The ARS management and support staff structure at the main laboratory in Ft. Collins, CO is well-organized and documented in the NPS Gaseous Pollutant Monitoring Program (GPMP) Quality Assurance Project Plan (QAPP), Revision 4 dated October 2020. The QA Manager and field support staff are knowledgeable of their job requirements and very cooperative during the audit. There is an established communication chain between ARS management and support staff and site operators and good documentation practice through the use of an electronic program, DataView, that allows the site operators to document maintenance and any issues.

Prior to the TSA, ARS sent the list of documents requested by RTI. This included the QAPP and the Standard Operating Procedures (SOPs) and other documentation such as the 6-month calibration reports, data summary reports and PE audit reports. Ms. Ward from ARS provided the link (http://ard-request.air-resource.com/project/) for the GPMP website for the NPS. At this website, the ARS-NPS QAPP, field SOPs, 6-month calibration reports, field site contacts information, and project reports for the ozone collection program were found. The QAPP on the NPS website is outdated. The QAPP and SOPs on the NPS GPMP website need to be replaced with the most recent versions. The field operations SOPs were checked and confirmed against the SOPs listed under the CASTNET website (CASTNET QAPP Appendix 3 ARS SOPs). The ARS SOPs on the CASTNET website need to be updated with the revised versions.

The NPS QAPP is written in accordance with U.S. EPA Guidance Documents, "*EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5)*" (EPA, 2001), and "*EPA Guidance for Quality Assurance Project Plans (EPA QA/G-5)*" (EPA, 2002) and contains all of the necessary elements for an EPA-approved QAPP. It integrates all technical and quality aspects of a project, including planning, implementation, and assessment, and documents the quality assurance and quality control that are applied to an environmental data operation to assure the results obtained are of the type and quality needed and expected. The SOPs are written in accordance with U.S. EPA Guidance Documents, "*EPA Guidance for Preparing Standard Operating Procedures (SOPs) (EPA QA/G-6)*" (EPA, 2001). The NPS QAPP and SOPs are reviewed annually. The ARS-NPS QAPP is revised every 5 years with interim changes documented in an email to the NPS. The QAPP was recently approved in January 2021.

FINDINGS

No problems or issues were found based on the review of the QA documentation. Some of the ARS SOPs on the CASTNET Website are outdated. Similarly, the NPS GPMP QAPP and SOPs on the NPS website are outdated.

RECOMMENDATIONS

Outdated SOPs on the CASTNET website need to be replaced with the most recent approved versions. Similarly, the QAPP and the SOPs on the NPS website need to be replaced with the most recent approved versions.

Section 3: Network Management

Wood and ARS operate and maintain the ozone collection network for the CASTNET program. ARS is primarily responsible for overseeing the NPS sites and reporting the data from those sites to NPS and AQS. Wood oversees the EPA sites and is responsible for the data collection, management, and reporting of the ozone data from the EPA CASTNET monitoring sites to AQS. The network consists of 86 monitoring sites. The most recent 5-year network assessment was dated July 1, 2020 and the most recent annual network plan (2020 CASTNET Annual Network Plan) was dated June 30, 2020. Both documents are available on the CASTNET website (Documents & Reports | Clean Air Status and Trends Network (CASTNET) | US EPA). Mr. Timothy Sharac of U.S. EPA CAMD in Washington D.C. Office has custody of the network plan and the plan is maintained on the CASTNET website.

During this TSA, RTI visited Mammoth Cave National Park (MAC426) near Bowling Green, KY. Based on 40 CFR Part 58, the site is within siting criteria requirements and has not requested or received any waivers. At each site, the distance from roadways, obstructions, trees were all within the EPA criteria. The inlet heights were all within the required range in 40 CFR 58, Appendix E. The site is outfitted with a datalogger and data is backed up on the computer and a server database.

Exhibit 1 displays the current organizational chart for the ARS-NPS management and staff working on the CASTNET program obtained from the QAPP. The Exhibit refers to AMEC instead of Wood and needs to be updated in the QAPP as part of the next revision cycle.

FINDINGS

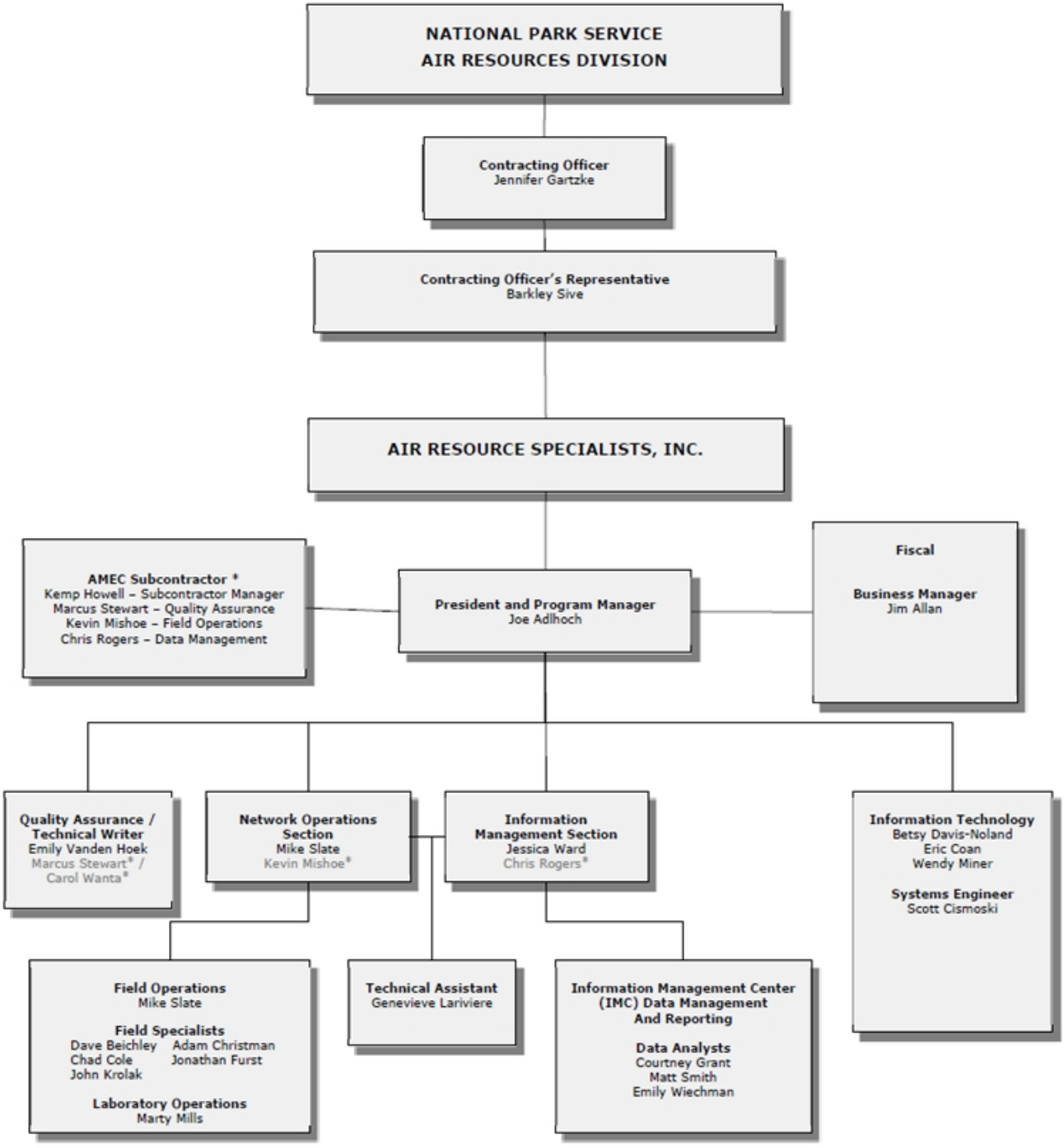
No problems or issues based on the review of one field site visit (MAC426) and discussions with the ARS management and QA Manager.

The organization chart in the QAPP refers to AMEC instead of Wood.

RECOMMENDATIONS

The name “AMEC” needs to be updated to Wood Environment and Infrastructure Solutions, Inc.

Exhibit 1. NPS/BLM/ARS CASTNET Project Organization



Section 4: Field Operations

ARS oversees the NPS-governed CASTNET monitoring sites. During this TSA, RTI visited the MAC426 site near Bowling Green, KY. **Exhibit 2** displays information regarding the site location, site and backup operators, equipment for each site, GPS coordinates, and site elevation. The GPS coordinates and site elevation were measured by the RTI auditor and confirmed against the data for the sites on the CASTNET website.

Exhibit 2. MAC426 Site Information

	MAC426
Site Location Address	Mammoth Cave National Park 107-199 Alfred Cook Rd, Park City, KY 42160
AQS Number	21-061-0501
Site Operator Contact Information	Johnathan Jernigan johnathan_jernigan@nps.gov
Backup Site Operator Contact Information	Brice Leech
Site Ozone Analyzer (Manufacturer, S/N, EPA decal)	Thermo 49i S/N 1030745085
Transfer Standard Site Ozone Analyzer (Ozone Station Reference) (Manufacturer, S/N, EPA Decal)	Thermo 49i S/N 1015543061
GPS Coordinates	37.1864° N 86.0411° W
Elevation	744 ft

The ARS field specialists oversee the field activities for the NPS-governed sites. The site operators (NPS ranger or other personnel) collect the field samples (filter pack) and complete the Site Status Report Forms (SSRFs) based on procedures listed in CASTNET QAPP Appendix 1 Standard Operating Procedures. The site operator uses the DataView software program on the site's laptop to document all activities at the site during their normal visit on Tuesday and non-routine visits due to issues or problems at the site. The site operator does not enter any ozone information on the SSRF. All data entries are electronic (DataView). Hard copy forms are only used if the DataView log is not working. There was no evidence of the DataView system not working, but there are several forms on hand at the site for the site operator in case of electronic system failure. The field oversight operation of the NPS-sites for the CASTNET program is led by Mr. Mike Slate and Mr. Mark Tigges. Site support is performed by a group of Field Specialists (Mr. Dave Beichley, Mr. Chad Cole, Mr. John Krolak, and Mr. Jonathan Furst). The QA group is led by Ms. Emily Vanden Hoek, the QA Manager, and she is supported by Mr. Christian Kirk, the QA Officer for the CASTNET program at ARS. The CASTNET program for NPS sites is led by Mr. Joe Adlhoch. The data management and data review is led by the Information Management Section (IMC) Manager, Ms. Jessica Ward. She is supported by data analysts (Ms. Emily Wiechman, Ms. Brittany Decker, Ms. Molly Andersen and Mr. Matt Smith). As a group, the Field Specialists are responsible for calibration and maintenance of the ozone analyzers, maintenance of the monitoring site, training the site operators, and conducting the 6-month calibrations of the analyzers. The data management group along with the Field Specialists is responsible for the field sites being fully operational and collecting valid data.

At the NPS sites, zero, span, and precision (ZSP) checks and monthly and multi-point calibrations are performed on the ozone analyzers. The ZSP checks are automated and occur every day at 1:46 am (takes approximately 20 minutes). The site operator performs a 6-point calibration (200, 150, 100, 60, 30 and 0 ppb) every 6 months. All electronic data are saved on the site's laptop and transmitted by the data logger to the ARS primary server. ARS

staff also use the Site Status Log, which is a web-based interface to the Air Quality Data Base Management System (AQDBMS) at ARS, to log operational and maintenance issue at monitoring sites. This is more comprehensive than entries in the DataView log.

The site operator visits the site every Tuesday as stated in the ARS Field SOPs. In some cases, the site operator might visit more frequently if they are responsible for other networks at that monitoring site. There is no independent flow rate check other than during the 6-month calibration, but the site operator does perform a leak check. The site operator also replaces the inline Teflon filter near the ozone inlet every 2 weeks. After collecting their filter packs and verifying the ozone collection process is working properly, the site operator documents all activities on the DataView software system and then submits sampled filter pack and SSRF to the Wood Laboratory in Newberry, FL.

4.1 Mammoth Cave National Park (MAC426) Field Site

On February 9, 2021, Mr. Dart met with Mr. Beichley, the ARS Field Specialist, at a hotel in Bowling Green, KY and followed him to the MAC426 field site. Mr. Beichley was at the site to conduct the 6-month calibration check on the CASTNET instrumentation. Mr. Johnathan Jernigan, the site operator, arrived to change out the filter and check the ozone system during his normal Tuesday operation. Mr. Dart was able to observe Mr. Jernigan removing and loading the filter pack, replacing the inline filter, and conditioning it for ozone collection, completing SSRF, and using DataView to check meteorological instrumentation and ozone check. Mr. Dart also discussed training provided, general operations, use of DataView system, troubleshooting, maintenance, and repair/replacement of equipment at the site with Mr. Jernigan.

The MAC426 site was established as a CASTNET site on July 24, 2002. Operations at the site are performed by following Weekly Station Visit Checklist and Multi-point Calibration Checklist on the DataView log. The CASTNET and ARS-NPS QAPPs and current field SOPs are stored on DataView system on the site's laptop.

When reviewing documentation maintained at the field site, Mr. Dart found an obsolete version of the ARS QAPP (QAPP Rev3 2015) on the DataView system. This needs to be updated to the most recent version dated October 2020 and approved January 2021. There were also outdated SOPs at the site.

Site operators are trained three ways under the ARS-NPS program for CASTNET. The first option is from the previous site operator. In the case of MAC426, Mr. Johnson was the previous site operator and Mr. Jernigan was an intern under Mr. Johnson. Mr. Johnson provided thorough training to Mr. Jernigan and this training is reinforced by the second option, training by the ARS Field Specialists during the 6-month calibration checks. The Field Specialists now complete a Tailgate Safety Meeting Form and Site Operator Training Form (see **Exhibit 3** for the entries for the last training provided) so that any training provided is documented and signed off by the trainer (ARS Field Specialist) and trainee (site operator). This document is hand-written and later placed in PDF format and sent to the site for their training records on the site's computer. The third training option is when a new site is established or relocated. For this option, the Field Specialist will train the site operator and site manager. In all cases of training options, the training is documented, the documentation is tracked and managed; and the site operators are provided with ARS contact information to answer any follow up questions.

Maintenance and repair work on instruments are performed at the monitoring site, if possible, by the Field Specialists during the 6-month calibration check. The Field Specialist completes a form as displayed in **Exhibit 4**. When repairs are not possible onsite, equipment is brought back to the ARS Ozone Calibration Laboratory, which serves as the centralized maintenance and repair facility.

Exhibit 3. Last Two MAC426 Tailgate Safety Meeting and Site Operator Training Forms

Air Resource SPECIALISTS

TAILGATE SAFETY MEETING FORM AND SITE OPERATOR TRAINING

Instructions
To be completed prior to the beginning of a new job, when changes in work procedures occur, or when additional hazards are present.

NAME, DATE, TYPE, LOCATION OF PROJECT OR WORK ACTIVITY:	NEAREST HOSPITAL:
11/6 - 11/8 2019 Semi-Annual Maintenance Mammoth Cave N.P.	Bowling Green

COORDINATES OF WORK LOCATION

N37 11' 11"
W 86 2' 28"

TOPICS/HAZARDS DISCUSSED:

climbing ladder to roof
stinging insects
watch for snakes
raising and lowering met/gas/castnet towers
be careful when doing electrical work

OPERATOR TRAINING CONDUCTED (Name, topics):

- General over all of the site
- Showed how to use deltaCal for Teom Flow/Temp/Pressure

Suggested Trainings:

☐ PM Monitor ☐ DataView ☐ Communications ☐ Met Checks ☐ Ozone ☐ CASTNET

NAMES OF ATTENDEES:	SIGNATURE OF ATTENDEES:
Dave Beichley	
Johnathan Jernigan	

Supervisors Signature/Date:

Air Resource SPECIALISTS

TAILGATE SAFETY MEETING FORM AND SITE OPERATOR TRAINING

Instructions
To be completed prior to the beginning of a new job, when changes in work procedures occur, or when additional hazards are present.

NAME, DATE, TYPE, LOCATION OF PROJECT OR WORK ACTIVITY:

Mammoth Cave N.P.S.
Houchin Meadows
Semi-annual maintenance

NEAREST HOSPITAL:

Medical Center
250 Park St.
Bowling Green, KY 42101
(270)-745-1000

COORDINATES OF WORK LOCATION

N 37 11' 11"
W 86' 2' 28"

TOPICS/HAZARDS DISCUSSED:

Site operator not available due to COVID19

OPERATOR TRAINING CONDUCTED (Name, topics):

Suggested Trainings:

☐ PM Monitor ☐ DataView ☐ Communications ☐ Met Checks ☐ Ozone ☐ CASTNET

NAMES OF ATTENDEES:	SIGNATURE OF ATTENDEES:
Dave Buckley	Dave Buckley

Supervisors Signature/Date: ark elg 10-26-20

Exhibit 4. Copy of the Semiannual Site Visitation Checklist

SITE VISITATION CHECKLIST

Air Resource SPECIALISTS

Station: Visit Conducted By:
Station Operator: Site Visit Dates:

1. SHELTER AND TOWER INTEGRITY (verify condition and proper operation)

ITEM	CORRECTIVE ACTION
☐ Shelter Exterior (roof, siding, door, etc.)	
☐ Shelter Interior (floor, walls, ceiling, door, racks)	
☐ Shelter Electrical (outlets, lights, grounding, polarity)	
☐ Shelter Heating and Air Conditioning (inspect, clean, check thermostats)	
☐ Meteorological Tower (supports, guys, hardware, grounding)	
☐ Flow Tower (supports, guys, hardware, grounding)	
☐ Other:	

2. SUPPORT SYSTEM INTEGRITY (verify condition and proper operation)

ITEM	CORRECTIVE ACTION
☐ Lightning Protection Panel (LPP)	
☐ Quality Assurance Monitor (QAM), STP Monitor	
☐ Power and Telephone Lines	
☐ Interconnect Cabling (tower and shelter)	
☐ Intake and Exhaust Manifolds (if applicable)	
☐ Other:	

3. AIR QUALITY EQUIPMENT CALIBRATIONS/MAINTENANCE

Pre Cal.	Maint. Completed	Post-Cal.	ITEM	CORRECTIVE ACTION
☐	☐	☐	O_3 Analyzer	
☐	☐	☐	O_3 Transfer Standard	
☐	☐	☐	Consumable Reagents Replaced (charcoal/dessicant)	
☐	☐	☐	Clean or Change Inlet Tubing	
☐	☐	☐	Other:	

4. CASTNET SAMPLING EQUIPMENT CALIBRATION/MAINTENANCE

Pre Cal.	Maint. Completed	Post-Cal.	ITEM	CORRECTIVE ACTION
☐	☐	☐	Sampling System Leak Check	
☐	☐	☐	Flow Controller Calibrated (pre and post values must be documented)	
☐	☐	☐	Replace Balston Particulate Filter	
☐	☐	☐	Rebuild Pump	

5. METEOROLOGICAL EQUIPMENT CALIBRATIONS/MAINTENANCE

Pre Cal.	Maint. Completed	Post-Cal.	ITEM	CORRECTIVE ACTION
☐	☐	☐	Wind Speed Range (4 point)	
☐	☐	☐	Wind Speed Starting Threshold	
☐	☐	☐	Wind Direction Orientation and Linearity (8 point)	
☐	☐	☐	Wind Direction Torque	
☐	☐	☐	Temperature Probes (3 point)	
☐	☐	☐	Relative Humidity Sensor (hourly averages)	
☐	☐	☐	Aspirators (Climatronics/Qualimetrics/RM Young/Rotronics)	
☐	☐	☐	Solar Radiation (hourly averages)	
☐	☐	☐	Precipitation	
☐	☐	☐	Other:	

-- Continued --

Exhibit 4. Copy of the Semiannual Site Visitation Checklist (Continued)

Air Resource SPECIALISTS

6. DATA ACQUISITION CALIBRATIONS/ MAINTENANCE/ OPERATIONAL VERIFICATION

Pre Cal.	Maint. Completed	Post-Cal.	ITEM	CORRECTIVE ACTION
☐	☐	☐	Datalogger Time and Date	
☐	☐	☐	Datalogger Keyboard (operations test, cleaned)	
☐	☐	☐	Datalogger Modem	
☐	☐	☐	DataView System (computer operational, software functioning, communication links functioning)	
☐	☐	☐	Printer (operations test, ribbon, cleaned)	
☐	☐	☐	Other:	

7. STATION MODIFICATIONS AND CONFIGURATION ENHANCEMENTS

Pre Cal.	Maint. Completed	Post-Cal.	ITEM	CORRECTIVE ACTION
☐	☐	☐		
☐	☐	☐		
☐	☐	☐		
☐	☐	☐		

8. OBSERVE/TRAIN STATION OPERATOR

ITEM	CORRECTIVE ACTION
☐ Observe Operator Competence	
☐ Review Log Notes, Data Documentation	
☐ Train, if necessary	
☐ Review Changes in SOPs or Other Operational Changes	
☐ Verify That On-Site SOPs are Available and Complete	
☐ Encourage/Answer Station Operator Comments or Questions	
☐ Inform Operator if Additional Action is Required	

9. VERIFY AND UPDATE SITE EQUIPMENT INVENTORIES AND DOCUMENTATION

ITEM	CORRECTIVE ACTION
☐ Inventory Completed	
☐ Site Documentation Photographs Taken:	

- Cardinal Directions
- Shelter Exterior Close-up
- Tower(s) with Instrumentation
- All Other Exterior Instrumentation
- Interior Instrumentation
- Scenic Photograph

-- End --

Site Description

The Mammoth Cave National Park Field Site is located 20 miles northeast of Bowling Green Kentucky along the southwest border of the Park. The entrance is located at the east side of the site with a small parking area near the entrance gate. There is a six-foot-high chain link fence along the perimeter of the site. The boundary of the site measures approximately 77 ft by 85 ft. The shelter which houses the CASTNET instrumentation is roughly 10 ft tall with two 10 m towers alongside. One tower houses the ozone inlet and filter pack. The other tower houses the ambient gas monitor inlet for SO_2, NO, and NO_y. The 10 m meteorological tower is independently supported approximately 7.5 m due west of the ozone inlet tower. Other instrumentation on the main shelter includes a Nephelometer sampler, NASA AERONET monitor, and a $PM_{2.5}$ TEOM sampler which was not in operation at that time. Also, at the site is an IMPROVE sampler station housed in a separate shelter, a 5 m tall meteorological tower for the RAWS program, and four separate rain/precipitation gages.

Items	Compass Degrees	Distance (m)	Height (m)
A. 10 m tower, ozone inlet and filter pack	-	-	10
B. $PM_{2.5}$ TEOM sampler inlet	165	2.7	1.7 (height above roof)
C. 10 m tower with gas analyzer inlet	260	4	10 (height above roof)
D. NASA UV meter	120	4.6	1 (height above roof)
E. Nephelometer sampler	90	3.4	1.5 (height above roof)
F. IMPROVE samplers	150	9.3 (shelter center)	3.7 (shelter height)
G. 10 m tower for meteorological tower	240	7.5	10
H. 5 m tower - RAWS meteorological	236	16.5	5
I. Tipping rain gages	190	13	1
J. Weighing rain gages	175	20.8	1.2

See Appendix A for responses to questionnaire and Appendix B for photos of the MAC426 site.

FINDING 1:
Obsolete copies (hard copies) of field operation SOPs were found at the field site location (MAC426).

Discussion:
When reviewing documentation maintained at the field site, Mr. Dart found a binder with old ARS SOPs for field operations at the site. The site operator (Mr. Jernigan) uses the DataView system for his visit as he demonstrated during the TSA. But when discussing the need for hard copies of SOPs at the site, Mr. Slate suggested these hard copy SOPs were used if the DataView system was down (inoperative). This practice is a good backup plan to have hard copies for when the computer system is down, but these SOPs need to be replaced with current SOPs.

RECOMMENDATION:

RTI recommends removing the obsolete hard copy versions of the field SOPs and replacing them with the current versions. Obsolete SOPs should be checked at all of the other NPS sites under the CASTNET program. Based on Section 9 Verify and Update Site Equipment Inventories and Documentation on the Semiannual Site Visit Checklist, it is recommended that a check be added to that section to specifically ensure documents are the latest version and to remove obsolete documents. RTI recommends that the ARS Field Operations Specialist Manager, QA Officer, and QA Manager discuss the handling of obsolete documents (hard copies) and have further discussion with the other Field Specialists to confirm that they are also looking for obsolete documentation in the site's shelters.

ARS Response:

Hard copies of SOPs and checklists will be reviewed by the ARS field specialists during each maintenance visit. Outdated copies will be removed and replaced with current versions.

FINDING 2:
Obsolete version of the ARS QAPP was found on the DataView system. A hard copy of the current QAPP was not available at the site.

Discussion:

Mr. Dart mentioned the obsolete document to Mr. Slate during a follow up phone call. Mr. Slate replaced the outdated QAPP with the latest version, Revision 4, dated October 2020 to the DataView system.

RECOMMENDATION:

RTI recommends that the Field Specialist(s) review the documentation in the shelter and remove any obsolete documents, when conducting their 6-month calibration check. Further, before leaving for the site visits, prepare a hard copy packet of current documents (QA documents, contact list, checklist, etc.) to replace obsolete documents during the 6-month calibration check.

Section 5: Laboratory Operations (Ozone Calibration Laboratory)

The Ozone Calibration Laboratory is staffed by experts in ambient ozone measurements. The audit consisted of a remote review of the processes and did not involve an onsite visit. The laboratory consists of a central laboratory for providing maintenance, repairs, testing, and verifying the equipment used in the ozone collection process. The Ozone Calibration Laboratory also ships and receives the Level II transfer standards used by the field technicians during the 6-month calibration checks.

Staff at the ARS Laboratory maintain and control all NIST-traceable certifications of their standards through a database. This database prompts when a standard is coming close to being out of certification. This database allows the Field Specialists to prepare a standards package prior to visiting the sites for a 6-month calibration check. The Level II standards are certified by EPA Regional Office and the Level III site analyzers are certified by ARS with Level II ozone analyzers. Currently, there are four Level II transfer standards (see **Exhibit 5**) and annual recertifications all of which are maintained in the database of certifications on the ARS server. The Ozone Calibration Laboratory also maintains one lab standard (also Level II) that always remains in the laboratory unless being recertified.

Exhibit 5. Standards Used by ARS on CASTNET Program

		Manufacturer S/N and EPA Decal Number	Last Certification Date
Level II Transfer Standards			
1	Thermo 49i	S/N: 1130450195	March 19, 2020 by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 5/26/2019)
2	Thermo 49i	S/N: 1130450196	February 11, 2020 by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 3/28/19)
3	Thermo 49i	S/N: 1130450197	February 25, 2020 by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 3/28/2019)
4	Thermo 49i	S/N: 1130450192	February 11, 2020 by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 3/28/2019)
Laboratory-Controlled Standards			
1	Thermo 49C	S/N: 75759380	October 13, 2020 by US EPA region 8 by Joshua, Rickard using NIST SRP (NIST Certified on 11/1/2019)

A primary responsibility of the staff in the Ozone Calibration Laboratory is to provide technical support to the site operators that operate the CASTNET monitoring sites. The staff can be reached by telephone and e-mail for regular communication. DataView Log and Site Status Log are both used to document maintenance, equipment issues, or problems encountered at the site. All telephone calls relating to issues at the monitoring sites are also documented in the Site Status Log. All records are electronically backed up and the QA Manager conducts internal reviews of the complete process.

The ARS QA Manager and QA Officer have worked with the Field Operations Manager to improve the documentation tracking of training provided to current Field Specialists and newly hired Field Specialists. **Exhibit 6** is an example of a Field Specialist's ARS Field Technician Technical Training Checklist that includes required EPA Air Pollution Training Online Course and field equipment used at the Ozone Calibration Laboratory and field sites. When a Field Specialist completes a training task, a senior Field Specialist (trainer) signs off and dates the completion. This checklist is an internal checklist used by the Ozone Calibration Laboratory and is provided to the QA Manager as a record of performance capabilities.

Exhibit 6. Example of ARS Field Technician Technical Training Checklist

ARS Field Technician Technical Training Checklist

https://www.apti-learn.net/LMS/EPAHomePage.aspx

Date completed	Employee Initials	Trainer Initials	Air Polution Training Institute Online Courses
1/5/21	CC	MS	100 Basic Concepts in Environmental Sciences
1/6/21	CC	MS	105 Introduction to Air Pollution
1/6/21	CC	MS	409 Basic Air Pollution Meteorology
1/8/21	CC	MS	433 Network Design & Site Selection for Monitoring PM2.5 & PM10 in Ambient Air
1/12/21	CC	MS	434 Introduction to Ambient Air Monitoring
1/22/21	CC	MS	436 Site Selection for Monitoring of SO2 and PM10 in Ambient Air
			471 General Quality Assurance Considerations For Ambient Air Monitoring (1984)
			473A Beginning Environmental Statistical Techniques

Date completed	Employee Initials	Trainer Initials	Field Training
10/17/19	CC	MS	Tower training and tower rescue training
1/7/20	CC	MS	First Aid/CPR Training
10/14/19	CC	MS	Review 49i and 49C Ozone Analyzer manual
12/3/20	CC	MS	Review Teledyne API 400E/T400 Ozone Analyzer manual
10/14/19	CC	MS	Ozone Quality Assurance Training
11/19/19	CC	DB	Zero Air Source Maintenance Training
12/9/19	CC	MS	CASTNET Flow Calibration and Maintenance Training
11/19/19	CC	DB	Wind Direction Orientation Training
11/19/19	CC	DB	Wind Speed and Wind direction calibration and maintenace (RM Young and Climatronics)
11/19/19	CC	DB	Ambient Temperature Calibration and Maintenance Training
11/19/19	CC	DB	Relative Humidity Calibration and Maintenance Training
11/19/19	CC	DB	Precipitation Calibration and maintenance Training (Tipping Bucket)
11/19/19	CC	DB	Solar Radiation Calibration and Maintenance Training
2/25/20	CC	MS	Barometric Pressure Calibration and Maintenance Training
3/11/20	CC	MS	Met One BAM 1020 Calibration and Maintenace Training
			Thermo TEOM 1400 AB Calibration and Maintenance Training
			Thermo TEOM 1405/1405DF Calibration and Maintenance Training
9/4/20	CC	DB	Thermo 5014i BAM Calibration and Maitenance Training
			Met One E-Sampler Calibration and Maintenance Training
			MetOne E-BAM Calibration and Maintenance Training
6/2/20	CC	MS	TSI Dust Trak Calibration and Maintenance Training
11/19/19	CC	MS	BIOS Definer 220 Operation Training
3/11/20	CC	DB	BGI DeltaCal Operation Training
			Thermo 43C/43i SO2 Analyzer Calibration and Maintenance Training
			Teledyne API 100E SO2 Analyzer Calibration and Maintenance Training
1/19/21	CC	MS	Thermo 42C/42i NO/NO2/NOx Analyzer Calibration and Maintenance Training
1/19/21	CC	MS	Teledyne API 200E NO/NO2/NOx Analyzer Calibration and Maintenance Training
			Thermo 48C/48i CO Analyzer Calibration and Maintenance Training
			Teledyne API 300E CO Analyzer Calibration and Maintenance Training
11/19/19	CC	DB	ESC 8816/8832 Datalogger Training
3/11/20	CC	MS	Campbell 23X Datalogger Training
6/2/20	CC	MS	Campbell CR850/CR1000/CR3000 Datalogger Training
11/18/19	CC	DB	Dataview Overview and Operation Training

The QA Department also has training checklist documents for staff (Field Specialist) for reading, understanding, and performing field SOPs for project work (see **Exhibit 7**). The QA Department also tracks through a checklist for new Field Specialist's understanding of 40 CFR Part 50 requirements as displayed in **Exhibit 8**. A senior Field Specialist will determine if the new employee has read and understood the SOPs and CFR requirements by observing their performance in the Ozone Calibration Laboratory and field site visits.

Exhibit 7. Example of ARS Field Technician SOP Technical Training Checklist

ARS SOP Review Checklist

Date completed	Employee Initials	Trainer Initials	SOPs to review
			N:\Project\ARS\SOP-new\FINAL\Field Operations\Maintenance and Calibration
1/8/21	CC	MS	F_GAS_MTCAL_O3TransferStd_2016Oct_F_1.0
1/8/21	CC	MS	F_GAS_MTCAL_OZONEL2_2016Oct_F_1.0
1/8/21	CC	MS	F_GAS_MTCAL_OZONEL3_2016Oct_F_1.0
1/19/21	CC	MS	F_GAS_MTCAL_NOX_2016Oct_D_1.0
1/29/21	CC	MS	F_GAS_MTCAL_CO_2016Oct_D_1.0
1/29/21	CC	MS	F_GAS_MTCAL_SO22016Oct_D_1.0
1/29/21	CC	MS	F_PM_MTCAL_BAM_2016Oct_F_1.0
1/20/21	CC	MS	F_MET_MTCAL_ATbath_2016_F_1.0
1/20/21	CC	MS	F_MET_MTCAL_ATRH_2016Oct_F_1.0
1/20/21	CC	MS	F_MET_MTCAL_BAR_2016Oct_F_1.0
1/21/21	CC	MS	F_MET_MTCAL_RNF_2016Oct_F_1.0
1/21/21	CC	MS	F_MET_MTCAL_SOL_2016Oct_F_1.0
1/21/21	CC	MS	F_MET_MTCAL_WD_2016Oct_F_1.0
1/21/21	CC	MS	F_MET_MTCAL_WS_2016Oct_F_1.0
1/21/21	CC	MS	F_SITEOPERATOR_AQSITE_2016Oct_F_1.0
2/11/21	CC	MS	F_SITING_AQSITE_2016Oct_F_1.0
1/29/21	CC	MS	F_VISIT_MTCAL_AQSITE_2016Oct_F_1.0
1/29/21	CC	MS	L_MET_MTCAL_ATRH_2016Nov_F_1.0
1/29/21	CC	MS	L_MET_MTCAL_WD_2016Nov_F_1.0
1/29/21	CC	MS	L_MET_MTCAL_WS_2016Nov_F_1
			3350 COLLECTION OF AMBIENT AIR QUALITY AND METEOROLOGICAL MONITORING DATA
			3450 AMBIENT AIR QUALITY AND METEOROLOGICAL MONITORING DATA VALIDATION
			3456 CONTINUOUS PARTICULATE MONITORING DATA VALIDATION
			3550 AMBIENT AIR QUALITY AND METEOROLOGICAL MONITORING DATA REPORTING
			IT_AQDB_UPDATES_2016Oct_F_1.0

Exhibit 8. Example of ARS Field Technician 40 CFR Part 50 Technical Training Checklist

ARS Field Technician Technical Training Checklist

Code of federal regulations 40 part 50: National and secondary ambient air quality standards (measurement methods)

https://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR :

Date completed	Employee Initials	Trainer Initials	
1/5/21	CC	MS	- Appendix A-1 Reference Measurement Principle and Calibration Procedure for the Measurement of Sulfur Dioxide in the Atmosphere (Ultraviolet Fluorescence Method)
1/5/21	CC	MS	- Appendix B Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method)
1/8/21	CC	MS	- Appendix C Measurement Principle and Calibration Procedure for the Measurement of Carbon Dioxide in the Atmosphere (Non-Dispersive Infrared Photometry)
1/11/21	CC	MS	- Appendix D Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere
1/12/21	CC	MS	- Appendix F Measurement Principle and Calibration Procedures for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence)
		MS	- Appendix G Reference Method for the Determination of Lead in Total Suspended Particulate Matter
1/13/21	CC	MS	- Appendix J Reference Method for the Determination of Particulate Matter as PM10 in the Atmosphere
1/13/21	CC	MS	- Appendix L Reference Method for Determination of Fine Particulate Matter as PM2.5 in the Atmosphere
1/14/21	CC	MS	- Appendix O Reference Method for the Determination of Coarse Particulate Matter as PM10-2.5 in the Atmosphere

Code of federal regulations 40 part 50: National and secondary ambient air quality standards (INTERPRETATION of standards)

https://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR :

1/6/21	CC	MS	- Appendix H Interpretation of the 1-Hour Primary and Secondary National Ambient Air Quality Standards for Ozone
1/6/21	CC	MS	- Appendix I Interpretation of the 8-Hour Primary and Secondary National Ambient Air Quality Standards for Ozone
			- Appendix K Interpretation of the National Ambient Air Quality Standards for Particulate Matter
			- Appendix N Interpretation of the National Ambient Air Quality Standards for PM2.5
			- Appendix P Interpretation of the Primary and Secondary National Ambient Air Quality Standards for Ozone
			- Appendix R Interpretation of the National Ambient Air Quality Standard for Lead
			- Appendix S Interpretation of the Primary National Ambient Air Quality Standards for Oxides of Nitrogen (Nitrogen Dioxide)
			- Appendix T Interpretation of the Primary National Ambient Air Quality Standards for Oxides of Sulfur (Sulfur Dioxide)
			- Appendix U Interpretation of the Primary and Secondary National Ambient Air Quality Standards for Ozone

Based on the discussions during the virtual review of the Ozone Calibration Laboratory, RTI could not find any discrepancies in the operations as stated in the NPS CASTNET QAPP or the ARS SOPs.

FINDINGS

No problems or issues found.

Section 6: Data and Data Management

Introduction

The evaluation of the data management system for ozone data was conducted by RTI that included a visit to the MAC426 site, a review of the ozone raw data records from the site and a comparison of the data posted to CASTNET, the NPS Air Resource Division website and EPA's Air Quality System (AQS) database. Mr. Dart performed the onsite visit and reviewed the records onsite, while Dr. Doraiswamy performed the off-site data evaluation.

Data Management Review

The audit of the data review and data management was comprised of five parts: Data Handling/Review, Software Documentation, Data Validation and Correction, Data Processing, and Reporting (Internal and Externally) as well as tracking selected data from a site (MAC426) through data review, validation, and posting. ARS has prepared and documented SOPs designed to cover each of these sections. Ms. Vanden Hoek, the QA manager authored the SOPs and Ms. Ward, the Information Management Section (IMC) Manager, reviewed and approved the SOPs.

Data management questionnaires were prepared following the guidance in the EPA QA Handbook. The questionnaire consisted of Part 1 Data Management and Part 2 Data Review that covered the areas noted above and followed the processes involved with the transferring data points from the ozone analyzer through their online system to the AQDBMS. The data handling process involves transferring of data through three primary devices: the ESC datalogger, the DataView software housed on a site laptop, and the AQDMBS located at the ARS office location.

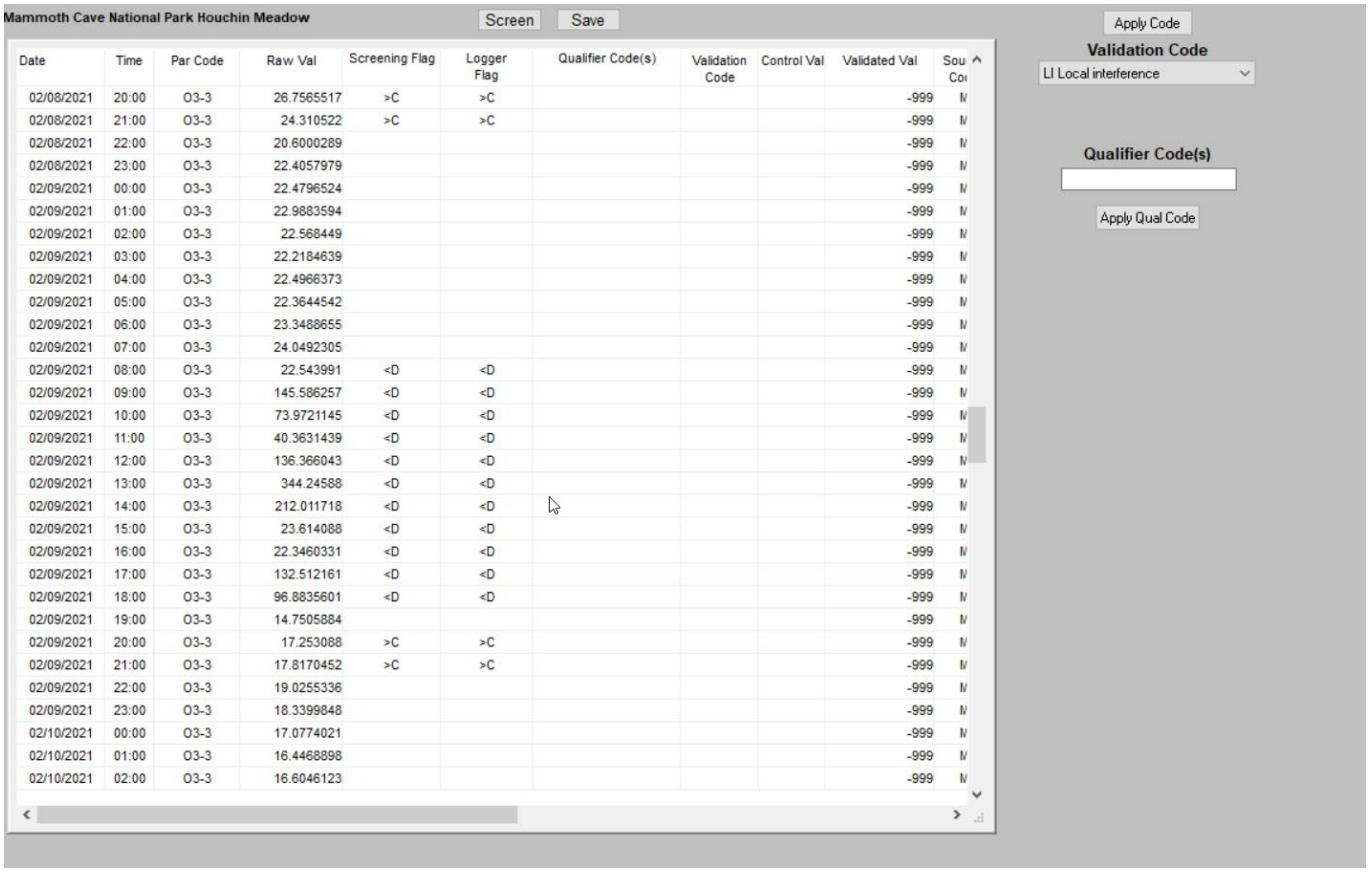
Dr. Doraiswamy reviewed and discussed Data Processing, Data Validation Procedures and Reporting with Ms. Ward. The auditors observed the daily checks, the monthly checks, and the final validation. Ms. Ward showed the stack plots for the ozone data as well as for the calibration data. The automated data validation converts the data logger codes to flags. On a monthly basis, the data analyst looks at the automated data validation and determines if the data and the flag look okay and whether any changes to flags were needed based on site information. The final validation looks at plots of raw data overlayed with invalidated data to quickly visualize invalidated data. They also do a monthly data review with the NPS during which they also look at other supporting data such as AirNow, meteorology, etc. The annual data review examines the time series on a quarterly basis rather than weekly basis.

Auditors discussed the process of a new hire performing the data validation. The new hire reviews SOPs, is trained by an experienced data analyst, observes validation performed by others, next performs the validation under the supervision of an experienced data analyst and once found to be competent with the process, performs on their own. New hires are typically assigned simple sites to begin with until they get familiar with the process.

Auditors also discussed the process for software updates and verifications. All roll-outs of new software are tested and validated as per the SOP titled "SOP Tracking Changes and Updates to ARS Developed Database Software (IT_AQDB_Updates_2016Oct_F_1.0) that outline the process for developing a design plan, test, plan troubleshooting, and acceptance plan for in-house developed software. As noted in the SOP, the verification involves using known data to process through the software to ensure correct performance.

No issues were observed. Upon Dr. Doraiswamy's request, Ms. Ward showed the raw data in the AQDBMS for the day of the field visit. Appropriate data logger flags were noticed for the hours with the calibration checks performed by the site operator (see **Exhibit 9**).

Exhibit 9. Screen capture of the AQDBMS showing raw data and flags for the day of the onsite field visit (Feb 9, 2021)



Date	Time	Par Code	Raw Val	Screening Flag	Logger Flag	Qualifier Code(s)	Validation Code	Control Val	Validated Val	Sou Co
02/08/2021	20:00	O3-3	26.7565517	>C	>C				-999	N
02/08/2021	21:00	O3-3	24.310522	>C	>C				-999	N
02/08/2021	22:00	O3-3	20.6000289						-999	N
02/08/2021	23:00	O3-3	22.4057979						-999	N
02/09/2021	00:00	O3-3	22.4796524						-999	N
02/09/2021	01:00	O3-3	22.9883594						-999	N
02/09/2021	02:00	O3-3	22.568449						-999	N
02/09/2021	03:00	O3-3	22.2184639						-999	N
02/09/2021	04:00	O3-3	22.4966373						-999	N
02/09/2021	05:00	O3-3	22.3644542						-999	N
02/09/2021	06:00	O3-3	23.3488655						-999	N
02/09/2021	07:00	O3-3	24.0492305						-999	N
02/09/2021	08:00	O3-3	22.543991	<D	<D				-999	N
02/09/2021	09:00	O3-3	145.586257	<D	<D				-999	N
02/09/2021	10:00	O3-3	73.9721145	<D	<D				-999	N
02/09/2021	11:00	O3-3	40.3631439	<D	<D				-999	N
02/09/2021	12:00	O3-3	136.366043	<D	<D				-999	N
02/09/2021	13:00	O3-3	344.24588	<D	<D				-999	N
02/09/2021	14:00	O3-3	212.011718	<D	<D				-999	N
02/09/2021	15:00	O3-3	23.614088	<D	<D				-999	N
02/09/2021	16:00	O3-3	22.3460331	<D	<D				-999	N
02/09/2021	17:00	O3-3	132.512161	<D	<D				-999	N
02/09/2021	18:00	O3-3	96.8835601	<D	<D				-999	N
02/09/2021	19:00	O3-3	14.7505884						-999	N
02/09/2021	20:00	O3-3	17.253088	>C	>C				-999	N
02/09/2021	21:00	O3-3	17.8170452	>C	>C				-999	N
02/09/2021	22:00	O3-3	19.0255336						-999	N
02/09/2021	23:00	O3-3	18.3399848						-999	N
02/10/2021	00:00	O3-3	17.0774021						-999	N
02/10/2021	01:00	O3-3	16.4468898						-999	N
02/10/2021	02:00	O3-3	16.6046123						-999	N

Review of data summary reports for September through November 2020 indicated good data completeness (96-99%) of ozone data during those three months. CO showed low data completeness (47.7%) in October 2020. Mr. Slate confirmed that it was due to pump failure on 10/14/2020 which was replaced on 10/28/2020.

The overall quantity and quality of CASTNET's project documentation was impressive, and the ARS personnel who assisted with the audit were knowledgeable and helpful. The data management audit looked at several aspects of the operation as well as verifying and comparing selected data, including calculated ozone concentrations, validity flags and status codes, and date/times.

Data were compared at the following points in the process:

- "raw" data from site data logger
- “raw” and validated data extracted from the in-house database
- data posted to the online databases including the NPS website, the CASTNET website, and the EPA AQS system.

In addition, data were extracted from the following external databases after it had been uploaded from the ARS’s database.

- **NPS website** (https://ard-request.air-resource.com/): This site is a live link to the ARS database and data are available as soon as they are validated. The NPS website provides both “raw” and validated data; however, the “raw” data is what has gone through the automated initial screening.
- **EPA/CAMD CASTNET website** (http://www.epa.gov/castnet): This site allows downloading of data from

all CASTNET sites. Hourly ozone data are available for download within 24 hours of the sampling date. Because of this quick turnaround, the most recent data are not fully validated.

- **EPA AQS system:** This is the final repository of fully validated data for compliance and reporting purposes. ARS uploads data to AQS typically about 60 days following the end of the measurement period for which the data is being reported. Data from the AQS system were queried using the AQS API (https://aqs.epa.gov/aqsweb/documents/data_api.html).

Data Collection

Data were collected for selected days over a 1-year period. This included days from within a month, within the past quarter, within the past 6 months and about a year back. Dr. Doraiswamy looked at data from CASTNET for MAC426 and identified specific days within these generic timelines. This included periods when there were missing data, periods of calibration and/or audit, and periods with high concentrations. Data were collected for the following days:

- 1-minute data and ZSP checks for February 7 and 8, 2021 (2 days prior to the onsite audit)
- January 10 and 11, 2021 (within a month),
- November 8 to 11, 2020 (prior quarter),
- August 23 to 25, 2020 (within 6 months), and
- January 20 to 24, 2020 (within the past year)

Data were downloaded from the data logger at the monitoring site for January and February time periods at 1-min and 1-hr time resolution. Older time periods were not available onsite. ARS sent raw and validated data at 1-hr resolution for all the time periods and at 1-min resolution for August 2020 time period as part of follow-up requests. Dr. Doraiswamy downloaded "raw" and validated data from NPS website at 1-min and 1-hr time resolution. Data were downloaded from the CASTNET and AQS systems at 1-hr resolution. Since data are posted to AQS about 60 days following the measurement period, data were not available for the January 2021 and February 2021 periods.

Site and parameter values used in the data queries were as follows:

- AQS: State-County-Site ID: 21-61-0501; Parameter code: 44201
- NPS ID: MACA-HM, Mammoth Cave National Park Houchin Meadow
- CASTNET ID: Mammoth Cave NP, Ozone Hourly

Data Evaluation Activities

- During the onsite field visit, RTI auditor Mr. Dart noted down the ozone readings from the analyzer screen and from the data logger. The data are shown in Appendix A, Field Site Questionnaire (Part 6 Data Management (Site). Minor discrepancies were seen between the reading on the screen and the data logger. Follow-up with the field technician Mr. Dave Beichley clarified that it is due to different averaging times. Mr. Beichley provided the following response: "*The readings on the front display of the ozone analyzer is generally set to 30 seconds averaging time. The readings on the logger are digital readings, and we use MODBUS to collect the data. Modbus updates I believe every 10 seconds. The lowest averaging time we collect data on the logger is 1 minute average readings. If conditions are stable, there will be some slight differences between media. If the readings are changing rapidly either because of ambient conditions or if a calibration is being performed the readings may differ much more.*" Based on this inherent difference in averaging times and considering that the readings were taken during the calibration checks, the observed differences are anticipated.
- Dr. Doraiswamy compared the hourly average concentrations between the different sources of data: raw data from site/ARS vs. raw data from NPS website, raw vs. validated data from NPS website, and validated

vs. validated data in all combinations among the CASTNET, AQS and the NPS datasets for each period noted above. For specific time periods, he also calculated hourly averages from the 1-min data. Following were the key observations based on these comparisons:

- Validated data agreed perfectly between different databases for all of the above noted dates: CASTNET vs. AQS, CASTNET vs. NPS, and AQS vs. NPS.
- Hourly average calculated from the raw 1-min data for the November 2020 period agreed with the recorded hourly data for the most part. The "raw" 1-min data from the NPS website has 2 to 3 significant digits while the reported hourly data is truncated to the nearest ppb. Due to these differences in significant digits, there were certain instances where the difference was at most 1 ppb. **Exhibit 10** shows the calculated vs. reported hourly values. When truncated to the nearest ppb, the highlighted values show a 1 ppb difference. ARS confirmed that the data logger calculates the hourly values and are retrieved. ARS does not calculate hourly averages from the 1-min data. Note that the "raw" data on the NPS website is following the initial screening. While 1-min data was not obtained directly from ARS for the Nov 2020 period, examination of raw 1-min data from the data logger for August 2020 period showed that the data had up to 8 to 9 significant digits. Calculation of hourly average for the August 2020 period using the raw 1-min data from the data logger showed exact agreement with the hourly values reported. This demonstrates that the differences in significant digits in the raw data between that on the NPS website and as obtained from the data logger is the reason for the minor differences in calculated vs. reported hourly values.

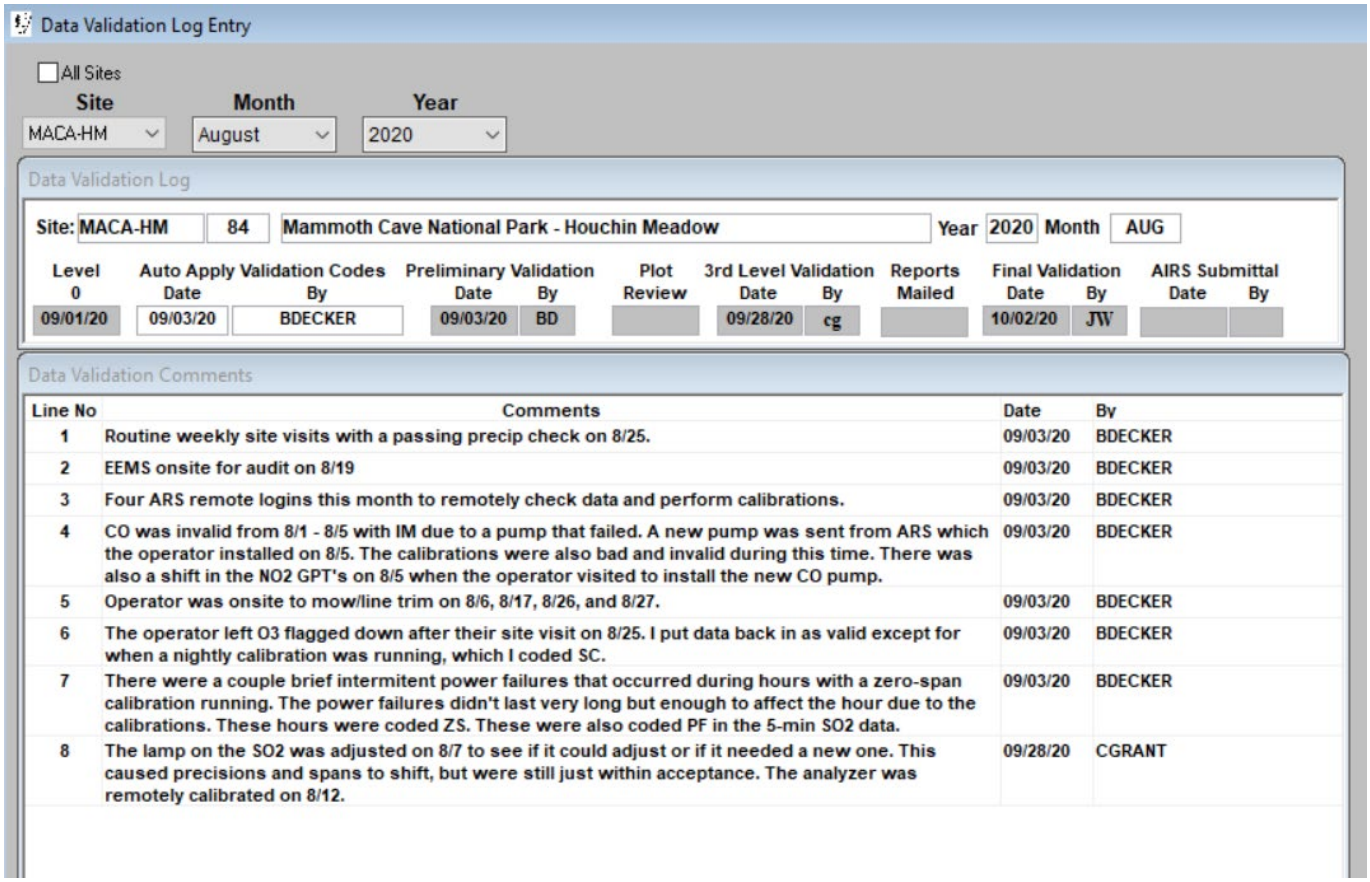
Exhibit 10. Calculated vs. Reported Hourly Average

NPS_DATE_TIME	NPS_O3_PPB_1-hr_raw	NPS_O3_1hr_from_1min_raw	ARS_O3_PPB_1-hr_raw
11/10/2020 10:00	30	30.34833	30.40252
11/10/2020 11:00	31	31.916	31.96191
11/10/2020 12:00	31	31.23667	31.28364
11/10/2020 13:00	31	30.965	31.01366
11/10/2020 14:00	30	30.39667	30.45639
11/10/2020 15:00	29	29.95333	29.99519
11/10/2020 16:00	25	25.38167	25.44355
11/10/2020 17:00	24	24.57333	24.61871
11/10/2020 18:00	22	22.09	22.14194
11/10/2020 19:00	18	18.81833	18.86437
11/10/2020 20:00	17	17.65556	17.70158
11/10/2020 21:00	16	16.53778	16.59334
11/10/2020 22:00	15	15.59167	15.64358
11/10/2020 23:00	15	15.17333	15.22949
11/11/2020 0:00	14	14.61667	14.66872
11/11/2020 1:00	14	14.04333	14.09192
11/11/2020 2:00	12	12.59333	12.64594
11/11/2020 3:00	13	13.39667	13.44849
11/11/2020 4:00	28	28.86333	28.91305
11/11/2020 5:00	31	31.33167	31.37576
11/11/2020 6:00	29	29.36333	29.41991
11/11/2020 7:00	28	28.20167	28.25597
11/11/2020 8:00	28	27.98333	28.03104
11/11/2020 9:00	25	25.73	25.77964

11/11/2020 10:00	22	22.22833	22.27556
11/11/2020 11:00	22	22.66667	22.72114
11/11/2020 12:00	21	21.225	21.27006
11/11/2020 13:00	20	20.58833	20.6408
11/11/2020 14:00	18	17.96333	18.01281
11/11/2020 15:00	19	19.59833	19.64404
11/11/2020 16:00	19	19.71333	19.76275
11/11/2020 17:00	17	17.49833	17.54574
11/11/2020 18:00	16	16.72833	16.77174
11/11/2020 19:00	18	18.05333	18.10683
11/11/2020 20:00	19	19.32667	19.37912
11/11/2020 21:00	20	20.53778	20.58998
11/11/2020 22:00	20	20.14333	20.19069
11/11/2020 23:00	18	18.47333	18.52796

- Comparison between the raw and validated data indicated some discrepancies for the August 2020 period. It was found that the data were first invalidated for several hours from 13:00 to 23:00 but later updated in October 2020 following the monthly data validation. Therefore, the validated dataset on NPS, AQS and CASTNET websites have valid values for most of the hours except 1300-1400 and 2000-2100 and agree among each other. However, the "raw" data from NPS website did not have the values for both 1-hr and 1-min. Ms. Ward of ARS clarified with the following response: "*The site operator inadvertently left the O3 channel on the logger flagged down following his site visit on 8/25. Our screening process for raw data would remove these data points due to the flags. However, when we validated the data we were aware that these flags were unintentional and so essentially overwrote them with valid codes. The 1300-1400 hours remained invalid because this was when he was performing maintenance, and the 2000-2100 hours remained invalid due to the nightly calibration checks.*" Since the "raw" data posted on the NPS website is a live link to the AQDBMS and exports the raw data after screening out for bad data based on logger and screening flags, the "raw" data on the NPS website still shows as missing for the raw data. **Exhibit 11** shows the screenshot of data validation log for August 2020 that documents the reason (line #6 in the log).
- The AQS dataset has QC flags that are descriptive and helpful to interpret. For the August 2020 instance described above, the AQS dataset had appropriate QC flags indicating zero/span checks for the hours that data were invalid. The CASTNET data has flags but for the above instance it just had a flag/QC code of "3" (Level 3 validated data) even for the missing values with no indication of why the data were missing. The NPS dataset had no flags reported. The raw data from the data logger obtained from ARS had logger and screening flags of "<D" for the periods with missing values. It would have been more appropriate for the CASTNET dataset to have a code of "Y" that corresponded to the QC zero/span status instead of "3" code. It would also be helpful to include the flags in the NPS dataset as well where both raw and validated data are available. Ms. Ward responded that ARS has no control on how the data is posted to the CASTNET website and they do not maintain that website. Regarding the feedback on flags in NPS dataset, Ms. Ward agreed about the usefulness of adding flags to the dataset, but noted that NPS has specified the format for the data exports that get posted on the NPS Website and ARS follows that format.

Exhibit 11. Screenshot of Data Validation Log for August 2020



Data Validation Log Entry

All Sites

Site	Month	Year
MACA-HM	August	2020

Data Validation Log

Site: MACA-HM 84 Mammoth Cave National Park - Houchin Meadow Year 2020 Month AUG

Level 0 Date	Auto Apply Validation Codes Date	Auto Apply Validation Codes By	Preliminary Validation Date	Preliminary Validation By	Plot Review	3rd Level Validation Date	3rd Level Validation By	Reports Mailed	Final Validation Date	Final Validation By	AIRS Submittal Date	AIRS Submittal By
09/01/20	09/03/20	BDECKER	09/03/20	BD		09/28/20	cg		10/02/20	JW		

Data Validation Comments

Line No	Comments	Date	By
1	Routine weekly site visits with a passing precip check on 8/25.	09/03/20	BDECKER
2	EEMS onsite for audit on 8/19	09/03/20	BDECKER
3	Four ARS remote logins this month to remotely check data and perform calibrations.	09/03/20	BDECKER
4	CO was invalid from 8/1 - 8/5 with IM due to a pump that failed. A new pump was sent from ARS which the operator installed on 8/5. The calibrations were also bad and invalid during this time. There was also a shift in the NO2 GPT's on 8/5 when the operator visited to install the new CO pump.	09/03/20	BDECKER
5	Operator was onsite to mow/line trim on 8/6, 8/17, 8/26, and 8/27.	09/03/20	BDECKER
6	The operator left O3 flagged down after their site visit on 8/25. I put data back in as valid except for when a nightly calibration was running, which I coded SC.	09/03/20	BDECKER
7	There were a couple brief intermitent power failures that occurred during hours with a zero-span calibration running. The power failures didn't last very long but enough to affect the hour due to the calibrations. These hours were coded ZS. These were also coded PF in the 5-min SO2 data.	09/03/20	BDECKER
8	The lamp on the SO2 was adjusted on 8/7 to see if it could adjust or if it needed a new one. This caused precisions and spans to shift, but were still just within acceptance. The analyzer was remotely calibrated on 8/12.	09/28/20	CGRANT

Findings and Recommendations

FINDING 1: All validated data agree perfectly between the different online systems and the data from ARS.

FINDING 2: The translation of flags and resulting data invalidation appears to be working properly. An instance in August 2020 due to an inadvertent error demonstrates reversal of errors following data validation. Two important points to be made here: (1) the true raw data from the data logger is unaltered and was provided to RTI to verify the inadvertent flags that caused the invalidation; and (2) the "raw" data on the NPS website is following the initial screening and therefore is not truly raw in nature. However, the live link to NPS website demonstrates the functioning of how it uses screening flags to omit bad data points. Moreover, the approach followed is consistent with the SOP *I_IMC_DATAVAL_F_1.0* on Data Validation that dictates the data analyst to "Investigate; can be valid or invalid" for datalogger flag of "D" (page 36).

RECOMMENDATION: The NPS should consider referring to the "raw" data on its website as something different to avoid confusion with the true raw data. For example, the data could be referred to as "Unvalidated but prescreened."

FINDING 3: The data on the NPS website lacks flags. Adding flags would help in data interpretation by end users.

RECOMMENDATION: NPS should consider adding flags to the format that it requires ARS to report in.

Since findings 2 and 3 are not in ARS's control, recommendations are made for NPS to consider updating its requirements.

Section 7: Quality Control and Quality Assurance

Quality Management Documentation

The quality management system (QMS) consists of the ARS-NPS QAPP and SOPs located on the NPS GPMP Project website (http://ard-request.air-resource.com). Dr. Doraiswamy also reviewed the CASTNET QAPP Appendix 3 ARS SOPs (ozone collection process) from the CASTNET website (http://www.epa.gov/castnet) to ensure those are the recent versions. Within the QMS is a controlled document network that consists of SSRFs; DataView Call Log; site and laboratory logbooks; results from internal and external audits and assessments; ARS databases; and records of e-mail transmittals.

On the CASTNET website, the current CASTNET QAPP and supplementary SOPs are in the 9.3 Revision and dated March 30, 2020. The QAPP entitled "Clean Air Status and Trends Network (CASTNET) Quality Assurance Project Plan (QAPP)" is written in accordance with EPA Guidance Document "*EPA Requirements for Quality Assurance Project Plans EPA QA/R*-5" and "*EPA Requirements for Quality Assurance Project Plans EPA QA/G*-5," and contains all necessary elements for an EPA-approved QAPP. The QAPP is divided into five sections (Project Overview, Field Operations, Laboratory Operations, Data Operations, and Quality Assurance) plus a References and Revision Tracking Sheet. The Project Overview section details purpose of the project, the organizational charts and personnel responsibilities for management of the CASTNET project, schedules and deliverables, data quality objectives (DQOs) and criteria, training, and data management requirements. The Field Operations section describes field activities such as sampling design, frequency, and acceptance criteria for collecting samples, field equipment verification and calibration, and field data management. The Laboratory Operations section details the sample handling and custody, the analytical methods, quality control, and data processing. The Data Operations section describes the software, verification and validation, calculations, and data submittal to EPA and NPS. The Quality Assurance section explains the assessment responsibilities through audits and reviews, examines the DQOs and data quality indicators (DQIs), and corrective action to nonconformities.

The ARS-NPS QAPP was revised in October 2020 (version 4) and also follows the EPA Guidance Document "*EPA Requirements for Quality Assurance Project Plans EPA QA/R*-5." This document resides on the NPS GPMP website and is not on the CASTNET website. This was noted during the October 2013 TSA and Wood and ARS have decided it was not necessary to post the ARS-NPS QAPP on the CASTENT website. The ARS-NPS closely follows the management structure and steps outlined in the ARS SOPs listed on both the NPS GPMP and CASTNET websites.

Since the last TSA, the ARS team has now developed a process to revise the QAPP and the SOPs. The ARS team reviews the QAPP annually and sends any minor updates (e.g., site changes) to the NPS management summarizing the changes in separate documents. The QAPP itself is revised approximately every 5 years. RTI auditors requested a copy of the previous communication to NPS. ARS provided a copy of the communication in 2018 (**Exhibit 12**). The QAPP revision cycle started in 2019 and finalized in 2020 and hence no such communication happened in 2019-2020.

All SOPs are reviewed and revised annually. Each SOP has a review history page that documents who reviewed it and when.

Finding 1

A review of the versions on the NPS and CASTNET websites indicated the following:

- The version of the QAPP and some SOPs on the NPS website are outdated. These need to be replaced with most recent approved versions.
- The versions of some of the SOPs in Appendix 3 of the CASTNET QAPP are outdated. These documents need to be replaced with the most recent versions.

Exhibit 12. Communication of QAPP Annual Review Changes to NPS

Air Resource SPECIALISTS

May 14, 2018

Barkley Sive
National Park Service
12795 W. Alameda Parkway
Lakewood, CO 80228

Dear Barkley:

In accordance with our National Park Service – Gaseous Pollutant Monitoring Program (NPS-GPMP) contract, this letter serves as notice that there have been changes to the site locations involved in the monitoring program in the past year. Enclosed are updated copies of Tables 3, 4, and 5 listing site location information, monitored parameters, as well as an updated list of sites which undergo annual data certification. Please print these pages and insert them into your hard copy of the QAPP.

With these minor changes, the GPMP Quality Assurance Project Plan, Revision 3 dated October 2015 remains in effect for the coming year.

Should any aspect of monitoring change in the interim, I will again review and revise the document as necessary. Please contact me if you need any additional information.

Sincerely,

Emily Vanden Hoek
Quality Assurance Manager

EKV:ekv
cc: John Vimont (NPS)
Joe Adlhoch (ARS)
Jessica Ward (ARS)

970 • 484 • 7941 ▲ www.air-resource.com
1901 Sharp Point Drive ▲ Suite F ▲ Fort Collins ▲ Colorado ▲ 80525

Audit and Assessment Program

QC and QA describe the two sets of practices related to a monitoring program that give agencies confidence that the data they collect represent the true air quality of the area. They are the mechanisms by which an organization manages its data collection in a systematic, organized manner and provides a framework for planning, implementing, and assessing work performed by an organization. A properly developed QA/QC program encompasses a variety of technical and administrative elements, including policies and objectives, organizational authority, responsibilities, accountability, and procedures and practices.

QA is a management or oversight function; it deals with setting policy and running an administrative system of management controls that cover planning, implementation, and review of data collection activities, and the use of data in decision making. QC is a technical function that includes all the scientific precautions, such as calibrations and duplications that are needed to acquire data of known and adequate quality.

All onsite ozone standards are certified as Level III because they have been calibrated against a traveling Level II ozone standard maintained by the ARS Ozone Calibration Laboratory. The traveling Level II transfer standards are used to calibrate the onsite ozone transfer standards twice per year during the 6-month check. The Level II transfer standards are calibrated once per year at one of the EPA regional laboratories against a Standard Reference Photometer (SRP), otherwise known as a Level I standard. The CASTNET ozone analyzers undergo nightly zero, span, and precision (ZSP) checks to quickly diagnose any problem with the system and also a multi-point verification every month. A data review is performed daily on the ZSP checks by an automatic screening system. Every CASTNET ozone analyzer within the network is audited once per year by an independent auditor who completes a Performance Evaluation (PE). The PE results are required to be submitted to AQS before annual data can be certified. The CASTNET sites are also subject to a Field Systems Audit (FSA) on a biannual basis. In addition, each year 20% of the network participates in the National Performance Audit Program (NPAP). State, local and Tribal agencies participate in the NPAP to provide consistency in the data across all monitoring organizations.

For the MAC426 site, the last 6-month calibration prior to the TSA was conducted on May 15-17, 2020 (see **Appendix D**). The last PE was conducted by EEMS on August 19, 2020 (see **Appendix E**). EEMS conducted a PE audit of the measurement parameters and an FSA of the MAC426 site for CASTNET on October 17, 2019. The complete results of this audit are presented in **Appendix F** of this report. The NPAP audit was conducted by the state of KY on January 22, 2020 (reported on February 6, 2020, see **Appendix G** for results). **Exhibit 13** below states the acceptance criteria for each of the assessments performed at the CASTNET monitoring sites.

Exhibit 13. Acceptance Criteria for Calibration and Audit Checks

Assessment	Acceptance Criteria
ZSP Checks	Zero value ≤ ±3 ppb in 24-hr period and 5 ppb in 14-day period Precision/Span ≤ ±7% between supplied and observed concentrations
6-Month Calibration Checks	All points within ±2% of full scale of the best fit straight line ±5% of actual for any value, $r^2 > 0.9950$, 0.9500 < slope < 1.050 -3.0 ppb < intercept < 3.0 ppb
PE Audits	All points within ± 2% of full scale of best fit straight line Linearity error < 5%

These audits indicate that the site satisfies the QA/QC criteria for ozone measurements. The 2019 FSA by EEMS had no negative findings for the ozone measurement system, but a couple of findings were reported for the filter pack measurements. ARS notes that the recommendations have since been implemented for the filter pack measurements. It must be noted that the filter pack measurements were outside the scope of this TSA.

ARS has applied sufficient steps in the electronic data management system for the ozone collection process to manage both data input and QA/QC to provide precise data quality reporting. ARS management and the QA Manager have done an excellent job of maintaining good quality monitoring data for the CASTNET program and the current staff and management have displayed the commitment to provide informed quality data to NPS, and AQS.

APPENDIX A

Mammoth Cave National Park
(MAC426)
Field Site and Laboratory Questionnaire

Technical Systems Audits (TSAs) for Ozone Measurements in the Clean Air Status and Trends Network (CASTNET) Program

Monitoring Site and Laboratory
Technical Systems Audit Form

RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709
Telephone (919) 541-6000

Table of Contents

Technical Systems Audits (TSAs) for Ozone Measurements in the Clean Air Status and Trends Network (CASTNET) Program

Monitoring Site and Laboratory Technical Systems Audit Form

This audit form was prepared by RTI International (RTI) to evaluate the technical systems for ozone measurements at the CASTNET air monitoring sites operated by Air Resource Specialists, Inc. (ARS). This form will be used to evaluate the QA/QC documentation, network management, basic site operations (ozone specific), sample siting requirements, and data management at the Mammoth Cave National Park (MAC426) site in Kentucky and the ARS CASTNET Ozone Calibration Laboratory in Fort Collins, Colorado. All questions are based on Title 40 Code of Federal Regulations (CFR) Part 58 requirements and Appendix H of Volume II of the EPA QA Handbook.

RTI will follow the US EPA's quality assurance guidance document for conducting technical systems audits entitled, *Conducting Technical Systems Audits of Ambient Air Monitoring Programs* document # EPA-454/B-17-004 November 2017. RTI will use the current Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOPs) provided by ARS, as well as quarterly Quality Assurance Reports posted on the CASTNET website (https://www.epa.gov/castnet). The current ARS QAPP is Revision 4 dated October 2020 with two appendices. These appendices or particular sections of the appendices will be used as a basis to prepare questionnaires for the TSA of the field sites (ozone activities), ARS Calibration Laboratory (ozone), and data management system for ozone reporting to the EPA Air Quality System (AQS) and AIRNow. Those appendices are:

- Appendix A – Standard Operating Procedures, Technical Instructions and Checklist Instructions
- Appendix B – IMC New Site/Site Relocation Form

We will also ensure consistency with Appendix 3 (ARS SOPs) of the CASTNET QAPP (current approved version: Revision 9.3) and verify that the pertinent procedures are contained in that appendix.

Part 1. General Information

Monitoring Site Information
(MAC426)

NAME/LOCATION OF MONITORING SITE: (Ozone): **Mammoth Cave NP/Mammoth Cave National Park, KY**

MONITORING SITE ADDRESS: 107-199 Alfred Cook Rd, Park City, KY 42160

MONITORING SITE AQS NUMBER: **21-061-0501** CASTNET SITE NUMBER: **MAC426**

MONITORING AGENCY AFFILIATION: **CASTNET**

NAME OF ANALYSIS/SUPPORT LABORATORY: **Air Resource Specialists, Inc. (ARS) in Ft. Collins, CO**

AUDIT TEAM MEMBERS/AFFILIATIONS: **Andrew Dart (field visit & remote ARS ozone calibration lab), Prakash Doraiswamy (remote ARS lab), both from RTI**

AUDIT DATE: **February 9 (field site – in-person) and February 17 (Ozone Calibration Laboratory- remote)**

PERSONNEL INTERVIEWED:

NAME	POSITION	PHONE/E-MAIL
Site		
Johnathan Jernigan	**Site Operator**	**johnathan_jernigan@nps.gov**
Dave Beichley	**ARS Field Specialist**	**dbeichley@air-resource.com**
ARS Ozone Calibration Laboratory and Data Handling		
Emily Vanden Hoek	**ARS (CASTNET) QA Manager**	**evandenhoek@air-resource.com** **970-484-7941**
Mike Slate	**ARS Field Operations Manager**	**mslate@air-resource.com** **970-484-7941**
Jessica Ward	**ARS Information Management Section Manager**	**jward@air-resource.com** **970-484-7941**

OPERATIONAL AREAS THAT WERE OBSERVED: Auditor observed site operator (Johnathan Jernigan) removing and loading the filter pack and completing the SSRF. We also discussed training provided, general operations, use of DataView system, troubleshooting, maintenance, mitigation strategies for power outage, repair/replacement of equipment at site, site selection criteria, and weekly checklist. Auditor observed field specialist (Dave Beichley) performing meteorological checks, ozone line leak test, ozone sampler 1x6 performance verification. We also discussed the instrument certification and calibration process, ARS QAPP, semiannual maintenance, and calibration visit procedures, and site status logs.

Part 2: Basic QA/QC

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
A. QAPP and SOPs				
1. Is there an EPA approved quality assurance project plan (QAPP) specific to the CASTNET work being conducted by the laboratory?			X	Current CASTNET QAPP in Revision 9.3 dated October 2019 for EPA- sponsored sites and laboratory (filter pack) operation. National Park Service (NPS)- sponsored sites use another QAPP developed for the NPS program titled " Gaseous Pollutant Monitoring Program Quality Assurance Project Plan (QAPP)", Revision 4 dated October 2020
2. What is the level of detail Category (i.e., 1, 2, 3, etc.) consistent with EPA guidelines) of the QAPP?				Both QAPP's are Category 1.
3. Does the QAPP reflect, present, and address specifications (i.e., MQOs, DQIs, MDLs, etc.) that are in accordance with those specified for the CASTNET program?	X			MDL – Table 6a of QAPP DQO & DQI – Tables 8 & 9 of QAPP
4. Does the QAPP follow the guidelines and requirements outlined in the EPA Guidance Documents (EPA QA/G-5 and EPA QA/R-5)?	X			
5. Does the QAPP identify a reviewing process for the QAPP and other QA documentation?	X			In Section A3, the QAPP is to be reviewed annually.
6. Are all the elements of the EPA Guidance Documents met in the QAPP?	X			
7. Has it been reviewed by all personnel (lab, field, management, etc.) associated with conducting the CASTNET work?	X			CASTNET QAPP (EPA-Melissa Puchalski-EPA Project Officer) Wood management (H. Kemp Howell-Project Manager, Ann Glubis-Project Quality Assurance Supervisor, and Marcus Stewart-Quality Assurance Manager) ARS-NPS QAPP (NPS-Barkley Sive-Program Manager and John Vimont, Chief of Research and Monitoring Branch) ARS management (Joe Adlhoch-Program Manager and Emily Vanden Hoek-QA Manager) The NPS serves as the regulatory agency.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
8. Has the Regional EPA Clean Air Markets Division (CAMD) Project Officer and QA Officer reviewed the QAPP?			X	CASTNET QAPP Melissa Puchalski-EPA Project Officer Carlos Martinez-EPA QA Officer Barkley Sive-NPS Contracting Officer's Technical Representative Ryan McCammon-Bureau of Land Management ARS-NPS QAPP Barkley Sive-NPS Program Manager John Vimont-NPS Chief of Research and Monitoring Branch Auditor: Even though this site is part of the CASTNET network, this is part of the NPS sites for which NPS serves as the regulatory agency. Hence, the ARS-NPS GPMP QAPP is only signed by NPS management and not by EPA.
9. Has the CAMD Project Officer and QA Officer approved and signed the QAPP?			X	CASTNET QAPP Date: October 2019 Melissa Puchalski (3/10/20)-EPA Project Officer Carlos Martinez (3/10/20)-EPA QA Officer Barkley Sive (3/11/20) NPS-Contracting Officer's Technical Representative ARS-NPS QAPP Date: October 2020 No EPA staff signature Barkley Sive (1/7/21)-NPS Program Manager John Vimont (1/11/2021)-NPS Chief of Research and Monitoring Branch For ARS, NPS serves as the regulatory agency
10. Has the National Park Service (NPS) Contracting Officer's Technical representative approved and signed the QAPP? (Listed on the distribution list)	X			Barkley Sive (1/7/21)-NPS Program Manager John Vimont (1/11/2021)-NPS Chief of Research and Monitoring Branch
11. Has the ARS Project Officer and QA Manager and other network leads approved and signed the QAPP?	X			ARS-NPS QAPP Joe Adlhoch (1/14/2021)-Program Manager Emily Vanden Hoek (1/14/2021)-QA Manager
12. Is the purpose of the QAPP clearly stated?	X			
13. Is the project organization clearly identified with their roles and responsibilities?	X			

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
14. Is the organizational chart in the QAPP up to date? If there are changes, provide an updated copy.	X			Auditor: A new data analyst has been hired in the data management team just a couple of weeks before the audit and is being trained now. The chart will need to be updated during the next review cycle later in 2021.
15. Is a copy of the approved QAPP available for review by the field operator(s)? If not, briefly describe how and where QA and QC requirements and procedures are documented.	X			
16. Is a signed copy of the approved QAPP onsite and available to the field operator(s)?	X			Electronic version on DataView system.
17. Has the approved QAPP been reviewed (or will be reviewed) on a periodic basis? Ask to see.	X			In Section A3, the QAPP is to be reviewed annually. Auditor: The QAPP was revised and finalized in 2020 (signed Jan 2021).
18. Is this review of the QAPP documented (or will it be documented)?	X			Auditor: The team reviews the QAPP annually and sends any minor updates (e.g., site changes) to the NPS management summarizing the changes in separate documents. The QAPP itself is revised approximately every 5 years. RTI auditors requested a copy of the previous communication to NPS. ARS provided a copy of the communication in 2018. The QAPP revision cycle started in 2019 and finalized in 2020 and hence no such communication in 2019-2020.
19. Are there amendments or deviations from the approved QAPP?		X		
20. Have they been NPS approved?			X	The NPS serves as the regulatory agency.
21. Are they available for review?			X	The NPS serves as the regulatory agency.
22. Has the QAPP been reviewed or will be reviewed on a periodic basis and re-approved? What is the review/approval schedule?	X			As-needed In Section A3, the QAPP is to be reviewed annually. Auditor: ARS updates and revises the QAPP approximately every 5 years. The approval schedule is linked to the QAPP revision schedule. However, the QAPP is reviewed annually and changes are communicated to NPS in an email. The most recent QAPP revision and re-approval happened in October 2020 and January 2021 respectively.
23. Are reviews/approvals documented? Review.	X			
24. Does the QAPP cover the complete field/laboratory operation for the CASTNET program?	X			Between the CASTNET (Wood) and the NPS (ARS) QAPPs, all field and laboratory operations are covered between the two companies.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
25. Is there an internal assessment program to verify conformity to quality assurance? What assessments are performed?	X			Regular meetings with program director and QA review of all calibration results The internal assessment program at the site for ozone collection includes: a daily ZSP check, a monthly multi-verification check, a 6-month calibration, and an annual PE for the ozone analyzer. During the 6-month calibration and annual PE, a TSA is conducted that might involve the site operator. The data from the DataView log is transmitted to the ARS Office. The field specialist and data analyst can view the data in the Site Status log.
26. Are Data Quality Objectives (DQOs) and Data Quality Indicators (DQIs) identified in the QAPP? How are realized?	X			DQO/DQIs are presented in ARS-NPS QAPP Section A7 and limits are presented in Tables 8-11.
27. What steps are performed if DQOs are not achieved and maintained?				ARS field specialists work with site operators to resolve.
28. Is there a corrective action process in place when Measurement Quality Objectives (MQOs) or operational specifications (e.g., out-of-control calibration data) are not met?	X			Depending on the issue, if an instrument fails to meet acceptance criteria it is calibrated or repaired, and data are invalidated as appropriate. The problem is documented in the site status log.
29. Is there a Quality Management Plan (QMP) developed by ARS?	X			
30. Does the QMP follow EPA Guidance Document (EPA QA/R-2)?	X			
31. Is the QMP signed and approved by EPA and available for review?			X	
32. Are written and approved standard operating procedures (SOPs) in place for the various samplers?	X			
33. Does the format of the SOPs follow the guidelines outlined in the EPA Guidance Document (EPA QA/G-6)? If not, describe what significant information is missing?	X			
34. Does the SOPs reflect, present and address specifications and operations that are in accordance with those applicable to the CASTNET program?	X			
35. Are the SOPs signed by management and QA staff?	X			
36. Are the SOPs available for review by auditor?	X			
37. Are the SOPs controlled documents?	X			
38. Are signed copies of the SOPs available to the field operator?	X			Electronically stored on the DataView system.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
39. Does the site operator have current up-to-date SOPs onsite? Electronic or hard copies.	X			Electronically stored on the DataView system.
40. Are there deviations from the SOPs?		X		
41. If yes, have these deviations been documented and approved?			X	
42. Are documented deviations available for review?			X	
43. Has training been conducted for these SOPs?	X			Training occurs in three possible ways: 1-from previous site operator 2- during new site or relocation setup 3-during each semi-annual visit Training is re-enforced during each semi-annual calibration and maintenance visit.
44. Is this training documented?	X			After the 6-month calibration, the ARS Field Specialist goes through all of the procedures conducted during the visit with the site operator and completes a Tailgate Safety Meeting Form and Site Operator Training Form. This form is handwritten by the Field Specialist and signed and dated by the Field Scientist and site operator. A PDF version is submitted back to the site operator and posted on the DataView system.
45. Are the SOPs current and up-to-date and meet the specifications presented in the CASTNET program?	X			
46. Is there a process in place to remove obsolete SOPs? Describe the process and where it is documented.	X			Once all ARS SOPs have been revised a memo describing the removal of obsolete SOPs will be prepared.
47. Have the SOPs been reviewed on a periodic basis?	X			
48. What is the frequency and approach?				Annual review – revised as needed
49. Is this review documented? (Review).	X			SOPs are current (reviewed and updated in October 2020). Auditor: Revisions and annual reviews are documented in each SOP.
Additional Comments:				

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
B. Organization and Responsibilities				
1. Key staff that oversee CASTNET operations:				
a. CASTNET Project Manager				Name: Kemp Howell
b. CASTNET Quality Assurance (QA) Manager				Name: Marcus Stewart
c. NPS Contracting Officer's Technical Representative				Name: Barkley Sive
d. ARS (CASTNET) Project Manager				Name: Joe Adlhoch
e. ARS (CASTNET) QA Manager				Name: Emily Vanden Hoek
f. CASTNET QA Auditor(s) Annual Ozone PE				Name: EEMS
g. ARS Field Operations Manager				Name: Mark Tigges and Mike Slate
h. ARS Field Specialist				Name: Dave Beichley, Chad Cole, John Krolak
i. ARS Information Management Section Manager				Name: Jessica Ward
j. ARS IMC Team Leader				Name: Emily Wiechman
k. ARS IMC Data Analyst/Technician				Name: Molly Anderson
l. ARS Data Analyst/Technician				Name: Brittany Decker
m. ARS IMC Air Quality Technician				Name: Matt Smith
2. Name of management responsible for (indicate which apply):				
a. Development of monitoring site,				Name: Field Specialists
b. Coordinates field operations,				Name: Mike Slate
c. Logistical support of field operations,				Name: Field Specialists
d. Training monitoring site operators, and				Name: Field Specialists
e. Review of routine sampler data and quality control data.				Name: Data Management Group and Field Specialists
3. Name of ARS staff or subcontractor responsible for (indicate which apply):				
a. Operation of sampler, monitors, and equipment;				Name: ARS Field Specialists
b. Calibration of sampler, monitors, and equipment;				Name: ARS Field Specialists
c. Maintenance of sampler, monitors, and equipment;				Name: ARS Field Specialists
d. Maintenance of monitoring site,				Name: ARS Field Specialists
e. Operation of ozone monitor,				Name: ARS Field Specialists
f. Calibration of ozone monitors, and				Name: ARS Field Specialists

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
g. Maintenance of ozone monitor.				Name: NPS
4. Is there someone who reviews the following completed forms:				
a. Field forms or electronic entries? Who?	X			Name: Administrative Assistants and Field Specialists
b. Chain of Custody (COC) forms? Who?		X		Name: No COC forms used
c. Review of electronic data from monitors? Who?	X			Name: Data Management Group and Field Specialists Auditor: There is no specific person assigned to a specific site. Different members of the data management group may review the data from the site on a weekly basis providing an independent review each week.
d. Review of field logbooks (site, monitor). Who?	X			Name: Data Management Group and Field Specialists (site uses electronic entries – DataView)
5. Has the review of completed field and COC forms been done?	X			The site operator does not enter any ozone information on the Site Status Report Form (SSRF). All data entries are electronic (DataView)
6. Is anyone responsible for QA audits of the site? If so, who?	X			QA: Field Specialists
7. What is the role of the ARS QA Manager in regard to the CASTNET program?				The QA Manager oversees the quality assurance program, reviews QA documentation, discusses with management the training and source needs for the program, and provides guidance to QA Officer(s).
8. What is the role of the ARS QA Officer in regard to the CASTNET program?				The QA Officer provides the QC guidance and requirements for specific programs, has technical capability to apply to the program, and provides and follows through training requirements and capabilities for each program.
9. What is the program relationship between Wood and ARS? QAPP project organization (Figure 1) shows "AMEC Subcontractor."	X			Wood is a subcontractor to ARS for CASTNET filter analysis. Auditor: The project organization chart in the QAPP needs to be updated to rename AMEC to Wood.
10. Can you provide a flow chart showing the management reporting and communications between Wood, ARS, US EPA, and NPS?	X			
11. Are there two levels of management separation between QA and QC operations? The QC operations can be performed by the site operator.	X			
12. Does the QA auditor have unique standards and equipment? (The QA audit should not be using the same standards, equipment, etc. as the site operator that performs the QC checks.)	X			
13. Has an audit(s) been performed? If so, when?	X			A PE audit was performed on 8/19/20.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
14. Were there any findings during the audits?		X		
15. Are audits documented? How?	X			Yes, in an audit report.
16. Are the audit results available for review by staff and auditors? Ask to view audits from this program.	X			Yes, on the network drive.
17. Does the site operator conduct performance checks of the ozone monitor? Frequency?		X		ARS has done this in the past but no longer finds it necessary.
18. What types of QC checks are conducted?				Daily ZSP checks are automatically performed at 0146.
19. Are the results of these checks available for review by staff and auditors? Ask to view check results from this program.	X			On DataView log Auditor: Reviewed the ZSP checks for the 3 days and found to be normal. Also,went over the results with the Field Specialist.
20. Is there any internal auditing program for the ozone monitor?	X			6-month visits include calibration challenge (internal PE) and site conditions check among other checks.
21. If yes, who conducts the internal audit?				Field Specialists
22. What is the frequency and where are the results posted?				Six months. Results posted on NPS website at https://ard-request.air-resource.com/project/
23. Is there a designated schedule for calibrations of the ozone monitor? Frequency?	X			Every six months
24. Are the calibration checks available for review by staff and auditors? Ask to view calibration checks from this program.	X			The six-month calibration checks are stored in the database and later posted on the NPS website.
25. Are the staff that work at the site agency employees? How many?	X			Site operators are part of the NPS for Mammoth Cave National Park.
26. Do any contractors work at the site? How many? Name?		X		
27. What steps are taken to ensure contract staff meet training and experience criteria?				Training occurs in three possible ways: 1-from previous site operator 2- during new site or relocation setup 3-during each semi-annual visit Training is re-enforced during each semi-annual calibration and maintenance visit.
28. Is this documentation maintained? Where?	X			The semi-annual maintenance and calibration results are stored in the database and later posted on the NPS website. Tailgate form used to track site operator training needs.
29. Is there a written procedure for the QA audit, QC checks, calibration, or internal audits for the CASTNET program?				

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
a. QA audit?	X			Performed once per year on a fixed schedule by an EPA subcontractor (EEMS) and four times a year by state auditor.
b. QC checks?	X			ZSP checks are performed daily at 1:46 A.M and monthly multi-point checks are performed by the site operator. Auditor: ZSP checks are programed to occur every 24 hours automatically, not performed by site operator.
c. Calibrations?	X			Every 6 months by a field specialist
d. Internal audits?	X			All parameters are checked during the semi-annual visits.
30. Who is responsible for reviewing results from audits and checks to determine if data should be invalidated?				Data Management Group and QA Officer (Christian Kirk)
31. How is the audit data (6-month) reviewed and what are the decisions (criteria) based on?				ARS follows the limits listed in QA Handbook Volume II with regards to evaluation ZSP checks (10% for data validity) The acceptance criteria for the ozone analyzer is: All points within ±2% of full scale of the best fit straight line, ±5% of actual for any value, r^2>0.9950, 09500<slope<1.050 -3.0 ppb < intercept < 3.0 ppb
32. Is this process documented? Where?	X			The semi-annual maintenance and calibration results are stored in the database and later posted to the NPS website.
33. Are there corrective action steps in place?	X			All data collected "as found" and the audit (calibrator) makes corrections as needed and documents changes. The results are recorded in DataView, the database, and ultimately posted on the NPS website.
34. Where are these steps documented? Review examples of corrective action, if possible.	X			In the checklist forms of the Semi-Annual Site Visitation Checklist
Additional Questions or Comments:				
C. Training, Safety and Chain-of-Custody				
1. Have the monitoring site operators been trained in the sampling procedures, including equipment operation, maintenance and data collection / documentation? If so, when?	X			Training occurs in three possible ways: 1-from previous site operator 2- during new site or relocation setup 3-during each semi-annual visit Training is re-enforced during each semi-annual calibration and maintenance visit.
2. Is it fully implemented?	X			
3. Is this training documented in a training record?	X			Training is documented on tailgate safety meetings and site operator training form, as well as the site laptop.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
4. Is the training record available for review?	X			On DataView laptop (Tailgate forms) Auditor: Reviewed Tailgate form with Dave. Training is accomplished during Tailgate meetings.
5. Is there any documentation maintained at the monitoring site documenting the training of the site operator? (e.g., site logbook)	X			Yes, the Tailgate forms are saved under station documentation.
6. Is there a process of training, testing, and qualification for job responsibilities?	X			
7. How is training provided and how often?	X			Training occurs in three possible ways: 1-from previous site operator 2- during new site or relocation setup 3-during each semi-annual visit Training is re-enforced during each semi-annual calibration and maintenance visit.
8. Has the operator been trained in the particular hazards of the instruments/materials that they are using?	X			
9. Are personnel outfitted with any required safety equipment?	X			
10. Are personnel adequately trained regarding appropriate safety procedures?	X			
11. Are personnel adequately trained regarding cylinder handling?	X			
12. Does the site use field data sheet (FDS) and/or Chain-of-Custody (COC) forms?		X		
13. Are these forms being completed properly?			X	
14. Is the CASTNET Site Status Report Form (SSRF) provided by Wood for this site? What information regarding the ozone collection is placed on the SSRF?	X			Yes, no ozone data is placed on this form.
Additional Questions or Comments:				
D. Monitoring Site Housekeeping				
1. How long has this site been used for the CASTNET program?				Ozone collection began:1/1/98
2. Are all site logbooks and/or forms filled in promptly, clearly, and completely?	X			Hard copy forms only used if the DataView log is not functioning properly. There was no evidence of the DataView system not working, but there are several hard copy forms available at the site if the operators need to utilize them.
3. Does the operator(s) keep the handling area neat and clean?	X			Auditor: Handling area was nicely organized.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
4. Is there adequate room to perform the needed operations?	X			
5. Do the samplers appear to be well maintained and free of dirt and debris, bird/animal/insect nests, excessive rust, and corrosion, etc.?	X			
6. Are the walkways to the station and equipment kept free of tall grass, weeds, and debris?	X			
7. Is the shelter (if any) clean and in good condition?	X			
8. Does the site have safety equipment (fire extinguisher, first aid kit, etc.)?	X			
9. Is the ground surface mostly natural materials?	X			
10. Are there separate Operation and Maintenance (O+M) logs for the CASTNET samplers/monitors/equipment?			X	Entries made in the DataView log system. ARS staff also use the Site Status Log (SSL), which is a web-based interface to our AQDBMS to log operational and maintenance issues at monitoring sites. The SSL will often contain more comprehensive information than entries in the DataView log.
11. If yes, check the O+M or instrument logs against the SOPs. Are these acceptable?			X	
Additional Questions or Comments:				
E. Documentation				
1. Is there a document control program?	X			The program consists of the QAPP and several attached appendices for SOPs used in the program. An electronic data system (DataView) is used for field entries on a weekly, monthly, and semi-annual basis.
2. Are the following documents for this project in the controlled document program:				
a. NPS approved ARS QAPP for the CASTNET Program work?		X		Not required for GPMP – National Park Service is regulatory agency. The site collects filter packs to send to CASTNET (Wood)
b. SOPs?	X			
3. Have the following necessary quality documents for this project been reviewed, approved, and signed:				
a. QAPP – by the NPS Program Manager, NPS Management, and ARS Project Manager and QA Manager	X			The CASTNET QAPP (Version 9.3) has been approved by all required management leads. This site works under the NPS-ARS QAPP that includes the proper management signatures. The response provided by ARS is correct for their QAPP.
b. SOPs – by the ARS Project Manager and Program QA Manager	X			

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
4. Is distribution of the project documents controlled to prevent unauthorized copies from being made/distributed? If so, how?	X			All versions are electronically controlled; no hard copies.
5. Are outdated controlled documents collected and disposed of at the sites?	X			
6. Is this documented?		X		
7. Are procedures in place if out-of-date documents are found? If so, briefly describe.			X	
8. Are the following being filled out promptly, legibly, and clearly:				
a. Logbooks?			X	Site operator uses the DataView system for logging activities at the site.
b. Forms?	X			
8. Are the logbooks and forms maintained at the site? Where and how?	X			SSRF forms for 3 years
9. If yes, are the logbooks/forms available for review?	X			The site operator uses the DataView system for logging visits to the site.
10. Are all entries being made in indelible ink (preferably a dark color)?	X			SSRF forms
11. Are corrections to the data being made with a single line through the entry so as not to obliterate the original entry, initials of the corrector, and date of the correction?	X			
12. Has a review of the logbooks/forms been performed? By whom?	X			ARS field specialists
13. Are previous logbooks/forms stored onsite? How?	X			Electronic entries made on DataView system.
14. If yes, are the logbooks/forms available for review?	X			In the DataView electronic logbook.
15. Does the site operator make electronic entries of field activities?	X			
16. If site operator is recording field operations electronically, how does he/she record activities if electronic recording is not available such as during power outage and telephone/internet service disruptions?	X			Hard copy forms only used if the DataView log is not functioning properly and several hard copy forms are available at the site if the operators need to utilize them.
17. Are hard copy records maintained for short term? Long term?	X			
Additional Questions or Comments:				

Part 3: Network Management

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
A. Key Individuals				
1. List all key individuals, job titles, e-mail extensions, and telephone numbers associated with this site.				
(Site operator)				Johnathan Jernigan
(Backup operator)				Brice Leech
2. Other than CASTNET, what other networks is the site associated with?				EPA NCORE site operated by ARS
3. What types of samples are collected at this site?				Filter pack and ozone
Additional Questions or Comments:				
B. Network Planning				
1. What is the date of the most recent network assessment (monitoring network plan)? (mostly likely performed by EPA CAMD)				CASTNET Plan for Part 58 Compliance dated July 1, 2020 for 2016 work plan
2. Is the annual network plan up-to-date?	X			See here - https://www.epa.gov/castnet/ozone
3. Do you collect collocated samples?	X			At MCK131/131 and ROM406/206
4. What is the date of the current network plan?				Previous CASTNET Plan for Part 58 Compliance dated July 1, 2020 for 2016 work plan.
5. Review the network plan includes the information required for each site.				
a. AQS Site ID Number	X			
b. Street Address and geographic coordinates	X			
c. Sampling and Analysis Method(s)	X			
d. Operating Schedule	X			
e. Monitoring objective and scale of representativeness	X			
f. Site suitable/not suitable for comparison to annual NAAQS standards	X			
g. Metropolitan Statistical Area (MSA), Core Based Statistical Area (CBSA), or Combined Statistical Area (CSA) indicated as required?	X			
6. Does the network plan include proposed changes to the network?	X			

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
7. Does any proposed change affect this site?		X		Changes are addressed as required. No changes are listed for MAC426.
8. Who (person) has custody of the network plan and where and how is it maintained?				EPA CAMD (Tim Sharac) on the EPA CASTNET website.
9. List any non-conformance waivers for the site visited?			X	
10. Where are the waivers documented and who gave approval?			X	
Additional Questions or Comments				
C. Monitors, Samplers, and Equipment at the Site				
1. List of monitors/ samplers/equipment at the field site and confirm the instrumentation manufacturer, model number, and serial number with the ARS Ozone Calibration Laboratory.				
a. (Site Ozone Analyzer)				S/N 1030745085
b. (Transfer Ozone Analyzer)				S/N 1015543061
c. (Other) Zero air System pump				Werther Model PC7014 pump
(Add additional rows as needed)				
2. Check for certification, validation, and calibration labels for samplers, monitors, and equipment.				
a. Flow pump				Thomas Model 107CAB18
b. Shelter temperature sensor				YSI Model 44000 Series sensor
c. Temperature probe for shelter temperature measurement.				Same as above
Datalogger				ESC Model 8832
3. How many primary standards and how many transfer standards? List of calibration (include transfer) and verification standards and certificates. Verify at ARS Ozone Calibration Laboratory.				One primary standard and four transfer standards
3. List of calibration (include transfer) and verification standards and certificates. ARS uses 4 transfer standards for 6-month calibration checks and one primary standard maintained at the ARS Ozone Calibration Laboratory. All five standards are Level 2.				Level 2 Ozone Standards used for Semi-Annual Calibration Audit
a. Thermo 49i ozone analyzer (last certified March 19, 2020) by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 5/26/2019)				S/N: 1130450195

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
b. Thermo 49i ozone analyzer (last certified February 11, 2020) by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 3/28/19)				S/N: 1130450196
c. Thermo 49i ozone analyzer (last certified February 25, 2020) by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 3/28/2019)				S/N: 1130450197
d. Thermo 49i ozone analyzer (last certified February 11, 2020) by US EPA in RTP, NC by Scott Moore using NIST SRP (NIST Certified on 3/28/2019)				S/N: 1130450192
e. (Primary) Thermo 49C PS ozone analyzer (last certified October 13,2020, signed November 5, 2020) by US EPA region 8 by Joshua, Rickard using NIST SRP (NIST Certified on 11/1/2019)				S/N: 75759380
Additional Questions or Comments: Recommend using a different terminology (e.g., Lab Standard) than "Primary" standard to avoid confusion with the Primary Level 1 standards in the strictest sense.				

Part 4: Specific Sampling Criteria (Ozone Sampling)

(There are four operations (site installation and initiation, site operations, field calibrations, and field operations) conducted at each site. The following sections will discuss each operation.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
A. Site Installation and Initiation Procedure				
1. Is there a required training program for the Field Installation Team and the Station Initiation Team before they are able to perform site installation?	X			The training program consists of senior field specialists training junior field specialists.
2. Is there any certification records for instrumentation used to install a CASTNET site? (Examples of this instrumentation would be compasses, inclinometers, measuring tapes, voltmeters, etc.)	X			A Brunton Compass is used to align the wind direction and are certified as needed by the manufacturer.
3. Does ARS use subcontractors for site installation? Does an ARS staff member oversee all of the installation process?	X			Overseen by ARS staff
4. Is there a checklist the Field Installation Team updates during installation?	X			New Site/Site Relocation Form in SOP "F_SITING_AQSITE_F_1.0"
5. If yes, where is it maintained, and can the MAC426 form be reviewed? If not, could ARS provide a completed form from another site?				Records are maintained on the Air Quality Database Management System (AQDBMS) server.
6. Does ARS need to obtain EPA approval for CASTNET site location? Discuss steps in determining site.	X			NPS and EPA approvals
7. Can ARS provide the paperwork to show the 5-step site selection process for selecting the MAC426 site?		X		This was done in 1998. Auditor: Technicians were aware of site selection criteria, but original 5-step site selection process records were not available on site due to age of site.
8. Does ARS perform an acceptance test or burn-in of all instrumentation prior to install at the site?	X			
9. Are records maintained of this acceptance testing and where are these records maintained?	X			
10. Are records maintained for the initial onsite equipment calibration for MAC426? If not, could ARS provide records from another site?	X			
11. If yes, where is it maintained and can it be reviewed?				Information is stored on the AQDBMS server. Auditor: Reviewed 1x6 MTCAL records for Level 3 standard (Station Reference) and ozone analyzer. Certification records for Level 2 std were reviewed onsite.
12. If calibration standards are used, can ARS provide records of certification? Where are the records maintained?	X			Records are maintained on the primary server.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
13. Does the CASTNET sites need to be inspected by local municipalities for Building Codes and Restrictions during the installation process?	X			
14. If yes, where are these records maintained?				Records are maintained on the primary server
15. Who provides the training to the site operator?				ARS Field Specialists
16. Is there a checklist or confirmation documentation that the site operator has completed the training?	X			Tailgate Safety Meeting Form and Site Operator Training Form.
17. If yes, is this documentation maintained and where?	X			On the AQDBMS server and the DataView system at the site.
18. Is the data acquisition system (DAS) validated during the initial installation? By whom? Records?	X			The Field Specialist verifies the DAS is working properly and the results are included in the Semi-Annual Site Visitation Checklist (Section 6). These records are maintained on the AQDBMS server.
19. Are records (e.g., Capital Equipment Inventory Checklist) maintained for the inventory of instrumentation installed at the site such as manufacturer, model number, ARS Property Number, EPA decal, etc.?	X			Auditor: Instrument decals were reviewed on site.
20. Who is responsible for maintaining the inventory records and where are they maintained?				Administrative assistant and records are maintained on the AQDBMS server
21. Does an ARS management staff person need to approve the site installation before sampling can begin?		X		
22. If yes, is this documented and where?			X	
Additional Questions or Comments:				
B. Site Operations Procedure				
1. Is the ozone sampling performed within the guidelines of an EPA- and ARS-approved SOP?	X			
2. On the average, how often do you visit the monitoring site per week?				Once per week (Tuesday)
3. Is ozone sampling conducted year-round? If not, document the timeframe.	X			
4. What is the frequency of sample collection during the peak season? (requirement = hourly)				Hourly Auditor: summer was noted as peak season during field visit.
5. Does the site measure ozone during the off season? If yes, what is the frequency of sample collection?	X			Hourly

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
6. Does the site operator follow the SOP for the weekly site visit? Any deviations? Is a copy of the SOP readily available?	X			
7. Where does the site operator document all procedures performed during each site visit?				DataView log Weekly Station Visit Checklist View checklist
8. If the site operator has a problem, who does he/she communicate with and how?				Information Management Center (IMC) and/or ARS Field Specialist
9. Where does the site operator obtain local weather conditions? Alternate source?				From the temperature sensor on the 10-meter tower. Weather app on smart phone
10. What device does the site operator use to confirm shelter temperature? Are values recorded within 20 to 30 ºC?	X			YSI Model 44000 Series sensor last calibrated on May 15, 2020. Shelter temperature probe has traceable calibration. Hourly data are collected and stored.
11. Is this device certified? Frequency?	X			During every semi-annual maintenance and calibration visit (May 15, 2020)
12. Does the site operator complete and document activities in checklists? Which checklist instructions does the site operator use for ozone sampling? (Observe.)	X			Weekly Station Visit Checklist
13. Are the checklists maintained and where?	X			Data View log
14. Is the DataView System Station Log available to track entries? (Review entries.)	X			
15. What steps does the site operator perform to verify a zero, span, and precision check occurred on the ozone monitor?				ZSP checks are performed automatically at 0146. The site operators only perform ZSP check if requested to do so by ARS.
16. If the ZSP verification operations in the previous question were not successful, what does the site operator do?				IMC contracts the field specialist to discuss and identify the issue; troubleshoot as needed.
17. Does the ozone system use a Nafion dryer? When was it installed?	X			Leak checks are performed every month or as needed. The operator does check for alarms weekly which would alert them to a low flow condition. Also, the flow rates are checked and noted during the semi-annual visit. If flows are below manufacturer specifications the pump is rebuilt or replaced.
18. Does the site operator perform a flow rate and leak check of the ozone monitor?				The site operator does not measure flow rates at the site for the ozone collection process. Leak checks are performed once a month.
19. What device (standard) does the site operator use to measure the flow rate?			X	

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
20. Is this standard certified? Review documentation.			X	
21. Where are these values (flow rate and leak checks) documented? Review previous entries if possible.				Leak checks are documented Monthly in the DataView log.
22. Is there any documentation on the FDS/COC forms for ozone sampling?	X			The site operator does not enter any information regarding ozone collection on the SSRF.
23. How are telephone conversations documented between the site operator and ARS Office?	X			Site operators primarily use the DataView station log to communicate with ARS. There are hard copy forms available in the event DataView is not working properly. These forms are e-mailed, faxed or mailed to the IMC and the information is entered into the AQDBMS by IMC. Additionally, field specialists use the Site Status Log to document correspondence with site operators regarding operational issues.
24. Review the DAS with the site operator.				
a. Data from ozone monitor to data logger.				
b. Datalogger to network router.				
c. Network router to computer for review onsite.				
d. Modem to ARS by Internet.		X		
25. Does the site use uninterruptable power supplies or backup power sources?		X		
26. What instruments or devices are protected (electrically)?				The entire site is protected by ILSCO brand surge protection.
27. How are the ambient ozone sampling and zero, span, and precision checks (ZSP) controlled?				Electronically
28. What device is used for the ZSP checks?				Manufacturer: Thermo Model: 49i Serial Number: 1030745085
29. What is the frequency of the ZSP checks?				Daily at 1:46 A.M.
30. Are the ZSP checks documented? Where and how.	X			DataView Log
31. Are steps in place if ZSP checks fail? Review.	X			
32. How long does it take to conduct a ZSP? Time of Day.				Approximately 20 minutes, beginning shortly before 2:00 A.M. Auditor: ARS field tech explained that ZSP checks take 28 minutes, not 20 min.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
33. Can the results of the ZSP be reviewed at the site? Review, if possible.	X			
34. What is the height of the inlet for the ambient ozone sampling?				10 meters
35. What is the supply line made of?				Teflon tubing
36. Does it connect to a manifold or designated supply line to the monitor?				Designated supply line to the analyzer.
37. Does the air stream flow through any filters before entering the ozone monitor?	X			A Teflon filter (outside) at the top of the tower.
38. What is the reporting measurement unit for the ozone measurement?				Parts per billion (ppb)
39. What device delivers zero air during the ZSP checks? List the device: manufacturer, model, and serial number.				The zero air supply consists of a compressor with a reserve tank (Werther Model PC7014 pump)
40. Does the air flow go through desiccant and carbon canisters from the zero air system during the ZSP checks?	X			
41. During the ZSP checks, does the air flow from the transfer ozone monitor to the inlet and then to the ambient ozone monitor?		X		Auditor: Ozone is generated from ambient analyzer then sent to the transfer standard and up to the inlet then back down to itself.
42. What concentrations are evaluated during a ZSP checks?				Zero air, 200 ppb ozone (span), and 60 ppb ozone (precision check).
43. Are MQOs being met at the site for ZSP checks?	X			Zero (≤± 3ppb in 24-hr period and 5 ppb in 14-day period) and precision and span (≤±7% between supplied and observed concentrations). ZSP checks are charted.
44. What is the frequency of calibrations of the ozone monitors?				A calibration check is performed by an ARS Field Specialist every 6 months.
45. How many calibration points are checked?				Six points (including zero) for the 6-month calibration verification check at: 200, 150, 100, 60, 30 and 0 ppb.
46. How are the multi-point calibration (Pre-Maintenance Ozone Calibration Form) reported and where is the data maintained? (Review data.)				The semi-annual calibration verification results are stored on the primary server.
47. Who are the results reported to?				Results are initially submitted to the QA Manager and/or officer for review, then provided to the IMC and ultimately posted on the NPS website.
48. Who repairs the monitors if outside acceptance during the calibration?				Field specialists
49. Where is the Operation Support Center located?				This is part of the IMC at the ARS offices in Fort Collins, CO

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
50. What is the frequency of checking and replacing the ozone particulate filter?				Filters are inspected weekly by the site operator and replaced as needed. The site operator replaces the filter every month. The filter is conditioned by running a ZSP and verified data is acceptable. Auditor: Ozone particulate filter is replaced every 2 weeks. ARS clarified that the typical frequency is on a monthly basis. Some site operators (as in this case) deem it necessary to replace it more often than the monthly cycle.
51. What is the frequency of replacing the desiccant?				Semi-annually
52. Who is responsible for providing maintenance to the DAS?				Data analyst in the IMC.
53. Who does the site operator contact if there is a problem with the DAS?				ARS field specialist
54. Discuss Data View software and document site operator's knowledge of the software and entries that he/she would make.				Operators are instructed to document any pertinent information.
55. Does the site operator follow the SOP for data entries into the DAS?	X			
56. Can the site operator provide the auditor a copy of the last data logger calibration? Review data and compare to form at the calibration lab.		X		Data logger calibration are not needed.
57. Who is responsible for performing preventive maintenance?				The site operator inspects the site every Tuesday and reports issues to the IMC. Auditor: Preventative Maintenance is performed by ARS during site visits.
58. Is special training provided for site operator for performing preventive maintenance on the monitors/ samplers/equipment? Briefly comment on background or courses.	X			1-from previous site operator 2- during new site or relocation setup 3-during each semi-annual visit Training is re-enforced during each semi-annual calibration and maintenance visit.
59. Is this training routinely reinforced?	X			During each semi-annual maintenance and calibration visit.
60. What is the site's preventive maintenance schedule for the ozone measuring system?				Six months, or if issues arise.
61. If maintenance, troubleshooting, or replacement of a sampler is required, who does the site operator contact and at what phone number?				Field Specialists are available during business hours for operator support via telephone and/or email (970) 484-7941
62. Who provides support to the site operator when a sampler replacement is preformed? How are these directions provided?				Field Specialist. Direction is provided via telephone support and email with photographs and/or diagrams if required.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
63. If preventive maintenance is MINOR, it is performed at (pick one or more): field station, headquarters facilities, or equipment is sent to manufacturer				Field station
64. If preventive maintenance is MAJOR, it is performed at (pick one or more): field station, headquarters facilities, or equipment is sent to manufacturer				Headquarters or at manufacturer
65. Does the agency have service contracts or agreements in place with instrument manufacturers? Indicate below or attach additional pages to show which instrumentation is covered?	X			
66. Comment briefly on the adequacy and availability of the supply of spare parts, tools and manuals available to the field operator to perform any necessary maintenance activities. Do you feel that this is adequate to prevent any significant data loss?	X			Sufficient spare parts are available in the ARS laboratories.
67. Is the agency currently experiencing any recurring problem with equipment or manufacturer(s)? If so, please identify the equipment or manufacturer, and comment on steps taken to remedy the problem.	X			
68. Have you lost any data due to repairs in the last 2 years? More than 24 hours? More than 48 hours? More than a week?		X		
69. Explain any situations where instrument down time was due to lack of preventive maintenance of unavailability of parts.				N/A
Additional Questions or Comments:				
C. Field Calibrations Procedure				
1. Has a biannual TSA been conducted at the site? When and who performed the last TSA.		X		No TSA has been performed at MAC426. The last TSA was performed at GRSM on April 25, 2017. EEMS performs a Field Systems Audit (FSA) every two years at the CASTNET sites. Last two FSAs at the MAC426 site were performed on 11/13/17 and 10/17/19.
2. Has a biannual performance evaluation (PE) been conducted at the site? When and who performed the last PE.	X			EEMS performed the last annual PE audit on August 19, 2020. These typically occur annually.

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
3. Is 'as found' data recorded?	X			Auditor: PE report specifies before, during and after audit cell pressure measurements were performed, but does not list the as-found and as-left ozone values. The semi-annual verifications performed by ARS lists the as-found and as-left ozone values.
4. Is "as found" data provided to the site operator after a PE is conducted? If so, review last few PEs.	X			Dave Beichley
5. Has an ARS site calibration been performed at this site? When and who performed the last calibration. Provide the Calibration Summary Form.	X			Field Specialist (Dave Beichley) performed the last maintenance and calibration visit on May 15, 2020.
6. Are the results of the calibration documented? If so, where and review if possible.	X			NPS Website
7. What is the frequency of the ARS site calibration?				Semi-annually
8. Review Data View System Station Log to track entries made during calibration.				Review completed on site.
9. Is the transfer ozone monitor allowed time to stabilize? If yes, what amount of time is allowed?	X			20 minutes or more.
10. What device is used to provide air for the zero-air check for the calibration?				Weather air compressor
11. During the calibration are ozone calibration points taken over the full range of the instrument?		X		
12. Is line loss test performed?	X			Auditor: ARS performs leak test twice per year during semiannual site visit.
13. What does a high line loss indicate (greater than 5%)?				Bad inlet tubing
14. How is this issue resolved and documented?				Inlet tubing is replaced
15.Is there criteria in place to determine if the ambient ozone or transfer ozone monitor used for ZSP checks need calibration?	X			
16. What is that criteria?				ZSP criteria: Zero value ≤±3 ppb over a 24-hour period and 5 ppb over a 14-day period Precision/Span ≤±7% between supplied and observed conditions. Semi-annual calibration verification criteria: All points within ±2% of full scale of the best fit straight line, ±5% of actual for any value, $r^2 > 0.9950$, 09500 < slope < 1.050 -3.0 ppb < intercept < 3.0 ppb

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
17. Besides running different concentrations of ozone through the site's ozone analyzer, what other steps are performed for the ozone collection system?				Monthly leak checks are performed on the ozone collection system. Auditor: Solenoid valves are checked during semiannual site visit.
18. Does the calibrator use NIST-traceable standards when conducting the calibration?	X			
19. Where is the documentation (certificates) maintained? Are they available for review during the audit?	X			On primary server.
20. Is there a checkout procedure for instrumentation taken from the Ozone Calibration Laboratory to the field sites during the 6-calibration?		X		No, but there is a folder documenting which machines have been calibrated against each Level 2.
21. Are these checkout list maintained after the calibration? Where? (Calibration Box Inventory and Spare Parts Inventory)	X			In the Level 2 folder
22. Is there a checklist for the 6-month site visit?	X			
23. If yes, who completes it, where is it maintained and can it be reviewed. Review MAC426 checklist for the most recent 6-month check.				The field specialist completes the pre-trip preparation checklist. The checklist is stored on the primary server.
24. If an analyzer does not perform within acceptance criteria, what does the calibrator do?	X			Troubleshoot the problem and repair or replace the analyzer.
25. Who determines when an analyzer can be repaired in the field or needs to be shipped back to the Ozone Calibration Laboratory?				Field specialist
26. If an analyzer is removed from the field for calibration failure, what are the steps for replacement and is there a documentation trail? Where is the documentation maintained?				Document maintained on the primary server in the Site Status Log (SSL)
27. If an analyzer fails the 6-calibration, is previous data collected from that site reviewed? By whom?	X			The IMC Data Manager and team lead review the data in conjunction with the field specialist and/or QA department.
28. Is there a form for documenting instrument's maintenance or repair for the 6-month site visit?	X			Field form (excel spreadsheet with several worksheets)
29. If yes, who completed it, where is maintained, and can it be reviewed? Review MAC426 instrumentation blue cards at lab.	X			Completed May 5, 2020 by Dave Beichley and stored on the primary server.
30. What steps are taken to confirm valid ozone data was collected?				ZSP checks are reviewed by data analyst and field specialist Auditor: ARS data team performs data validation process.
31. Who is responsible for calibrating the DAS?				Field Specialist

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
32. Is there a calibration check form to document the DAS calibration? If so, where is it maintained? Review latest DAS calibration for MAC426 site.		X		ARS has determined this is no longer necessary with the ESC 8816/8832 dataloggers. Although the analog outputs of the ozone analyzers and station reference instruments are tested during semi-annual site visits, analog communications are being phased out and replaced with digital communications.
33. Who is responsible for providing maintenance to the DAS?				The Field Specialist performs any maintenance performed on the DAS. This site is mostly digital.
34. Who determines if the DAS is operating properly after a calibration check?				The Field Specialist confirms all systems are operating prior to leaving the site.
35. Who is responsible for calibration the analog input card on the ESC datalogger?				Since the network transitioned to ESC 8816-8832 series dataloggers, it is not necessary to calibrate the analog input card.
36. Is there a calibration check form to document the ESC datalogger calibration? If so, where is it maintained? Review latest datalogger calibration for MAC426 site.		X		Since the network transitioned to model 88/16/8832 dataloggers, the ESC voltage Analog Input Card Check is no longer performed.
37. Who is responsible for providing maintenance to the datalogger?				Field Specialist
38. What type of training has been conducted during the 6-month site visits?				Training is conducted on any aspect of the instrument/station operations, including ZSP checks, data reporting, data transmittal or other operational requirements where deficiencies are observed.
39. Where is this training documented?				Tailgate safety and site operator training forms.
Additional Questions or Comments:				
D. Field Operations Procedure (performed by the Ozone Calibration Laboratory)				
1. Is there a procedure used by the lab to certify their ozone transfer standards? What is the SOPs title?	X			Lab standards are sent to EPA for certification annually
2. Is there an ozone primary standard for the lab? Obtain copy of most recent certification.	X			There is a Level 2 Lab Standard: Thermo 49C-PS 75759-380
3. Is this unit (primary standard) certified? By whom and at what frequency? Review documents.	X			Annually- by EPA region 8
4. What are the test points used for verifying the ozone transfer standards?				O ppb, 225 ppb, 180 ppb, 125 ppb, 90 ppb, 50 ppb
5. What is the minimum frequency of certifying the ozone transfer standards?				Level 2 transfer standards are certified annually

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
6. Who performs the ozone transfer standard certification process?				Level 2 transfer standards are certified by EPA Regional Offices
7. Is there any required training to perform the process and is there any documentation of this training?			X	Performed by EPA
8. Is this documented (Ozone Transfer Standard Certification Worksheet) and are the documents available for review?	X			
9. What is the frequency of calibration of the site's ozone transfer standards?				Semi-annually
10. How many sample runs are performed during the transfer standards certification?	X			Ozone Transfer Standard Certification form stored on the primary server.
11. Where is this data maintained? Is it reviewable?				Level 2 transfer standards are certified by EPA annually.
12. Describe the certifying process for transfer standard?				Level 2 transfer standards are certified by EPA annually.
13. How are the transfer standards evaluated? A single point or linear regression over concentration range?				Linear regression
14. What is the evaluation criteria?				The acceptance criteria for the ozone analyzer is: All points within ±2% of full scale of the best fit straight line, ±5% of actual for any value, $r^2 > 0.9950$, $0.9500 <$ slope < 1.050 -3.0 ppb < intercept < 3.0 ppb
15. Who gives final approval the transfer standard performed acceptable?				QA Officer (Christian Kirk)
16. Is the certification of the transfer standards performed manually or automatic?				Manually
17. Describe the traceability process of all ozone analyzers used in the CASTNET program? (Level 1, 2, and 3)				Level 2 transfer standards are certified by EPA Regional Offices, Level 3 station reference analyzers are certified by ARS using a traveling Level 2 transfer standard.
18. Is there an SOP that identifies maintenance requirements for the ozone transfer standards at the ARS Ozone Lab?		X		
19. Is there a maintenance and calibration schedule for the ozone transfer standards? If yes, where is it maintained and review?	X			Primary server

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
20. What analyzer is used as the primary standard? Review documentation and request electronic copies of the certificates. Flow meters Temperature sensors Barometric pressure sensors Voltage meters				Bios Definer 220 Eutechnics 4400 Druck – various models Fluke – various models
21. Is there an SOP that identifies the acceptance limits for the temperature and barometric pressure sensors in the ozone analyzers?		X		Limits are based on manufacturer's specifications and recommendations.
22. What is the acceptance limit for the temperature sensor in the ozone sampler? What is done if the sensor is outside the limit? What standard is used to confirm the temperature sensor?				Limit: 2°C Corrective Action: replace sensor NIST-certified transfer standard
23. What is the acceptance limit for the barometric pressure sensor in the ozone sampler? What is done if the sensor is outside the limit? What standard is used to confirm the pressure sensor?				Limit: 5 mm Hg Corrective Action: calibrate NIST-certified transfer standard
24. Is there an SOP that identifies the acceptance limits for leak checks or ozone loss test in the ozone analyzers?		X		
25. What is the acceptance limit for the leak check in mm Hg for the ozone sampler? What is done if the leak check is outside the limit? What standard is used to measure the leak pressure?	X			Limit: 250 mm Hg Above 230 mm Hg prompts corrective action, which is to replace tubing and check transducers.
26. For the ozone line loss test, what ozone certification detector is used? When was it last certified and by whom? Are records of the certifications maintained and where?	X			The on-site analyzer; last certified 5/15/20 by Dave Beichley
27. Is the flow rate checked on the ozone analyzers? If yes, what device is used? Is it certified? Last certification.	X			A Bios Definer 220H serial number 122997 was used; its last certification is dated 6/18/20. Auditor: Flow rate checks are performed by the Field Specialists. (Note that Q18 refers to site operator).
28. How are transfer standards tracked when shipped to sites? Where is this documented?				FedEx Courier Service

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
29. For what reasons would you need to calibrate an ozone analyzer?				1. Acceptance testing of a new instrument 2. Installation of instrument at monitoring site 3. Whenever control limits are exceeded 4. Prior to any corrective action, service, or maintenance to any portion of the instrument that affect its operation principle 5. at a maximum interval of 6 months
30. Who performs the calibrations of the site analyzers and transfer standards?				Field specialists
31. How is data tabulated?				Ozone Transfer Standard Certification form on primary server
32. How many sample concentrations are performed during the transfer standards certification? What values are normally run?				Six 200, 150, 100, 70, 30, 0 ppb
33. Where is this data maintained? Is it reviewable?	X			On the calibration report
34. Describe the process of certifying the transfer standard and document the SOP number?				Based on EPA ozone guidance
35. Is there a single-point accuracy criterion?	X			Based on EPA ozone guidance
36. Describe the calculations for the slope, intercept, and correlation coefficient?				Based on EPA Guidance EPA-454/B-13-004 Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone, Technical Assistance Document.
37. Provide records of purchased equipment for site MAC426 relating to the ozone sampling operation. Where is this information maintained? (QAPP Section A6.2)				Equipment Inventory Database
38. Provide the SOP that gives guidance for purchasing, maintaining inventory records, testing, and calibration of equipment procurements. (QAPP, Section A6.2)			X	Equipment inventory database and inventory report (provided to program manager annually) are available for review by the auditor.
39. Does the ARS QA Manager conduct internal audits of the Calibration Lab?		X		No, we perform internal QC checks
40. If yes, what is the frequency?				45 days or less
41. If yes, can these audit reports be reviewed? Review past three reports.	X			Yes

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
42. Can Calibration Lab provide the Sample Site Inventory Form for MAC426? If so, check items (ozone analyzers and data acquisition system) against equipment found at site.	X			

Additional Questions or Comments:

Genevieve Lariviere (Administrative Assistant) oversees the scheduling of the standards (ozone, temperature, barometric pressure, flow rate, and voltmeters) used for the CASTNET Ozone collection program. She uses a database to track the scheduling, certificates, and location of the standards.

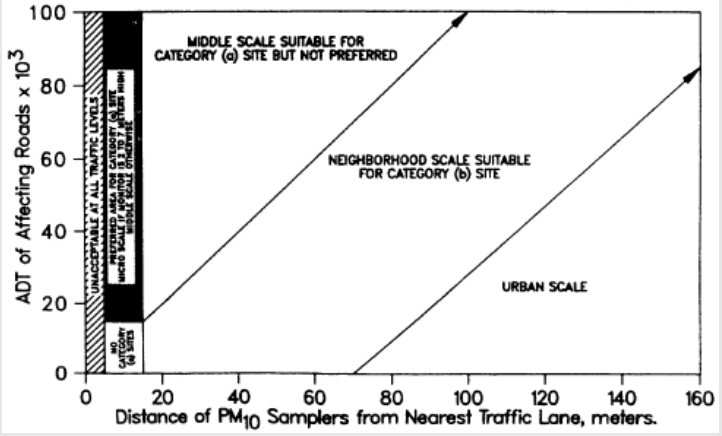
PART 5. Sampler Siting

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
A. Sampler Siting				
1. Does the location for the samplers conform to the siting requirements of 40 CFR 58, Appendix E?	X			
2. Are there any visible hazards or noticeable problems at the site?		X		
3. Are there any changes at the site that might compromise original siting criteria (e.g., fast-growing trees or shrubs, new construction)?		X		
4. Are there any visible sources that might influence or impact the monitoring instrument?		X		
5. Is the spatial scaling for the site visited neighborhood (0.5 to 4 km), urban (50+ km), or regional (100+ km)?	X			Urban to regional
6. Sampler siting as stated in 40 CFR Part 58 Appendix E. Indicate Y/N to criteria for each sampler, and if no, specify why:				
a. The inlet probe must be between 2-15 m above ground level.	X			
b. The probe must be at least 1 m vertically or horizontally away from any supporting structure, wall, parapets, etc., and away from dusty or dirty areas. If the probe is located near the side of a building, it should be located on the windward side relative to the prevailing wind direction during the season of highest concentration potential for the pollutant being measured.	X			
d. Spaced properly from minor sources. (Away from direct flow of plumes, furnaces, etc.)	X			
c. The probe must have unrestricted airflow and located away from obstacles so that the distance from the monitoring path is at least twice the height the obstacle protrudes above the monitoring path.	X			
e. The monitoring path must be clear of all trees, brush, buildings, plumes, dust, or other optical obstructions, including potential obstructions that may move due to wind, human activity, growth of vegetation, etc.	X			
f. Air flow must be unrestricted in an arc of 270 degrees around the sampler except for street canyon sites.	X			
g. The predominant direction for the season with the greatest pollutant concentration potential must be included in the 270-degree arc.	X			
h. The probe must be at least 10 m from the drip line of the tree or trees.	X			

AUDIT QUESTIONS	RESPONSE			COMMENTS
	Y	N	NA	
i. Spacing from roadways. If the area is primarily affected by mobile sources and the maximum concentration area(s) judged to be a traffic corridor or street canyon, the monitor should be located near roadways with the highest traffic volume. See Figure 2 below or 40 CFR 58 App. E.	X			
7. What are the GPS coordinates (latitude and longitude) for the field site?				37.1864° N 86.0411° W Auditor: Confirmed using GPS on mobile phone.
8. What is the elevation of the site (feet)?				Auditor: Site elevation is 744 ft. Confirmed with site technician and ARS field tech.
9. Nearest meteorological site?				A temperature sensor (2 meters high) is in operation on the 10-meter tower. Auditor: Yes, confirmed on site.
Additional Questions or Comments:				

For Ozone Sampling	
Roadway Average daily traffic, vehicles/day	**Minimum separation distance, m**
<10,000	**10**
15,000	**20**
20,000	**45**
30,000	**80**
40,000	**115**
50,000	**135**
>60,000	**150**

Figure 2. Acceptable Areas for PM_{10} Micro, Middle, Neighborhood, and Urban Samplers Except for Microscale Street Canyon Sites.

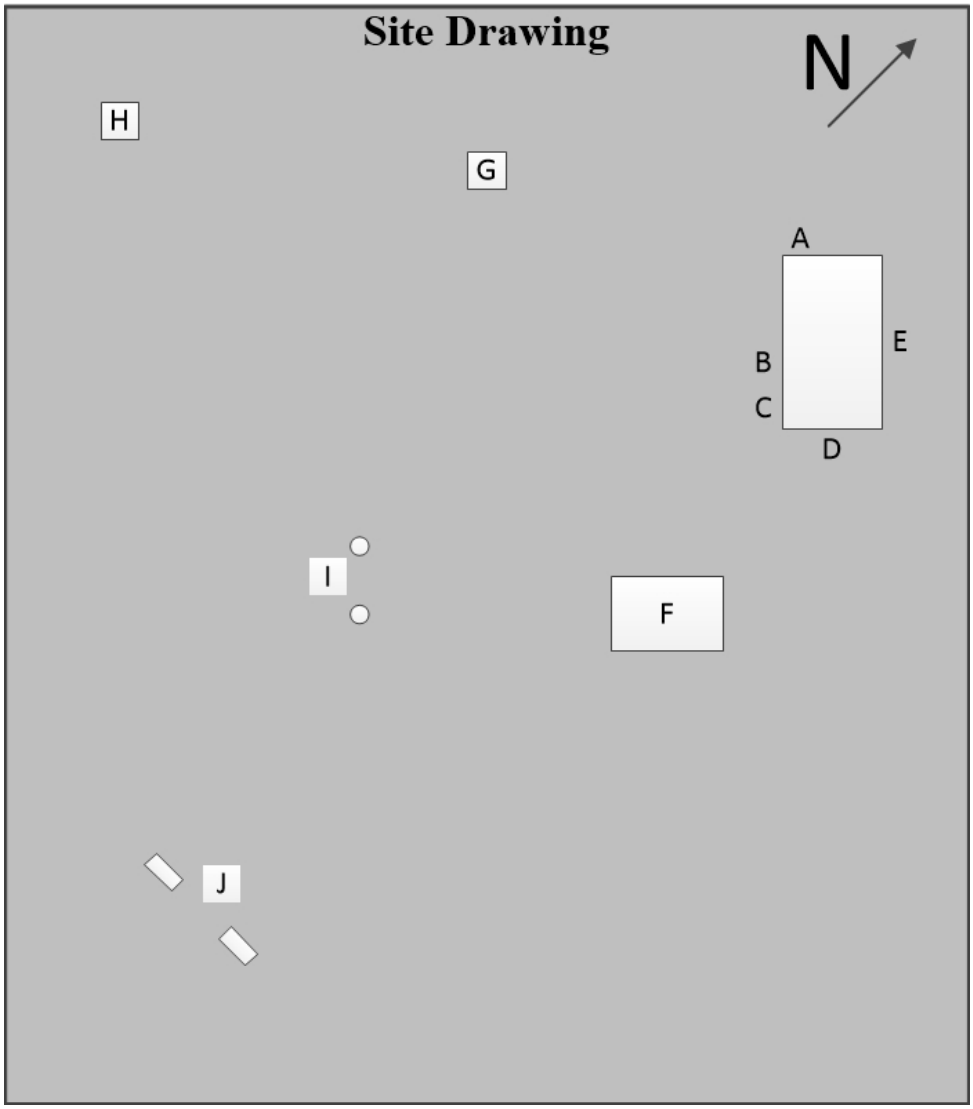


B. Site Sketch (To be completed by RTI Auditor)

Mammoth Cave National Park Field Site (MAC426) Measurements (2/2021)

The Mammoth Cave National Park Field Site is located 20 miles northeast of Bowling Green Kentucky along the southwest border of the park. The entrance is located at the east side of the site with a small parking area near the entrance gate. There is a six-foot-high chain link fence along the perimeter of the site. The boundary of the site measures approximately 77 ft by 85 ft. The shelter which houses the CASTNET instrumentation is roughly 10 ft tall with two 10 m towers alongside. One tower houses the ozone inlet and filter pack. The other tower houses the ambient gas monitor inlet for SO_2, NO, and NO_y. The 10 m meteorological tower is independently supported approximately 7.5 m due west of the ozone inlet tower. Other instrumentation on the main shelter includes a Nephelometer sampler, NASA AERONET monitor, and a $PM_{2.5}$ TEOM sampler which was not in operation at that time. Also, at the site is an IMPROVE sampler station housed in a separate shelter, a 5 m tall meteorological tower for the RAWS program, and four separate rain/precipitation gages.

Items	Compass Degrees	Distance (m)	Height (m)
A. 10 m tower, ozone inlet and filter pack	-	-	10
B. $PM_{2.5}$ TEOM sampler inlet	165	2.7	1.7 (height above roof)
C. 10 m tower with gas analyzer inlet	260	4	10 (height above roof)
D. NASA UV meter	120	4.6	1 (height above roof)
E. Nephelometer sampler	90	3.4	1.5 (height above roof)
F. IMPROVE samplers	150	9.3 (shelter center)	3.7 (shelter height)
G. 10 m tower for meteorological tower	240	7.5	10
H. 5 m tower - RAWS meteorological	236	16.5	5
I. Tipping rain gages	190	13	1
J. Weighing rain gages	175	20.8	1.2


Site Drawing
N
H
G
A
B
C
D
E
I
F
J

Part 6. Data Management (Site)

Data to gather at the field monitoring sites:

- Download or print data from Ozone instrument, if possible. Include time and O_3 ppb data at a minimum, but include other information such as ambient temperature, BP, RH, shelter temperature, flow rate, etc., if available. Include a zero-span check if available. Later, the times and O_3 results will be compared with the reported data in AirNow and AQS.

- Hand-record readings directly from the front panel of the ozone ambient analyzer and the logger for several minutes. Compare it with the data above while you are on site. No follow-up should be necessary unless discrepancies are found.

		Ozone Reading				Ozone Reading					Ozone Reading
Interval	Time	Screen	Logger	Interval	Time	Screen	Logger	Interval	Time	Screen	Data file
1	16:00	32.4	32.62	16	16:15	23.7	23.39	31			
2	16:01	28.2	34.6	17	16:16	23.4	23.57	32			
3	16:02	24.6	27.3	18	16:17	23.8	23.45	33			
4	16:03	24.1	24.79	19	16:18	24.8	23.77	34			
5	16:04	24.7	24.29	20	16:19	23.8	24.38	35			
6	16:05	24.3	24.59	21	16:20	23.8	23.9	36			
7	16:06	24.4	24.25	22	16:21	23.4	23.58	37			
8	16:07	25	24.61	23	16:22	23.1	23.54	38			
9	16:08	24.1	24.77	24	16:23	22.8	22.95	39			
10	16:09	23.8	23.78	25	16:24	22.6	22.77	40			
11	16:10	24.4	23.82	26	16:25	22.9	22.72	41			
12	16:11	23.7	24.26	27	16:26	22.9	22.84	42			
13	16:12	24.1	23.83	28	16:27	23.3	23.09	43			
14	16:13	24.2	24.17	29	16:28	23.1	22.94	44			
15	16:14	23.4	24.13	30	16:29	22.7	22.92	45			

NOTE: Minor discrepancies are seen between the reading on the screen and the data logger. Follow-up with the field technician clarified that it is due to different averaging times. Dave Beichley provided the following response: "The readings on the front display of the ozone analyzer is generally set to 30 seconds averaging time. The readings on the logger are digital readings, and we use MODBUS to collect the data, Modbus updates I believe every 10 seconds. The lowest averaging time we collect data on the logger is 1 minute average readings. If conditions are stable there will be some slight differences between media. If the readings are changing rapidly either because of ambient conditions or if a calibration is being performed the readings may differ much more."

Data (1 minute) and ZSP checks from 2 days prior to onsite audit (February 7 and 8, and part of February 9, 2021) and prior month (January 1-31, 2021) were downloaded from the Datalogger and saved to a portable hard drive.

- Make a note of any interruption in monitoring data that occur due to the TSA (however, no interruptions of data are planned). Record exact times when the ozone data was interrupted. This will be checked later against the data records.

NOTE: No disruption in the data collection

- With the Site Operator, discuss any recent instances when data was flagged because of malfunctions, weather, site conditions, or any other reason. Get a copy, if possible, of the reporting forms, logbook pages and any other backup data. This information can be examined at the data center as part of the validation process audit, and later when the flags in AQS and AirNow data are checked.

NOTE: No recent events of data lost or flagged due to malfunction, weather, or site conditions. Possible data loss due to power outage in November 2020.

Activities and data gathering at the laboratory or data management center:

- Review findings of recent PE audit reports and discuss these findings, corrective actions, and data flagging with the data management and validation staff. Make notes of site ID, dates, and times so that we can look at the flags in AirNow and AQS.

NOTE: The last audit was performed by EEMS on August 19, 2020 and was found to be satisfactory.

- Observe the data validation process using the IMS software and other procedures and software – follow the SOP to the extent possible. Download electronic data and take screen shots, if possible, of O_3, shelter temp, ambient temp, flow, BP, RH, and other data that were downloaded or printed during the on-site audit. Note any deviations from the SOP and discuss. If any validity flags were applied while you were observing the process, include them as examples to use for the next item.

NOTE: Raw data was received from ARS at the field site for 1-min and 1-hr ozone results for January 1 to 31, 2021, February 7 to 9, 2021, November 8 to 11, 2020 (prior quarter), August 23 to 25, 2020 (within 6 months), and consecutive 5-day period in 2020 (Jan 20-24) centered on the audit date – 2 days before the audit and 2 days following the audit. Data was placed on a flash drive to check against data placed on AQS.

- Ask the data management Staff to identify a few examples where they had to add data flags or change/invalidate data, as a result of higher-level data validation. Record the reason for the change, and site IDs, dates and times of the data affected. Example data need not be for the site that had field TSA. If changes were made to data that had previously been entered into an external database (AIRNow or AQS), also record the date/time when the change was uploaded to the external database.

NOTE: This will be completed during the field site audit or when RTI meets with ARS [virtually] for ARS Ozone Calibration Laboratory (Ft. Collins, CO) and data management review.

- Perform other records checking that you would normally do for a TSA. If you encounter any information that should have resulted in data flags or changes, make a note so that the data changes can be verified later in AQS.

NOTE: ZSP checks from 2 days prior to onsite audit (February 7 and 8, and part of February 9, 2021) and prior month (January 1-31, 2021) were downloaded from the datalogger to a portable hard drive. ZSP checks were within acceptable limits.

APPENDIX B

Mammoth Cave National Park
(MAC426)
Site Photos


LOOKING NORTH


LOOKING EAST


LOOKING SOUTH


LOOKING WEST

APPENDIX C

Data and Data Management Questionnaire

Technical Systems Audits (TSAs) for Ozone Measurements in the Clean Air Status and Trends Network (CASTNET) Program

Data Review and Data Management Technical Systems Audit Form

RTI International
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Research Triangle Park, NC 27709
Telephone (919) 541-6000

DATA REVIEW AND DATA MANAGEMENT

Auditee Identification: **Air Resource Specialists, Inc. (ARS), Ft. Collins, CO**

Location of Audit: **Mammoth Cave NP/Mammoth Cave National Park, KY (MAC426, in-person), ARS Ozone Calibration Laboratory and Data Management in Fort Collins (performed virtual), CO, and remote communications with Data Management team**

Audit Date: **February 9, 2021 (site visit) and email exchanges prior to and after visit**

Auditor's name and affiliation: **Prakash Doraiswamy (off-site) and Andrew Dart (in-person for site visit), both from RTI International**

PERSONNEL INTERVIEWED:

NAME	POSITION	PHONE/E-MAIL
Jessica Ward	ARS Information Management Center (IMC) Manager	JWard@air-resource.com 970-484-7941
Emily Vanden Hoek	ARS (CASTNET) QA Manager	Evandenhoek@air-resource.com 970-484-7941

OPERATIONAL AREAS THAT WERE OBSERVED: Auditors discussed the data validation steps with Jessica and had her walk through the data validation process. The auditors observed the daily checks, the monthly checks, and the final validation. Jessica showed the stack plots for the ozone data as well as for the calibration data. The automated data validation converts the data logger codes to flags. On a monthly basis, the data analyst looks at the automated data validation and determine if the data and the flag look okay and whether any changes to flags were needed based on site information. The final validation looks at plots of raw data overlayed with invalidated data to quickly visualize invalidated data. They also do a monthly data review with the NPS during which they also look at other supporting data such as AirNow, meteorology, etc. The annual data review examines the time series on a quarterly basis rather than weekly basis.

Auditors discussed the process of a new hire performing the data validation. The new hire reviews SOPs, is trained by an experience data analyst, observes validation performed by others, next performs the validation under the supervision of an experienced data analyst and once found to be competent with the process, performs on their own. New hires are typically assigned simple sites to begin with until they get familiar with the process.

Auditors also discussed about the process for software updates and verifications. As noted in the SOP, the verification involves using known data to process through the software to ensure correct performance.

Part 1. Data Management

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
A. Data Handling				
1. Is there a procedure, description, or a chart which shows a complete data sequence from point of acquisition to point of submission of data to EPA?	X			See Figure 2-1 in SOP I_IMC_DATAVAL_F_1.0
2. Is there a detailed data flow diagram that shows the data flow within the reporting organization, including inputs and outputs from the system?	X			
3. Is there a data flow diagram that shows the different components of the data management system?				See Figure 2-1 in SOP I_IMC_DATAVAL_F_1.0
4. Are procedures for data handling (e.g., data reduction, review, etc.) documented?	X			In SOPs
5. Does any personnel (site operator, field specialist, data analyst, etc.) have the permission/ability to change or alter any of the data on the collection instrumentation? Has there been any situation where this was done?		X		
6. Are site operator comments included in any reports?	X			
7. How are these comments captured and utilized?				Site operator comments are entered in the digital station logs. They are then collected and loaded into the database for use in the data validation process.
8. Are field specialist comments included in any reports?	X			Trip reports, site status log, site station logs
9. How are these comments captured and utilized?				Field specialist comments are included in the trip reports, site status logs, and site stations logs. Each of these items are archived digitally and are utilized in the data validation process.
10. In what media (e.g., USB drive, compact discs, telemetry) and formats does data arrive at the data processing location?				Automated electronic transfer in ASCII format.
11. How often are data received at the processing location from the field sites and laboratory?				Every hour of every day.
12. Is the routine data retrieval process conducted automatically?	X			
13. Who is responsible for the conducting the data retrieval? Who is their back-up?				Matt Smith. Data technicians or Wendy Miner (software developer/programmer) are the back-ups.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
14. What are the processes if a reporting location cannot transmit data?				Automated processes retry several times. If the issue persists, a site status log is created, and the issue is tracked until resolved. The site operator is contacted to help troubleshoot from the station. Data are retrieved from the DataView laptop if the issue isn't resolved quickly.
15. If part of dataset (i.e. ozone results) is not transmitted, is an attempt made to retransmit the whole dataset or just the missing information? If the whole dataset is retransmitted successfully, does repeated data overwrite already captured data?		X		The entire dataset for the missing hour is retransmitted. Data that were captured previously are not overwritten in the database. If filling in data directly from the instrument only the missing information is retrieved.
16. Is there documentation accompanying the data regarding any media changes, transcriptions, or flags which have been placed into the data before data are released to agency internal data processing?	X			
17. How is data actually entered to the computer system (e.g., computerized transcription [copy from disk or data transfer device], manual entry, digitization of strip charts, or other)?				Data are automatically consumed by the database every time a file is collected.
18. If data is manually entered by a person, is it checked for transcription errors? Is data doubly entered and automatically checked for comparability?		X		Data are not manually entered.
19. Is Blank-filling done at any point before Level 0 Validation? If so, what circumstances would cause this?	X			Missing records are blank-filled automatically as needed when transferring real-time data. A blank-filled record is just a placeholder until the data record is collected and loaded.
20. What information/data is contained in: a. Datalogger b. Computer with DataView How often is each queried? Can systems be controlled remotely?				The logger contains hourly data with flags as well as 1-minute data for ozone. The datalogger is queried hourly. The DataView laptop retrieves its data from the datalogger. It also stores station logs. The DataView laptop is queried twice per week or as needed. Both can be controlled remotely.
21. How frequently are collected and calculated data stored? Where and how are they stored?				Data are collected and stored every hour. They are stored in the original ASCII files as well as in the database.
Additional Comments:				

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
B. Hardware and Software Documentation				
22. What hardware components are used as part of the data management system in each step of the data handling procedure from acquisition to submission?				HP Workstations HP Proliant DL380 Gen10 Silver 2.1GHZ Database Server ESC 8816, 8832 and 8864 dataloggers Sierra Wireless GX 450 modems at cell sites Hughesnet Generation 4 and 5 modems at satellite sites
23. When were the hardware systems last updated? Are these systems under warranty?	X			The database server was purchased in March 2020 and is under warranty.
24. Is there a review process in place to verify the normal operation of the hardware systems (e.g., data logger)? Are there periodic checks / maintenance of the hardware systems? Would documentation on the most recent semiannual check of the data acquisition system be available for review?	X			Workstations and database server hardware are monitored ongoing. We used to check the analog inputs on the dataloggers but have found this is no longer necessary.
25. Please list the documentation for the most important custom software currently in use for data processing. Include the original author, current revision number and date. Include the required operating system and application (e.g., Microsoft Windows, Microsoft Access)				Documentation in N:\Project\ARS\SOP-new\FINAL\Data Operations\Word docs – not for distribution MS Windows/VB.Net applications: Datacollection.exe – ARS version 2020.09.17.0920 Dataloading.exe – ARS version 2020.11.18.1 Dataview – ARS version 2.20160622 DvDAS (the data acquisition piece) – ARS version 2.20201120
26. Does your agency use any AQS Manual?	X			
27. Does your agency use any AirNow Manual?	X			
28. If yes, list the title of manual used including the version number and date published for AQS and AirNow.				https://www.epa.gov/aqs AIRNow-I AQCSV Format Specifications Document Version 3.0
29. What is (are) the current Operating System(s) used on computers in the Network?				MS Windows 10 Pro, Oracle Linux 7.8
30. Are there any software incompatibilities which require human transcription/transfers of datasets to achieve final reported data? If so, which process in the chain requires human intervention?		X		
31. How often are software updates/changes made and by whom?				Workstation and Network software updates/changes are ongoing and are managed by the IT department.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
32. What determines the need for the changes?				A variety of things such as a new ozone standard (requires new report products be created based on the new rules), the clients need for new report products, changing technology needs, etc.
33. How thoroughly are internal programs tested, and by whom?				Betsy Davis-Noland is the database manager and the ARS software development team revises and updates the software. They use the SOP Tracking Changes and Updates to ARD Developed Database Software (Version 0, IT_AQDB_Updates_2016Oct_F_1.0). Workstation patches and updates are ongoing and applied as recommended by vendors. They are initially released to a test group of users to allow for testing of internal commercial and custom software before being released to all workstations.
34. Have there been any recent upgrades since 2017?				Oracle Database was upgraded from 12c to 19c and the database server OS was upgraded from Oracle Linux 6.7 to Oracle Linux 7.8.in April 2020.
35. Are procedures in place to protect data and minimize downtime in the event of a significant computer problem, power outage, etc. at the datacenter? Cite documentation that describes contingency planning applicable to this program.	X			Disaster recovery procedures are detailed in "ARS Computer System Disaster Recovery 202008" (Provided in separate attachment)
36. Has data processing software been tested to ensure its performance? (See QA Handbook, Volume II, Section 14.0.) Are any previous test results available?	X			Software is constantly being utilized in production; automatic processes running 24x7 and manual processes during normal business hours. Database performance, network, and process monitoring software are in place to alert the IT department via text message and email whenever automatic processes fail and if metric thresholds are exceeded. Data output products are compared to AQS products and reviewed annually for accuracy.
37. What software packages (if any) are used to automatically review the data?				Multiple products that were developed and are maintained in house. AQDBMS and Stackwin are the primary tools.
38. Does any software package have the capability of automatically changing the data?		X		Raw data are never changed.
39. Does any software package have the capability to automatically assign validation flags? Can the flags be changed if they are assigned in error?	X			Logger flags are used by the database to determine the appropriate validation code (which is applied in a separate field). The data analyst has the ability to change any flag that is assigned in error.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
40. Is there a unique log-in into programs where data can be changed? Who has access to make the changes?	X			The primary data source is the AQDBMS. Only IMC staff have access to this database. Raw values are never changed.
41. Who has the technical expertise to make changes to the Oracle database? AQDBMS database?				The database administrator (Betsy Davis-Noland) and the data manager (Jessica Ward).
42. Is data automatically sorted into defined tables after transmission? Is this process QC checked to ensure data is incorporated into the correct location?	X			Data review would reveal if data were incorporated into the wrong location because all plots that are used for data review are configured to retrieve data from a specific location.
43. Is software capable of disseminating multiple units (ppb/ppm, °C/°F, etc.) and correcting values automatically? Is user intervention ever needed?	X			The only user intervention needed would be to select the units desired when exporting data if non-standard units are desired.
44. Does the agency have information on reporting precision and accuracy data available?	X			In addition, precision and accuracy data are reported to AQS.
Additional Comments:				
C. Data Validation and Correction				
45. Who performs the different levels (levels 0-3) of data review/validation? List their educational background/ qualifications and years of experience performing this specific task.				Data technicians/analysts and IMC team lead. (Resumes provided in separate attachment.)
46. Who approves the different levels (levels 0-3) of data validation? List their educational background/ qualifications and years of experience performing this specific task.				Jessica Ward (data manager) (Resume provided in separate attachment.)
47. Is the validation criteria established and documented?	X			QAPPs and SOPs
48. Does the ozone instrument provide a direct readout on the screen? Is there a check of the instrument readout to the data from the data logger as part of the data validation steps? If so, at what level of data validation is this performed?	X			This readout isn't directly comparable to the value on the logger since the logger applies a correction factor. The analog output is compared to the logger during the field calibration visits.
49. What is the time resolution at which data is collected?				Hourly and 1-minute for ozone, hourly for meteorological parameters.
50. Is it recorded in the instrument and if so at what time resolution?				Hourly and 1-minute.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
51. At what time resolution is it recorded in the datalogger?				Hourly and 1-minute for ozone, hourly for meteorological parameters.
52. What is the minimum number of individual points to obtain a suitable hourly average for reporting?				75% of the minutes for each hour
53. Does documentation exist on the identification and applicability of flags (i.e. identification of suspect values) within the data as recorded with the data in the computer files?	X			QAPPs and SOPs
54. Is there documentation for the data validation criteria including limits for values such as flowrates, calibration results, or range tests for ambient measurements?	X			QAPPs and SOPs
55. What actions are taken if data is found outside limits in the validation process (e.g., flags, modifications, deletions, etc.)?				Each instance is thoroughly investigated, and data are invalidated where warranted using the appropriate code.
56. Please provide an example of actions taken when limits were exceeded.				Grand Canyon ozone data were invalidated from 11/10/20 – 11/12/20 because the 1-point QC check that ran on 11/11/20 was out by -7.2%.
57. Can data be changed after submission to AQS?	X			Data are uploaded to AQS monthly per project requirements. If data are invalidated after the fact based on annual data review or the results of semi-annual maintenance visits, these updates must be reflected in AQS. The DB logs when changes are made to data after monthly data validation.
58. Please describe documentation procedures for changes made to data already submitted to AQS.				The database automatically tracks changes made to data after data have been marked as final. In addition, the person making changes logs the change in the data corrections spreadsheet.
59. Who has signature authority for approving corrections? Do the same personnel have authority for updating submitted data to AQS?				The data manager and the IMC team lead. The same personnel can update the data in AQS.
60. Are data points ever deleted? What criteria are used to determine if a data point should be deleted? When in the validation process is this determined?		X		Raw data are never deleted and/or altered.
61. Are data points ever reprocessed? What criteria are used to determine if a data point should be reprocessed? When in the validation process is this determined?		X		
62. Are changes to site information/coding/file structures/units documented in AQDBMS? Are there any records available for review?	X			Database report logs any changes to data that occur after final validation.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
63. In the past year, were there any instances of power loss at the MAC426 site? Please identify relevant dates if applicable. In such events, did the data have to be corrected?				There was a short power outage on November 9, however all instruments were powered off until November 10 when the site operator cycled the outlets on the webswitch. Data during this time were not recoverable.
64. Who is responsible for determining when the data review steps are within DQO goals and can be sent on to data validation processes?				The QA department reviews semi-annual calibration results. Results are provided to the IMC and used in conjunction with nightly precision checks to assess if data meet established DQO goals. Monthly validation is performed by IMC staff and reviewed by the IMC Team Leader and/or Data Manager during additional validation review.
65. How many data review steps are performed when reviewing ozone data?				5 in total; Level 0, preliminary, 3rd level, final review/plot review, and annual data review.
66. Are other data (meteorological) reviewed as well? Does it go through the same review steps?	X			
67. Who is responsible for each step of the data validation? Is there one person assigned to each of the three levels of validation, or is one person responsible for multiple levels?				The IMC shares responsibility for levels 0 through 3rd level (although the same person may not perform preliminary and 3rd level for any given site/month). The data manager is responsible for final review and annual data review. Auditor: No single person is assigned to a specific site and/or the three levels of validation.
68. Are any QC checks done to ensure that transferred data is accurate?	X			Automated programming routines verify that data in the database match values reported from the datalogger.
69. Are any components of the data other than the ASCII files reviewed regularly (i.e. strip charts, ZSP, calibrations)? Are these performed by software, staff, or both?	X			Plots are automatically generated by software and reviewed daily and monthly by staff. These include hourly data, 1-minute data, and nightly calibrations.
70. Are there any typical post-processing calculations done to any of the data (STP corrections, modifications for humidity levels, etc.)?		X		
71. If a data correction is performed, how is this documented? Is there a table of the allowable times where this is correction is used? Who has authority to approve these corrections?				Adjustments to data are documented in the data validation log for that site/month and also are documented within the data record itself in the adjust field. The data manager has the authority to approve these corrections.
72. What is the minimal amount of minutes of collected data are needed to report an hourly point? Are there any requirements excluding two back-to-back minimal collections?				75% of the minutes. There are no back-to-back minimum requirements, but in general a few hours surrounded by many hours of invalid data will be invalidated as well.
73. Could a 30 minute block of missing time still produce no missed data points?	X			A missing 30 minute block of time could produce no missed data points if that 30 minute period was split evenly across 2 hours.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
74. Examine a few recent examples of actions that were taken when data had to be flagged: • Please provide an example of software flagging and validation flagging (2 records - does not need to be for the same time period) • Identify the flagging criteria and SOP or other document where these are defined • RTI will examine the AQS and/or the CASTNET website database to verify that the data records were appropriately flagged.				Great Smoky Look Rock ozone data on 11/3/20, 0900 was flagged <D by the logger and the software. The validation process coded this hour as invalid with a MT flag. Rocky Mountain ozone data on 11/24/20, 1100 was flagged <C by the logger and the software. The validation process coded this hour as invalid with a ZS flag.
75. Are there any instances where a non-documented database or program would be used in the validation process?		X		
76. Is any original/raw data over-written if it is altered?		X		
77. If a change to a data point needs to be made prior to submission to AQS (and other reporting databases), are any records of the original point maintained?	X			
78. What does "blank-filling" missing data entail? Are these values updated after Level 0 validation?				Blank-filling is a place holder to fill in a missing record. All values are updated during preliminary validation.
79. Does blank-filling entail entering a -999 value? At what point (if ever) is the value removed prior to reporting? What is it replaced with?	X			The value is removed if the missing record is later recovered.
80. Is there a list of validation codes?	X			
81. Are data flags (anomaly screening, datalogger, etc.) reported to AQS?	X			Null data codes (invalidation codes) are reported to AQS.
82. Are comments from data validating incorporated into flags?	X			
83. Are these reported to AQS?	X			
84. Is invalid data ever changed to valid during final validation?	X			If it was determined the data should not have been invalidated it will be changed to valid during final validation review.
85. Are there copies of the monthly validation checklist available for review? Are the monthly validation checklists maintained electronically anywhere?	X			Stackplots, Site Station Log, DataView Log, Power Failure Log, Data Validation Log.
86. How are "expected" values/limits defined?				In tables.
87. Are there any additional data post-processing steps (after Level 3 validation) before reporting?	X			A final review of data occurs between 3rd level validation and data reporting.
88. If a request is received for high resolution data traces, is it QC checked prior to submission to the requestor? Does it go through the same review process, or is it presented as is with a disclaimer?				It depends on whether or not it's within our contract with the NPS to validate 1-minute data. If yes than it goes through the same review process, if no it's delivered as raw data.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
Additional Comments:				
D. Data Processing				
89. Are regular data summary reports issued by the organization? Please attach a list of reports routinely generated, including title, distribution, and period covered. Provide a citation to project documentation	X			Monthly and annual data reports are prepared and sent to site operators and park superintendents.
90. How often are data submitted to AQS and the NPS website?				Data are submitted to AQS on a monthly basis approximately 60 days following the end of the period for which the data is being reported. The NPS request web site (https://ard-request.air-resource.com/) is a live link to the database, so data are available there as soon as they are validated. Raw data are available hourly.
91. Has there been any recent difficulties in coding and submitting data following AQS guidelines?		X		
92. Are hard copy printouts requested after submission to AQS?		X		
93. What is the contractual requirement for maintaining and archiving records? Are records maintained for that long by the organization in an orderly, accessible form?	X			Hard copy records are required to be kept for 5 years. All records are archived electronically and stored indefinitely.
94. If records are kept, do they include raw data, calculation, QC data, reviewed data, and reports? If no, please comment.	X			
95. Are concentrations of ozone corrected to EPA standard temperature and pressure before input into AQS?		X		This is done by the ozone analyzer.
96. Are audits (internal or external) on data reduction procedures performed on a routine basis?	X			
97. If audits on data reduction are performed, what is their frequency?				Annually or any time there is a systematic change.
98. Are data precision and accuracy checked each time they are calculated, recorded, or transcribed to ensure that incorrect values are not submitted to EPA?	X			Data submissions for less than a month may occur when changes are made to data after it's been submitted to AQS.
99. Are partial monthly reports ever submitted to AQS?	X			
100. Does the AQS report come directly from AQDBMS database?	X			

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
101. Does the AQDBMS database directly supply any other place with data (CASTNET website, AirNow, etc.)?	X			The AQDBMS is the primary data source and therefore supplies the data for any and all data requests or routine data submittals.
Additional Comments:				
E. Reporting (Internal and External)				
102. Are internal reports prepared and submitted as a result of the audits (NPAP and any TSA performed outside of ARS) required under 40 CFR 58, Appendix A? List Report Titles and Frequency.	X			The auditor provides the audit results in a report.
103. What internal reports are prepared and submitted as a result of precision checks required under 40 CFR 58, Appendix A? (List Report Titles and Frequency)				Precision check results are summarized in the Annual Data Summary Report as well as the Annual Performance Summary Report. These checks are also uploaded to AQS every quarter.
104. Do either the audit or precision check reports include a discussion of corrective actions initiated based on audit.		X		Corrective actions are documented in the database (validation log, site status log) and in the calibration tracking spreadsheet.
105. Who has the responsibility for the calculation and preparation of data summaries? To whom are such summaries delivered? List Name, Title, Type of Report, and Recipient(s).				The data manager is responsible for the preparation and review of the annual data summary report. The report is delivered to and reviewed by the NPS ARD. It is then delivered to site operators, park superintendents, and EPA regions. Monthly data summaries are prepared by data technicians/analysts and is delivered by the IMC team lead to the NPS ARD and site operators.
106. Is the data reported to the AQS? AirNow?	X			
107. When was the last annual data summary report submitted (40 CFR 58.15(b))?				It was last posted to the GPMP data request web site on 3/6/2020 and an email announcing its completion was sent that same day.
108. Was precision and accuracy information included?	X			In the supplementary QA summary report.
109. Was location, date, pollution source and duration of all episodes reaching significant harm levels included?	X			Highest concentrations are listed by date and pollutant for each site in the network. These concentrations are then compared to the NAAQS.
110. Was Data Certification signed by a senior officer of your agency?	X			Data certification is signed by Barkley Sive, the head of the GPMP program with NPS ARD.

Audit Questions	Response			Comments and References (provided by ARS personnel unless otherwise indicated)
	Y	N	NA	
Additional Comments:				

Part 2. Data Review

Detailed questions and data requests:

Request to see raw data from the MAC426 site for:

1. January 10 and 11, 2021 (within a month),
2. November 8 to 11, 2020 (prior quarter),
3. August 23 to 25, 2020 (within 6 months), and
4. Consecutive 5-day period in January/February 2020 centered on the calibration date – 2 days before the calibration and 2 days following the calibration.
5. 1-minute data and ZSP checks for February 7 and 8, 2021 (2 days prior to the onsite audit)

Audit Questions	Response			Comments and References (provided by RTI personnel unless otherwise indicated)
	Y	N	NA	
111. Download or print hourly data from Ozone instrument. Include time and O_3 ppb data at a minimum, plus other information such as ambient temperature, BP, RH, shelter temperature, flow rate, etc., if available. Include a zero/span/precision (ZSP) check. Auditor will compare the data obtained at the site vs. the data reported in the NPS and CASTNET websites and AQS. Identify any discrepancies and follow-up with ARS staff.				ARS: Raw data files can be provided for any period of time requested. Or data can be exported from the database. The following web site will allow you to download raw or validated data: https://ard-request.air-resource.com/data.aspx Auditor: Data were downloaded from NPS, CASTNET and EPA websites and compared to the raw data obtained from the above site as well as those obtained from data logger or ARS. No discrepancies were found.
112. While on site, for the TSA, the auditor will record (if possible) 1-min readings up to an hour of raw ozone data directly from the front panel of instrument output and compare it to raw data obtained from ARS. • Are there any discrepancies in ozone concentration between the monitor readout and downloaded or printed data? • If any data flags are appended to the data by the instrument, later trace them to records on AQS and on the NPS and CASTNET websites.				Auditor: Data was recorded onsite for 30 minutes. Minor discrepancies were seen between the reading on the screen and the data logger. Follow-up with the field technician Mr. Dave Beichley clarified that it is due to different averaging times between the front display (30 seconds averaging) and the data logger (1 minute).

113. Obtain 1-minute data directly from the instrument or from ARS. Also obtain 1-minute data and ZSP checks from 2 days prior to the onsite audit. Do recalculated hourly averages agree with the reported hourly data? (The auditor will calculate data completeness for hourly data that contains one or more invalidated 1-minute values and verify any completeness flags that should have been applied.)				Auditor: Data have been obtained. Hourly average calculated from the raw 1-min data for the November 2020 period agreed with the recorded hourly data for the most part. The "raw" 1-min data from the NPS website has 2 to 3 significant digits while the reported hourly data is truncated to the nearest ppb. Due to these differences in significant digits, there were certain instances where the difference was at most 1 ppb. When using raw 1-min data from the data logger for August 2020 period (8 to 9 significant digits), calculated hourly averages for the August 2020 period showed exact agreement with the hourly values reported. It must be noted that ARS does not calculate hourly averages. They use the hourly average calculated and reported by the data logger and therefore the issue of significant digits affecting the hourly average is not present.
114. While on site, the auditor performing the TSA should note the time of any interruption in monitoring data that occur during the TSA. If any were observed: • Check that the raw data records reflect the data gap at the correct time. • Do the correct flags appear in the hourly data records?				Auditor: No interruptions occurred to the regular operation due to the audit. The auditor however verified the raw data to confirm correct flags were assigned due to the ongoing calibration activities during the day of the audit.
115. Have any recent PE audits resulted in data revisions or reflagging? List site IDs, dates and times. RTI will compare corresponding data records on the NPS and CASTNET websites and in AQS and will determine if the appropriate changes or flags were applied.				ARS: The ozone analyzer failed the audit at Sequoia Ash Mountain on October 14, 2015. The problem was due to a kink in the pump tubing inside the ozone analyzer. The kink was fixed by the site operator on 10/20/15. Ozone data were invalidated from the last good precision check on 10/7/15 until the kink was fixed on 10/20/15. The site was re-audited on 10/30/15 and the analyzer passed with good results. This example was used last time as well, but we haven't had another failure of a PE audit since then that resulted in data loss as it's rare that a PE audit fails.
116. Auditor will observe the data validation process with the datalogger and Data View software and will follow the steps in the SOP. Were any deviations from the data processing and validation SOPs observed? Note any significant deviations that should be reflected in a revised SOP.				Auditor: Auditor had ARS walk through the data validation process and observed the checks and the plots generated and reviewed. No issues were observed.

117. Auditor will ask the data management staff to identify a few examples where they had to add data flags or change/invalidate data, as a result of higher-level data validation. Record the reasons for the changes, site IDs, dates and times of the data affected. (Example data need not come from the site that is audited for the field TSA.) Answer the following questions: • When higher-level validation identifies new data flags or other data changes, how are these sent to the NPS and CASTNET websites to replace data already posted? • Have data already in AQS ever had to be changed or updated? Record the date/time when the change was uploaded to the external database. Is the process for making changes to AQS data documented?				Annual data review revealed wind speed at Denali had been lower than normal since the wiring was moved from the mainframe to the met card during a semi-annual maintenance visit in May 2019. The data group worked with the field group and determined the scaling had been incorrect since then. Data were adjusted to account for the incorrect scaling from 5/22/19, 1900 – 6/5/20, 1200. A higher level review revealed the precision checks that were outside of tolerance at Shenandoah on 7/24/20 and 7/25/20 were likely due to a low analyzer response rather than an inaccurate calibration response as originally thought. Ozone data were invalidated with PQ from the last good check on 7/23/20 until the next good check on 7/26/20. Changes to data don't need to be sent to the GPMP request web site because the site is a live link to the database. As soon as changes are made in the database these changes are available on the web site. Data are re-uploaded to AQS when changes are made to data after the initial upload has been completed. Auditor: During the remote data audit, auditor had ARS staff walk through the process demonstrating the data review steps and the steps taken to correct or update data. Raw data always remains intact as also seen during the data audit of the August 2020 time period.
118. Based on the three data sources (ARS raw data; AQS; CASTNET web site) determine the following: • Do all identifiers and flags from the three sources agree? If not, prepare a table or crosswalk of discrepancies. • Do hourly concentration averages computed from 1-minute data sources agree? • Do hourly averages posted on AQS and the CASTNET website agree as to both concentration and time?				Auditor: All validated data agreed perfectly between the different online systems and the data from ARS. Flags and identifiers agree. However, the nature of the flags differ between the three sources: • AQS data contains QA flags that provides the data user with additional information as to the data quality and potential causes. • CASTNET has some flags but is much more limited. It is more of a data validation level flag rather a QA flag. • The NPS dataset does not have any flags reported. This is a recommendation made to NPS to consider including flags in the datasets reported.

119. Review ARS's validation records for a past issue. How are outliers identified and marked invalid by the validation process? - Was the outlier correctly identified? - Was the correct data flag applied?				The data group noticed large spikes in the 1-minute ozone data that were affecting the hourly averages. The spikes were identified by reviewing stackplots and the minute trace. Data were invalidated with IM during the affected hour.
120. Was anyone contacted (site operator, auditor, and network service person) to ask about the outlier? Discuss the general process of investigating unexplained outliers in the data.				Data validation staff look at information in the site status log and station log to determine data discrepancies. An example is the August 2020 period that was initially invalidated by the automated screening, but later validated by the staff based on their knowledge of the site operations and information in the site log. Reason for change is documented in the data validation log.
121. For the observed issue, did enough valid observations remain to compute a valid hourly average? (RTI will re-compute the hourly average and compare it to the hourly averages posted in AQS and on the CASTNET website)				Auditor: Data review showed that the calculation of hourly averages by the data logger correctly takes into account the needed number of 1-min observations. Instances where less than 45 minutes of valid 1-min data were available did not have an hourly average calculated.

Additional Comments:

Data systems appear to be working properly. All validate data agree between the different systems. NPS data does not have any flag associated with the dataset. It is recommended that flags are added to the datasets reported on the NPS website.

APPENDIX D

6-Month Calibration Audit of the Mammoth Cave National Park (MAC426) Site

Semiannual Maintenance and Calibration Report
Prepared by Air Resource Specialists, Inc.

Client:	National Park Service	**Field Personnel:**	Dave Beichley
Site:	Houchin Meadows (MACA-HM)	**Service Date(s):**	5/15/2020 -5/17/2020
Site Operator:	Johnathan Jernigan	**Subject:**	Semi-Annual Maintenance

All site visit and calibration forms are attached, detailing the pre- and post-maintenance calibrations and test results. Calibration acceptance criteria are defined as the thresholds at which corrective action is required. Data acceptance criteria are defined as the thresholds at which the quality of the ambient data is questionable and may require invalidation. This report is not complete without the inclusion of the calibration form worksheets.

SUMMARY OF FINDINGS

GASEOUS POLLUTANT SUPPORT EQUIPMENT

Zero-Air System (Teledyne-API M701H):

Maintenance - No maintenance for the pump or compressor was required at this time. The media for the zero-air system was not replaced.

Gas Dilution Calibrator (Teledyne-API M700EU):

Maintenance - All mass flow controllers were tested against a certified flow transfer standard. The diluent mass flow controller was calibrated. The calibration gas mass flow controller was calibrated.

Station Temperature:

Pre-Maintenance Testing - The sensor was compared against a certified temperature transfer standard. The sensor was found to be responding within calibration acceptance criteria.

Maintenance - No other maintenance was performed.

Post-Maintenance Testing - No post-maintenance checks were performed.

GASEOUS POLLUTANT ANALYZERS

Ozone Analyzer (Thermo 49i):

Pre-Maintenance Testing - The ozone analyzer was compared against a Level 2 ozone transfer standard. The ozone analyzer was found to be responding within calibration acceptance criteria.

Maintenance - The cabinet filters were cleaned. The instrument was calibrated at zero and span level.

Post-Maintenance Testing - The ozone analyzer was compared against a Level 2 ozone transfer standard. The ozone analyzer was found to be responding within calibration acceptance criteria.

Ozone Station Reference (Thermo 49i):

Pre-Maintenance Testing - The Level 3 ozone station reference was recertified using a Level 2 ozone transfer standard. The ozone station reference was found to be responding within calibration acceptance criteria.

Maintenance - The cabinet filters were cleaned.

Post-Maintenance Testing - The ozone station reference was compared against a Level 3 ozone transfer standard. The ozone station reference was found to be responding within calibration acceptance criteria.

NO_Y Analyzer (Thermo 42iTL NOy):

Pre-Maintenance Testing - The analyzer was challenged using a gas dilution calibrator and an EPA-protocol gas cylinder containing nitric oxide. The analyzer was confirmed to be responding outside of calibration acceptance criteria for nitric oxide. The analyzer was challenged via gas phase titration (GPT) using a gas dilution calibrator and an EPA-protocol gas cylinder containing nitric oxide. The analyzer was confirmed to be responding outside of calibration acceptance criteria for nitrogen dioxide. The converter efficiency of the analyzer was confirmed to be responding within acceptance criteria.

Maintenance - A small leak was discovered and fixed in the analyzer. The by-pass pump was rebuilt. A new perma-pure dryer was installed. The cabinet filters were cleaned. The analyzer was calibrated at zero and span level.

Post-Maintenance Testing - The analyzer was challenged using a gas dilution calibrator and an EPA-protocol gas cylinder containing nitric oxide. The analyzer was confirmed to be responding within calibration acceptance criteria for nitric oxide. The analyzer was challenged via gas phase titration (GPT) using a gas dilution calibrator and an EPA-protocol gas cylinder containing nitric oxide. The analyzer was confirmed to be responding within calibration acceptance criteria for nitrogen dioxide. The converter efficiency of the analyzer was confirmed to be responding within acceptance criteria.

SO_2 Analyzer (Thermo 43i):

Pre-Maintenance Testing - The analyzer was challenged using a gas dilution calibrator and an EPA-protocol gas cylinder containing sulfur dioxide. The analyzer was confirmed to be responding within calibration acceptance criteria.

Maintenance - The pump was rebuilt and the PMT was adjusted. The instrument was calibrated at zero and span level.

Post-Maintenance Testing - The analyzer was challenged using a gas dilution calibrator and an EPA-protocol gas cylinder containing sulfur dioxide. The analyzer was confirmed to be responding within calibration acceptance criteria.

CO Analyzer (Thermo 48i):

Pre-Maintenance Testing - The analyzer was challenged using a gas dilution calibrator and an EPA-protocol gas cylinder containing carbon monoxide. The analyzer was confirmed to be responding within calibration acceptance criteria.

Maintenance - Performed the pre-amp board calibration and adjusted the S/R ratio. Calibrated the instrument at zero and span level.

Post-Maintenance Testing - The analyzer was challenged using a gas dilution calibrator and an EPA-protocol gas cylinder containing carbon monoxide. The analyzer was confirmed to be responding within calibration acceptance criteria.

METEOROLOGICAL SENSORS

Ambient Temperature and Vertical Temperature Difference (RM Young 41342VC):

Pre-Maintenance Testing - The sensor was compared against a certified temperature transfer standard in three water baths controlled at temperatures between 0 and 50 degrees Celsius. The sensor was confirmed to be responding within calibration acceptance criteria. The aspirator fan was functioning correctly.

Maintenance - No other maintenance was performed.

Post-Maintenance Testing - No post-maintenance checks were performed.

Relative Humidity (Rotronic MP601):

Pre-Maintenance Testing - The sensor was collocated with a certified relative humidity transfer standard. The sensor was confirmed to be responding within calibration acceptance criteria. The aspirator fan was functioning correctly.

Maintenance - A newly serviced sensor was installed.

Post-Maintenance Testing - The sensor was collocated with a certified relative humidity transfer standard. The sensor was confirmed to be responding within calibration acceptance criteria.

Wind Speed (Climatronics 100075):

Pre-Maintenance Testing - The sensor was challenged with a certified anemometer drive. The sensor was confirmed to be responding within calibration acceptance criteria. The starting threshold test for the sensor was within acceptance criteria. The heater for the sensor was found to be functioning correctly.

Maintenance - A newly serviced sensor was installed.

Post-Maintenance Testing - The sensor was challenged with a certified anemometer drive. The sensor was confirmed to be responding within calibration acceptance criteria. The starting threshold test for the sensor was within acceptance criteria. The heater for the sensor was functioning correctly.

Wind Direction (Climatronics 100076):

Pre-Maintenance Testing - The reference alignment for the sensor was checked using a compass. The reference alignment for the sensor was confirmed to be within acceptable limits. The accuracy of the sensor was tested by comparison to a reference. The sensor was confirmed to be responding within calibration acceptance criteria. The linearity of the sensor was within acceptable limits. The starting threshold test results were within acceptance criteria. The heater for the sensor was confirmed to be functioning correctly.

Maintenance - A newly serviced sensor was installed.

Post-Maintenance Testing - The reference alignment for the sensor was checked using a compass. The reference alignment for the sensor was confirmed to be within acceptable limits. The accuracy of the sensor was tested by comparison to a reference. The sensor was confirmed to be responding within calibration acceptance criteria. The linearity of the sensor was within acceptable limits. The starting threshold test for the sensor was within acceptance criteria. The heater for the sensor was functioning correctly.

Barometric Pressure (RM Young 61202):

Pre-Maintenance Testing - The sensor was challenged by a certified barometric pressure transfer standard. The sensor was confirmed to be responding within calibration acceptance criteria.

Maintenance - No other maintenance was performed.

Post-Maintenance Testing - No post-maintenance checks were performed.

Solar Radiation (Li-Cor Pyranometer):

Pre-Maintenance Testing - The sensor was collocated with a certified solar radiation transfer standard. The sensor was confirmed to be responding outside of calibration acceptance criteria. The sensor was found to be level and clean.

Maintenance - A new sensor was installed.

Post-Maintenance Testing - The sensor was collocated with a certified solar radiation transfer standard. The sensor was confirmed to be responding within calibration acceptance criteria.

Precipitation (Climatronics 100508):

Pre-Maintenance Testing - The sensor was challenged using a known volume of water. The sensor was found responding within calibration acceptance criteria. The sensor was found to be level and clean. The heater was found to be functional.

Maintenance - No other maintenance was performed.

Post-Maintenance Testing - No post-maintenance checks were performed.

PARTICULATE MONITORS AND SAMPLERS

CASTNET Filter Pack Flow:

Pre-Maintenance Testing - A leak check on the system was performed and results were within acceptable limits. The flow was checked using a certified flow standard measuring flow in standard conditions. The measured flow was found to be within calibration acceptance criteria.

Maintenance - The pump was rebuilt.

Post-Maintenance Testing - The flow was checked using a certified flow standard measuring flow in standard conditions. The measured flow was confirmed to be within calibration acceptance criteria.

Air Resource SPECIALISTS

TEMPERATURE / VERTICAL TEMPERATURE DIFFERENCE SYSTEM VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	6/16/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Temperature Reference	Eutechnics	4400	308287	9/18/2020

AS FOUND		List sensors according to height on tower, from highest to lowest.	AS LEFT	
2m Temperature Sensor				
Manufacturer	RM Young		Manufacturer	
Model	41342VC		Model	
Serial Number	15104		Serial Number	
		Temp. Deltas		

DATA ACCEPTANCE CRITERIA (<=)	
Ambient Temperature Difference (°C)	1.0
Vertical Temperature Difference (°C)	N/A

AS FOUND	2m Temperature		
Bath Temp (°C)	DAS	Difference	
0.09	0.44	0.35	PASS
23.68	23.95	0.27	PASS
45.00	45.91	-0.09	PASS
MAX ABS Difference		0.35	PASS

MAX ABS Difference						

Aspirator fan functional 2m?	☑ Yes ☐ No ☐ N/A
	☐ Yes ☐ No ☐ N/A
	☐ Yes ☐ No ☐ N/A
	☐ Yes ☐ No ☐ N/A

Each sensor was verified against its data channel ? ☑ Yes ☐ No ☐ N/A

Each Temperature Difference = Upper - Lower ? ☐ Yes ☐ No ☐ N/A

AS LEFT						
Bath Temp (°C)						
MAX ABS Difference						

MAX ABS Difference						

NOTES:

Air Resource SPECIALISTS

STATION TEMPERATURE SENSOR VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Temperature Reference	Eutechnics	4400	308287	9/18/2020

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Temperature Difference (°C)	1.0

AS FOUND	Temperature		
Reference (°C)	DAS (°C)	Difference	
25.14	25.57	0.4	PASS
25.88	25.95	0.1	PASS
26.20	26.35	0.2	PASS

AS LEFT	Temperature		
Reference (°C)	DAS (°C)	Difference	

NOTES:

Air Resource SPECIALISTS

RELATIVE HUMIDITY SENSOR VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
RH SENSOR REFERENCE	Rotronic	HC2S3	20039891	11/13/2020

AS FOUND

Manufacturer	Rotronic
Model	MP601A
Serial Number	87259

AS LEFT

Manufacturer	Rotronics
Model	MP601A
Serial Number	52068

DATA ACCEPTANCE CRITERIA (<=)	
Relative Humidity Difference (%)	10%

AS FOUND	Relative Humidity (%)				V
Hour	STD	DAS	Difference		
400	95.2%	94.8%	-0.4%	PASS	
500	96.1%	94.8%	-1.3%	PASS	
600	87.8%	85.2%	-2.6%	PASS	
700	74.6%	66.8%	-7.8%	PASS	
800	71.1%	63.1%	-8.0%	PASS	
	Average		-4.0%	PASS	

AS LEFT	Relative Humidity (%)				V
Hour	STD	DAS	Difference		
1000	60.6%	63.5%	3.0%	PASS	
1100	59.3%	58.8%	-0.4%	PASS	
1200	54.0%	56.2%	2.2%	PASS	
1300	54.0%	54.1%	0.1%	PASS	
1400	50.3%	48.0%	-2.3%	PASS	
	Average		0.5%	PASS	

Aspirator fan functional?	☑ Yes	☐ No	☐ N/A

NOTES:

Air Resource SPECIALISTS

BAROMETRIC PRESSURE SENSOR VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Barometric Pressure Reference	Druck	DPI705	70573705	8/22/2020

AS FOUND

Manufacturer	RM Young
Model	61202V
Serial Number	BP06203

AS LEFT

Manufacturer	
Model	
Serial Number	

DATA ACCEPTANCE CRITERIA (<=)	
Pressure Difference (mmHg)	3.00

AS FOUND	Barometric Pressure		
Reference (mmHg)	DAS (mmHg)	Difference	
743.2	743.7	0.5	PASS

AS LEFT	Barometric Pressure		
Reference (mmHg)	DAS (mmHg)	Difference	

Common Pressure Conversions					
Value	Units	mmHg	mmHg	Value	units
1.000	atm	760.00	760.00	1.000	atm
29.28	inHg	743.74		29.92	inHg
1013.2	mb	760.00		1013.2	mb
1013.2	hPa	760.00		1013.2	hPa
14.70	psi	760.00		14.70	psi

NOTES:

Air Resource SPECIALISTS

WIND SPEED SENSOR VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Wind Speed Reference	RM Young	18820A	CA 03358	6/20/2020
Wind Speed Torque Gauge	RM Young	18310		

AS FOUND	
Manufacturer and Model	Climatronics - 100075 / Heavy Duty Aluminum
Sensor Serial #	1071
Cups Serial #	2341

AS LEFT	
Manufacturer and Model	Climatronics - 100075 / Heavy Duty Aluminum
Sensor Serial #	3414
Cups Serial #	2341

DATA ACCEPTANCE CRITERIA (<=)		
Wind Speed Difference (m/s)	0.25	if wind speed <= 5 m/s
Wind Speed Difference (%)	5.0%	if wind speed > 2 m/s

Select UNITS	m/s

AS FOUND

		Wind Speed			
Motor Speed (rpm)	Target Speed	DAS	Difference		
0	0.000	0.224	N/A	N/A	N/A
300	7.274	7.274		0.0%	PASS
600	14.325	14.320		0.0%	PASS
900	21.375	21.800		2.0%	PASS
1200	28.426	28.430		0.0%	PASS
1800	42.527	42.580		0.1%	PASS
				PASS	

Starting Threshold	TORQUE
Torque <= 0.3 g-cm	0.3
	NO ACTION REQUIRED

Heater sleeve functional? ☐ Yes ☐ No ☐ N/A

AS LEFT

		Wind Speed			
Motor Speed (rpm)	Target Speed	DAS	Difference		
0	0.000	0.224	N/A	N/A	N/A
300	7.274	7.274		0.0%	PASS
600	14.325	14.320		0.0%	PASS
900	21.375	21.360		-0.1%	PASS
1200	28.426	28.430		0.0%	PASS
1800	42.527	42.530		0.0%	PASS
				PASS	

Starting Threshold	TORQUE
Torque <= 0.3 g-cm	0.3
	NO ACTION REQUIRED

NOTES:

Air Resource SPECIALISTS

WIND DIRECTION SENSOR VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Direction Alignment Reference	Brunton	5006LM	5060408265	
Direction Linearity Reference	Wilson Machinery	8 point disc	#31	
Direction Torque Gauge	RM Young	18310	na	

AS FOUND	
Manufacturer & Model	Climatronics - 100076
Sensor Serial #	22288
Vane Serial #	3945

AS LEFT	
Manufacturer & Model	Climatronics - 100076
Sensor Serial #	1725
Vane Serial #	3945

Local Magnetic Declination (degrees)	-4.0
Method	Solar Azimuth

Mag. Dec. from NOAA (deg/min/sec): 0.00

http://www.ngdc.noaa.gov/geomag-web/#declination

Landmarks	Degrees
From the North	0
From the South	180
From the East	90
From the West	270

ACCEPTANCE CRITERIA (<=)	
Cross-arm Alignment Error (degrees) (CAL)	2
Total Align. Diff (degrees) (DATA)	5
Sensor Linearity (degrees) (CAL)	5

Is the Reference Alignment intended to be N-S: YES

Is the Reference Alignment intended to be N-S: YES

AS FOUND

Reference Alignment (degrees)	0.0	PASS

AS LEFT

Reference Alignment (degrees)	0.0	PASS

SENSOR ALIGNMENT

N-S Reference	Degrees	DAS	Difference
From the North	0	1.6	1.6
From the South	180	183.3	3.3
From the East	90	92.9	2.9
From the West	270	273.3	3.3
Total Alignment MAX ABS Diff		3.3	PASS

OR

SENSOR ALIGNMENT

Landmark	Degrees	DAS	Difference
From the North	0		
From the South	180		
From the East	90		
From the West	270		
Total Alignment MAX ABS Diff			

OR

SENSOR ALIGNMENT

X Reference	Degrees	DAS	Difference
	0		
	180		
	90		
	270		
Total Alignment MAX ABS Diff			

SENSOR ALIGNMENT

N-S Reference	Degrees	DAS	Difference
From the North	0	1.8	1.8
From the South	180	183.6	3.6
From the East	90	89.6	-0.4
From the West	270	269.6	-0.4
Total Alignment MAX ABS Diff		3.6	PASS

OR

SENSOR ALIGNMENT

Landmark	Degrees	DAS	Difference
From the North	0		
From the South	180		
From the East	90		
From the West	270		
Total Alignment MAX ABS Diff			

OR

SENSOR ALIGNMENT

X Reference	Degrees	DAS	Difference
Align with Ref (N)	0		
Align with Ref (S)	180		
Perp with Ref (E)	90		
Perp with Ref (W)	270		
Total Alignment MAX ABS Diff			

SENSOR LINEARITY

Point	DAS	Difference	
1	82.0	N/A	
2	126.6	0	PASS
3	171.1	-1	PASS
4	215.3	-1	PASS
5	259.9	0	PASS
6	305.2	0	PASS
7	350.5	0	PASS
8	33.4	-2	PASS
1	79.9	1	PASS
MAX Difference		2	

NO ACTION REQUIRED

SENSOR LINEARITY

Point	DAS	Difference	
1	119.6	N/A	
2	164.8	0	PASS
3	209.4	0	PASS
4	254.7	0	PASS
5	300.2	1	PASS
6	345.3	0	PASS
7	28.5	-2	PASS
8	73.9	0	PASS
1	119.1	0	PASS
MAX Difference		2	

NO ACTION REQUIRED

Starting Threshold	TORQUE
Torque <= 6.0 g-cm	5.0

NO ACTION REQUIRED

Starting Threshold	TORQUE
Torque <= 6.0 g-cm	5.0

NO ACTION REQUIRED

Heater sleeve functional? ☑ Yes ☐ No ☐ N/A

NOTES:

Air Resource SPECIALISTS

SOLAR RADIATION SENSOR VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE	MULTIPLIER
Solar Radiation Reference	CSI	Pyranometer	68694	8/20/2020	

AS FOUND

Manufacturer	Apagee	
Model	SP-110	
Serial Number	62292	
Translator	NA	
Logger Type	High Input (V)	1.0000
ESC	Low Input (V)	0.0000
	High Output	5000.0000
	Low Output	0.0000

AS LEFT

Manufacturer	Apogee	
Model	CS301	
Serial Number	328530	
Translator		
Logger Type	High Input (V)	1.0000
ESC	Low Input (V)	0.0000
	High Output	5000.0000
	Low Output	0.0000

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Difference from CTS (%)	5%

DATA ACCEPTANCE CRITERIA (<=)	
Difference from CTS (%)	10%

AS FOUND

Hour	Solar Radiation CTS (W/m²)	DAS (W/m²)	Difference	V
500	62.19	59	-5.3%	
600	199	185	-7.2%	
700	365.5	332	-9.1%	
800	512	475	-7.3%	
900	329.5	311	-5.6%	
	MEAN ABS % DIFF	6.9%	ACTION	

	DAS (W/m²)
DARK RESPONSE	0

Sensor found clean?	☑ Yes ☐ No
Sensor found level?	☑ Yes ☐ No

AS LEFT

Hour	Solar Radiation CTS (W/m²)	DAS (W/m²)	Difference	V
1130	914	934	2.2%	
1145	1038	1061	2.2%	
1200	980	1000	2.0%	
1215	849	866	2.0%	
1230	476	486	2.1%	
	MEAN ABS % DIFF	2.1%	PASS	

	DAS (W/m²)
DARK RESPONSE	0

NOTES: A new sensor was installed.

Air Resource SPECIALISTS

CASTNET INLET VENT AND PRESSURE VALUES

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

Flow Reference Type	BIOS

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Flow Reference	BIOS	Definer 220H	122997	6/18/2020

OZONE VENT FLOW	LPM
Without LEVEL 2 transfer standard attached	2.0+
With LEVEL 2 transfer standard attached	1.40

OZONATOR REGULATOR PRESSURE		
	24.0	psi

1. All flow measurements should be recorded in volumetric or actual conditions.
2. Flow measuring device must be removed during ozone challenges.

SAMPLE PRESSURES	Analyzer	Station Ref.	Level 2
During ambient sampling	731.50		
During PSZ check	731.50	763.20	
During pre-maintenance checks	731.50	753.60	756.30

1. During ambient sampling, the station reference sample pump must be off and the Level 2 transfer must not be pneumatically connected.
1. During PSZ checks, the Level 2 transfer must not be pneumatically connected.

Air Resource SPECIALISTS

OZONE ANALYZER VERIFICATION & CALIBRATION (AS FOUND)

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

AS FOUND

TRANSFER STANDARD		AMBIENT ANALYZER		STATION REFERENCE	
Manufacturer	Thermo	Manufacturer	Thermo	Manufacturer	Thermo
Model	49i	Model	49i	Model	49i
Serial Number	1130450197	Serial Number	1030745085	Serial Number	1015543061
Coefficient	1	Coefficient	.999	Coefficient	1
Background	0	Background	-.1	Background	0
Cell A Intensity (Hz)	100450	Cell A Intensity (Hz)	101508	Cell A Intensity (Hz)	76547
Cell B Intensity (Hz)	98070	Cell B Intensity (Hz)	109919	Cell B Intensity (Hz)	95774
Flow A (lpm)	0.726	Flow A (lpm)	.777	Flow A (lpm)	.740
Flow B (lpm)	0.771	Flow B (lpm)	.783	Flow B (lpm)	.716
Pressure (mmHg)	742.2	Pressure (mmHg)	731.2	Pressure (mmHg)	763.5
Bench Temp (°C)	26.1	Bench Temp (°C)	34.1	Bench Temp (°C)	29.7
Bench Lamp Temp (°C)	53.1	Bench Lamp Temp (°C)	53.9	Bench Lamp Temp (°C)	54.4
Ozone Lamp Temp (°C)	67.1	Ozone Lamp Temp (°C)	68.2	Ozone Lamp Temp (°C)	na
		Ozone Source		Ozone Source	
Transfer Standard Level	LEVEL 2	Full Scale (ppb)	250	Transfer Standard Level	LEVEL 3
				Logger Slope Correction	1.0034
				Logger Intercept Correction	-0.0578

Transfer Standard Correction Factors	SLOPE	INT
	0.9943	-0.0870

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	3%
Maximum Absolute Difference (%)	3%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	10%
Maximum Absolute Difference (%)	10%

		LAMP%	TRANSFER STANDARD		AMBIENT ANALYZER				STATION REFERENCE			
POINT	TARGET	or mV	Display	Corrected	DAS	Diff	%Diff	LINEAR%	DAS	Diff	%Diff	LINEAR%
ZERO	0	0	-1.5	-1.4	-0.3	1.1	N/A	-0.3%	-0.5	0.9	N/A	-0.2%
1	200	28.2	204.5	205.8	209.5	3.7	1.8%	-0.3%	207.7	1.9	0.9%	-0.1%
2	150	20.5	111.7	112.4	113.3	0.9	0.8%	0.4%	113.5	1.1	1.0%	0.0%
3	100	18	81.2	81.8	82.7	0.9	1.1%	0.2%	82.4	0.6	0.8%	0.1%
4	70	16	57.8	58.2	59.1	0.8	1.4%	0.1%	58.5	0.3	0.5%	0.2%
5	50	13.3	31.15	31.4	32.1	0.7	2.2%	0.0%	31.9	0.5	1.6%	0.0%
ZERO	0	0	0	0.1	0.3	0.2	N/A	0.0%	0.2	0.1	N/A	0.1%
					Mean ABS % Diff		1.5%	PASS	Mean ABS % Diff		1.0%	PASS
					Max ABS % Diff		2.2%	PASS	Max ABS % Diff		1.6%	PASS
					Slope		1.013		Slope		1.007	
					Y-Intercept		0.25		Y-Intercept		0.29	
					Correlation		1.0000		Correlation		1.0000	

Analog Test	Analyzer DAS	Reference DAS
Zero	na	na
Full Scale	na	na

Line Loss Test	Analyzer Display		
Span (site tubing)	208	%	P/F
Span (bypass tubing)	206	1.0%	PASS

NOTES:

Air Resource SPECIALISTS

CASTNET OZONE ANALYZER DIAGNOSTIC TESTS

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Temperature Reference	Eutechnics	4400	308287	9/18/2020

INSTRUMENT SERIAL NUMBER	1030745085

THERMO 49C/i BENCH TEMP CHECK

	Reference	Analyzer	
PRE	33.3	33.6	PASS
POST			

ESC LOGGER SCALING

High Input	Low Input	High Output	Low Output

Only perform POST if calibration is necessary
Make sure to calibrate the analog output, if necessary

THERMO 49C/i SOLENOID LEAK TEST

	Cell A	Cell B
1	518	520
2	515	520
3	519	522
4	521	520
5	520	522
6	522	514
7	520	518
8	518	521
9	521	522
10	522	519
AVG	520	520
%DIFF	0.0%	PASS

Generate an ozone concentration of approximately 500 ppb.
Display the Cell A/B O3 concentrations
Once the instrument stabilizes, the average of 10 successive simultaneous readings should agree within ±3 percent.

THERMO 49C/i SCRUBBER TEST

CELL A	C (ppb)	
	FREQ1	
	FREQ2	
	P (mmHg)	
	T (°C)	
	% Efficiency	
CELL B	C (ppb)	
	FREQ1	
	FREQ2	
	P (mmHg)	
	T (°C)	
	% Efficiency	

Generate a source of ozone of about 500 ppb and feed into the instrument. Note the concentration as C. This should be measured with a different photometer
Scroll to Service Menu>Intensity Check> Int A Reference Gas
When the frequency stabilizes, note the frequency as FREQ 1.
Turn ozonator off and when the frequency stabilizes, note the frequency as FREQ 2.
Determine pressure and temperature, note as P and T.

Repeat test using Service Menu>Intensity Check> Int B Reference Gas

Air Resource SPECIALISTS

CASTNET OZONE STATION REFERENCE TESTS

DIAGNOSTIC

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Temperature Reference	Eutechnics	4400	308287	9/18/2020

INSTRUMENT SERIAL NUMBER	1015543061

THERMO 49C/i BENCH TEMP CHECK

	Reference	Analyzer	
PRE			
POST			

ESC LOGGER SCALING

High Input	Low Input	High Output	Low Output

Only perform POST if calibration is necessary
Make sure to calibrate the analog output, if necessary

THERMO 49C/i SOLENOID LEAK TEST

	Cell A	Cell B
1	523	518
2	522	522
3	525	523
4	526	522
5	516	528
6	523	517
7	529	513
8	527	520
9	524	520
10	520	528
AVG	524	521
%DIFF	0.5%	PASS

Generate an ozone concentration of approximately 500 ppb.
Display the Cell A/B O3 concentrations
Once the instrument stabilizes, the average of 10 successive simultaneous readings should agree within ±3 percent.

THERMO 49C/i SCRUBBER TEST

CELL A	
C (ppb)	
FREQ1	
FREQ2	
P (mmHg)	
T (°C)	
% Efficiency	

CELL B	
C (ppb)	
FREQ1	
FREQ2	
P (mmHg)	
T (°C)	
% Efficiency	

Generate a source of ozone of about 500 ppb and feed into the instrument. Note the concentration as C. This should be measured with a different photometer
Scroll to Service Menu>Intensity Check> Int A Reference Gas
When the frequency stabilizes, note the frequency as FREQ 1.
Turn ozonator off and when the frequency stabilizes, note the frequency as FREQ 2.
Determine pressure and temperature, note as P and T.

Repeat test using Service Menu>Intensity Check> Int B Reference Gas

Air Resource SPECIALISTS

OZONE ANALYZER VERIFICATION & CALIBRATION (AS LEFT)

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

AS LEFT

TRANSFER STANDARD		AMBIENT ANALYZER		STATION REFERENCE	
Manufacturer	Thermo	Manufacturer	Thermo	Manufacturer	Thermo
Model	49i	Model	49i	Model	49i
Serial Number	1130450197	Serial Number	1030745085	Serial Number	1015543061
Coefficient	1	Coefficient	1.003	Coefficient	1
Background	0	Background	-.1	Background	0
Cell A Intensity (Hz)	100450	Cell A Intensity (Hz)	101506	Cell A Intensity (Hz)	76438
Cell B Intensity (Hz)	98070	Cell B Intensity (Hz)	109895	Cell B Intensity (Hz)	95752
Flow A (lpm)	0.726	Flow A (lpm)	.772	Flow A (lpm)	.735
Flow B (lpm)	0.771	Flow B (lpm)	.774	Flow B (lpm)	.718
Pressure (mmHg)	742.2	Pressure (mmHg)	728.8	Pressure (mmHg)	763.6
Bench Temp (°C)	26.1	Bench Temp (°C)	33.9	Bench Temp (°C)	32.9
Bench Lamp Temp (°C)	53.1	Bench Lamp Temp (°C)	53.8	Bench Lamp Temp (°C)	54.4
Ozone Lamp Temp (°C)	67.1	Ozone Lamp Temp (°C)	68.2	Ozone Lamp Temp (°C)	
		Ozone Source	x	Ozone Source	
Transfer Standard Level	LEVEL 2	Full Scale (ppb)	250	Transfer Standard Level	LEVEL 3
				Logger Slope Correction	1.0030
				Logger Intercept Correction	0.0543

Transfer Standard Correction Factors	SLOPE	INT
	0.9943	-0.0870

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	3%
Maximum Absolute Difference (%)	3%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	10%
Maximum Absolute Difference (%)	10%

		LAMP%	TRANSFER STANDARD		AMBIENT ANALYZER				STATION REFERENCE			
POINT	TARGET	or mV	Display	Corrected	DAS	Diff	%Diff	LINEAR%	DAS	Diff	%Diff	LINEAR%
ZERO	0	0	-0.2	-0.1	0.3	0.4	N/A	0.0%	0.1	0.2	N/A	0.0%
1	200	28	210	211.3	210.5	-0.8	-0.4%	0.0%	210.6	-0.7	-0.3%	0.0%
2	150	23.4	146.8	147.7	147.0	-0.7	-0.5%	0.1%	147.1	-0.6	-0.4%	0.1%
3	100	19.4	100.2	100.9	100.9	0.0	0.0%	-0.1%	101.0	0.1	0.1%	-0.1%
4	70	17.1	71.7	72.2	72.3	0.1	0.1%	0.0%	72.0	-0.2	-0.3%	0.0%
5	50	13.2	30.7	31.0	31.3	0.4	1.2%	-0.1%	31.2	0.2	0.8%	-0.1%
ZERO	0	0	0	0.1	0.1	0.0	N/A	0.1%	0.0	-0.1	N/A	0.1%
					Mean ABS % Diff		0.4%	PASS	Mean ABS % Diff		0.4%	PASS
					Max ABS % Diff		1.2%	PASS	Max ABS % Diff		0.8%	PASS
					Slope		0.995		Slope		0.996	
					Y-Intercept		0.35		Y-Intercept		0.15	
					Correlation		1.0000		Correlation		1.0000	

Analog Test	Analyzer DAS	Reference DAS
Zero		
Full Scale		

NOTES: Cleaned the cabinet filters.

Air Resource SPECIALISTS

GAS DILUTION SYSTEM VERIFICATION & CALIBRATION
ZERO-AIR MFC

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
High Flow Reference	BIOS	Definer 220H	122997	6/18/2020

AS FOUND

GAS DILUTION SYSTEM	
Manufacturer	Teledyne-API
Model	700EU
Serial Number	957

ZERO-AIR MFC	
Manufacturer	Teledynne
Model	HFC-212
Serial Number	5574400002
Range (SLPM)	20
Z-Air (psi)	30

ENTER VALUES IN SCCM

POINT	DRV	DISPLAY	REF. FLOW	% DIFF	
20	5000	21434	22056	-2.8%	--> ADJUST -->
19	4750	21074	20922	0.7%	--> ADJUST -->
18	4500	19703	19774	-0.4%	
17	4250	18442	18608	-0.9%	--> ADJUST -->
16	4000	17379	17491	-0.6%	--> ADJUST -->
15	3750	16219	16312	-0.6%	--> ADJUST -->
14	3500	15090	15207	-0.8%	--> ADJUST -->
13	3250	14005	14140	-1.0%	--> ADJUST -->
12	3000	12908	13005	-0.7%	--> ADJUST -->
11	2750	11811	11896	-0.7%	--> ADJUST -->
10	2500	10753	10789	-0.3%	
9	2250	9675	9686	-0.1%	
8	2000	8590	8593	0.0%	
7	1750	7494	7513	-0.3%	
6	1500	6419	6433	-0.2%	
5	1250	5323	5362	-0.7%	--> ADJUST -->
4	1000	4249	4272	-0.5%	--> ADJUST -->
3	750	3173	3209	-1.1%	--> ADJUST -->
2	500	2105	2128	-1.1%	--> ADJUST -->
1	250	1029	1048	-1.8%	--> ADJUST -->
0	0	0	0	N/A	

DISPLAY to REF Relationship	
Slope	0.99075
Y-Intercept	25.87
Correlation	0.99982

MFC linearity	
Slope	0.90739
Y-Intercept	32.28
Correlation	0.99993

AS LEFT

GAS DILUTION SYSTEM	
Manufacturer	Teledyne-API
Model	700EU
Serial Number	957

ZERO-AIR MFC	
Manufacturer	Teledynne
Model	HFC-212
Serial Number	5574400002
Range (SLPM)	20
Z-Air (psi)	30

POINT	DRV	DISPLAY	REF. FLOW	% DIFF
20	5000	22056	22097	-0.2%
19	4750	20922	20924	0.0%
18	4500	19703	19774	-0.4%
17	4250	18608	18606	0.0%
16	4000	17491	17445	0.3%
15	3750	16312	16319	0.0%
14	3500	15207	15208	0.0%
13	3250	14140	14105	0.2%
12	3000	13005	13016	-0.1%
11	2750	11896	11896	0.0%
10	2500	10753	10789	-0.3%
9	2250	9675	9686	-0.1%
8	2000	8590	8593	0.0%
7	1750	7494	7513	-0.3%
6	1500	6419	6433	-0.2%
5	1250	5362	5363	0.0%
4	1000	4292	4273	0.4%
3	750	3209	3199	0.3%
2	500	2128	2123	0.2%
1	250	1049	1047	0.2%
0	0	0	0	N/A

DISPLAY to REF Relationship	
Slope	0.99908
Y-Intercept	5.31
Correlation	0.99999

MFC linearity	
Slope	0.90716
Y-Intercept	33.29
Correlation	0.99992

NOTES:

Air Resource SPECIALISTS

GAS DILUTION SYSTEM VERIFICATION & CALIBRATION
GAS MFC#1

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL NUMBER	EXPIRATION DATE
Low Flow Reference	BIOS	Definer 220L	123077	6/18/2020

AS FOUND

GAS DILUTION SYSTEM	
Manufacturer	Teledyne-API
Model	700EU
Serial Number	957

GAS MFC	
Manufacturer	Teledyne
Model	HFC-212
Serial Number	52986000007
Range (sccm)	100
Gas (psi)	30

ENTER VALUES IN SCCM

POINT	DRV	DISPLAY	REF. FLOW	% DIFF	
20	5000	107.00	108.20	-1.1%	--> ADJUST -->
19	4750	101.70	102.70	-1.0%	--> ADJUST -->
18	4500	96.20	97.20	-1.0%	--> ADJUST -->
17	4250	91.00	91.80	-0.9%	--> ADJUST -->
16	4000	85.60	86.50	-1.0%	--> ADJUST -->
15	3750	80.00	81.10	-1.4%	--> ADJUST -->
14	3500	74.90	75.70	-1.1%	--> ADJUST -->
13	3250	69.80	70.10	-0.4%	
12	3000	64.50	65.00	-0.8%	--> ADJUST -->
11	2750	59.10	59.70	-1.0%	--> ADJUST -->
10	2500	53.80	54.30	-0.9%	--> ADJUST -->
9	2250	48.40	49.00	-1.2%	--> ADJUST -->
8	2000	43.10	43.60	-1.1%	--> ADJUST -->
7	1750	37.80	38.20	-1.0%	--> ADJUST -->
6	1500	32.40	32.80	-1.2%	--> ADJUST -->
5	1250	27.00	27.30	-1.1%	--> ADJUST -->
4	1000	21.60	21.80	-0.9%	--> ADJUST -->
3	750	16.10	16.30	-1.2%	--> ADJUST -->
2	500	10.60	10.90	-2.8%	--> ADJUST -->
1	250	5.20	5.30	-1.9%	--> ADJUST -->
0	0	0.00	0.00	N/A	

DISPLAY to REF Relationship	
Slope	0.99051
Y-Intercept	-0.04
Correlation	0.99999

MFC linearity	
Slope	0.92646
Y-Intercept	-9.17
Correlation	0.99999

AS LEFT

GAS DILUTION SYSTEM	
Manufacturer	Teledyne-API
Model	700EU
Serial Number	957

GAS MFC	
Manufacturer	Teledyne
Model	HFC-212
Serial Number	52986000007
Range (sccm)	100
Gas (psi)	30

POINT	DRV	DISPLAY	REF. FLOW	% DIFF
20	5000	108.00	108.10	-0.1%
19	4750	102.70	102.70	0.0%
18	4500	97.20	97.40	-0.2%
17	4250	91.80	91.82	0.0%
16	4000	86.50	86.52	0.0%
15	3750	81.10	81.00	0.1%
14	3500	75.70	75.70	0.0%
13	3250	70.10	70.30	-0.3%
12	3000	65.00	65.00	0.0%
11	2750	59.70	59.70	0.0%
10	2500	54.30	54.30	0.0%
9	2250	49.00	49.00	0.0%
8	2000	43.60	43.60	0.0%
7	1750	38.20	38.20	0.0%
6	1500	32.80	32.80	0.0%
5	1250	27.30	27.30	0.0%
4	1000	21.90	21.90	0.0%
3	750	16.40	16.36	0.3%
2	500	10.90	10.87	0.3%
1	250	5.30	5.32	-0.4%
0	0	0.00	0.00	N/A

DISPLAY to REF Relationship	
Slope	0.99918
Y-Intercept	0.03
Correlation	1.00000

MFC linearity	
Slope	0.92644
Y-Intercept	-9.96
Correlation	0.99999

NOTES:

Air Resource SPECIALISTS

NO_Y ANALYZER VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	6/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2018

AS FOUND

	AMBIENT ANALYZER	GAS DILUTION SYSTEM
Manufacturer	Thermo	Teledyne-API
Model	42i-NOY	700EU
Serial Number	0734025663	957
NO Coefficient	1.075	CALIBRATION GAS
NO Background	2.94	Cylinder S/N: CC506134
NOx Coefficient	1.040	Expiration Date: 9/10/2022
NOx Background	3.21	Cylinder Pressure: 1100
NO2 Coefficient	1.000	Delivery Pressure: 30
Sample Flow (LPM)	1.057 / .626	Tank Conc. NO (ppm): 12.92
O3 Flow (ccm)	ok	Tank Conc. NO_X (ppm): 12.97
Chamber Pressure (mmHg)	329 / 477.6	
Internal Temp (°C)	31.8	
Chamber Temp (°C)	50.5	
Cooler Temp (°C)	-9.7	
Converter Temp (°C)	327.4	
PMT Voltage	-1006.0	

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	5%
Maximum Absolute Difference (%)	5%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	15%
Maximum Absolute Difference (%)	15%
Converter Efficiency	96%

Trace Level Calibrator?	No
FULL SCALE (ppb)	200

NO DILUTION		GAS DILUTION		NO			DIFF	NO_Y		
Point	Target	Z-air Flow	Gas Flow	Actual	DAS	%Diff	DAS	Actual	DAS	%Diff
ZERO	0	6000	0.00	0.0	-0.07	N/A	0.166	0.0	0.0345	N/A
SPAN	160	5994	74.73	159.1	144.9	-8.9%	-1.24	159.7	143.7	-10.0%

GPT			GAS DILUTION SYSTEM			NO			DIFF				NO_Y		
Point	NO	O_3	Z-air Flow	O3 Flow	Gas Flow	Actual	DAS	%Diff	Actual	DAS	%Diff	LINEAR%	Actual	DAS	%Diff
ZERO	0	0	6000	0.00	0.00	0.0	-0.0618	N/A	0.0	0.1483	N/A	-0.2%	0.0	0.059	N/A
GPTZ	160	80	5901	113.00	74.86	158.8	144.7	-8.9%	0.6	-1.345	N/A	0.9%	159.5	143.4	-10.1%
GPT	160	80	5883	113.00	74.79	N/A	69.53		83.3	74.9	-10.0%	0.3%	N/A	144.3	
GPTZ	120	60	5925	113.00	56.30	119.4	108.4	-9.2%	0.5	-0.2099	N/A	0.2%	119.8	107.8	-10.0%
GPT	120	60	5908	113.00	56.23	N/A	51.7		62.8	56.32	-10.3%	0.3%	N/A	108	
GPTZ	100	50	5931	113.00	47.01	99.7	89.75	-10.0%	0.4	-0.5609	N/A	0.4%	100.1	89.24	-10.9%
GPT	100	50	5916	113.00	46.92	N/A	43.42		51.3	47.11	-8.2%	-0.3%	N/A	90.59	
GPTZ	80	40	5948	113.00	37.77	80.0	72.77	-9.1%	0.3	-1.109	N/A	0.6%	80.3	71.71	-10.7%
GPT	80	40	5927	113.00	37.69	N/A	34.46		42.4	38.29	-9.8%	0.1%	N/A	72.69	
GPTZ	70	35	5943	113.00	35.43	75.1	68.13	-9.3%	0.3	-1.096	N/A	0.6%	75.4	67.24	-10.9%
ZERO	0	0	6000	0.00	0.00	0.0	-0.06	N/A	0.0	0.1209	N/A	-0.1%	0.0	0.1119	N/A

Per 40 CFR Part 50 App F 1.5.9 &1.5.10

$[NO_2]_{conv}$	$[NO_2]_{tot}$	$[NO]_{avg}$	$[NO]_{conv}$	$[NO_x]_{avg}$	$[NO_x]_{conv}$
84.27	83.27	159.29	76.64	159.86	160.87
63.03	62.61	119.38	57.03	120.21	120.43
52.83	51.33	98.87	47.03	99.54	101.04
43.52	42.43	80.20	38.08	80.01	81.11

	NO	DIFF	NO_Y
Mean ABS % Diff	8.3%	8.8%	10.6%
	ACTION	ACTION	ACTION
Max ABS % Diff	10.0%	10.3%	10.8%
	ACTION	ACTION	ACTION

Slope	0.908	0.889	0.888
Y-Intercept	-0.17	0.22	-0.13
Correlation	1.0000	0.9999	1.0000

Converter Efficiency	98.1%	PASS

Analog Test	NO DAS Conc.	DIFF DAS Conc.	NO_Y DAS Conc.
Zero	na	na	na
Full Scale	na	na	na

NOTES:

Air Resource SPECIALISTS

NO_Y ANALYZER VERIFICATION & CALIBRATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	6/16/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/6/2019

AS LEFT

	AMBIENT ANALYZER	GAS DILUTION SYSTEM
Manufacturer	Thermo	Teledyne-API
Model	42i-NOY	700EU
Serial Number	0734025663	957
NO Coefficient	.969	CALIBRATION GAS
NO Background	3.25	Cylinder S/N: CC506134
NOx Coefficient	1.019	Expiration Date: 9/10/2022
NOx Background	3.19	Cylinder Pressure: 1100
NO2 Coefficient	1.000	Delivery Pressure: 30
Sample Flow (LPM)	1.044 / .842	Tank Conc. NO (ppm): 12.92
O3 Flow (ccm)	50	Tank Conc. NO_2 (ppm): 12.97
Chamber Pressure (mmHg)	329.3 / 394.2	
Internal Temp (°C)	29.8	
Chamber Temp (°C)	49.9	
Cooler Temp (°C)	-10.1	
Converter Temp (°C)	321.5	
PMT Voltage	-999.8	

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	5%
Maximum Absolute Difference (%)	5%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	15%
Maximum Absolute Difference (%)	15%
Converter Efficiency	96%

Trace Level Calibrator?	No
FULL SCALE (ppb)	200

NO DILUTION	GAS DILUTION			NO			DIFF	NO_Y		
Point	Target	Z-air Flow	Gas Flow	Actual	DAS	%Diff	DAS	Actual	DAS	%Diff
ZERO	0	6000	0.00	0.0	0.0134	N/A	-0.156	0.0	-0.03	N/A
SPAN	160	5997	74.76	159.1	159.2	0.1%	0.3169	159.7	159.5	-0.1%

GPT			GAS DILUTION SYSTEM			NO			DIFF				NO_Y		
Point	NO	O_3	Z-air Flow	O3 Flow	Gas Flow	Actual	DAS	%Diff	Actual	DAS	%Diff	LINEAR%	Actual	DAS	%Diff
ZERO	0	0	6000	0.00	0.00	0.0	0.029	N/A	0.0	0.039	N/A	-0.1%	0.0	-0.028	N/A
GPTZ	160	80	5904	113.00	74.87	158.8	159.6	0.5%	0.6	0.5429	N/A	-0.1%	159.4	160.1	0.4%
GPT	160	80	5884	113.00	74.79	N/A	76.83		83.0	84.62	1.9%	-0.7%	N/A	161	
GPTZ	120	60	5925	113.00	56.30	119.4	119.9	0.5%	0.5	0.054	N/A	0.1%	119.8	119.9	0.1%
GPT	120	60	911	113.00	56.22	N/A	57.04		65.2	63.72	-2.3%	0.8%	N/A	121	
GPTZ	100	50	5931	113.00	47.01	99.7	99.68	0.0%	0.4	-0.008	N/A	0.1%	100.1	99.7	-0.4%
GPT	100	50	5914	113.00	46.92	N/A	47.98		51.9	53.32	2.8%	-0.7%	N/A	101.3	
GPTZ	80	40	5940	113.00	37.74	80.1	79.58	-0.6%	0.3	0.358	N/A	-0.1%	80.4	79.76	-0.8%
GPT	80	40	5927	113.00	37.67	N/A	38.06		41.7	42.79	2.7%	-0.6%	N/A	80.86	
GPTZ	70	35	5948	113.00	33.09	70.2	69.78	-0.5%	0.3	0.8232	N/A	-0.4%	70.4	70.21	-0.3%
ZERO	0	0	6000	0.00	0.00	0.0	-0.013	N/A	0.0	-0.19	N/A	0.0%	0.0	-0.2345	N/A

Per 40 CFR Part 50 App F 1.5.9 &1.5.10

$[NO_2]_{conv}$	$[NO_2]_{tot}$	$[NO]_{eq}$	$[NO]_{wm}$	$[NO_x]_{eq}$	$[NO_x]_{wm}$
83.93	83.03	159.17	78.78	159.92	160.82
66.29	65.20	119.64	57.05	119.85	120.95
53.48	51.87	99.51	48.03	99.72	101.32
42.75	41.65	79.49	38.15	79.85	80.94

	NO	DIFF	NO_Y
Mean ABS % Diff	0.4%	2.4%	0.4%
	PASS	PASS	PASS
Max ABS % Diff	0.8%	2.8%	0.8%
	PASS	PASS	PASS
Slope	1.004	1.010	1.003
Y-Intercept	-0.26	0.04	-0.35
Correlation	1.0000	0.9995	1.0000

Converter Efficiency	99.1%	PASS

Analog Test	NO DAS Conc.	DIFF DAS Conc.	NO_Y DAS Conc.
Zero	na	na	na
Full Scale	na	na	na

NOTES: Found and fixed a small leak. Rebuilt the by-pass pump. Installed a new perma-pure dryer, and cleaned the cabinet filters.

Air Resource SPECIALISTS

SO_2 ANALYZER VERIFICATION & CALIBRATION (AS FOUND)

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

AS FOUND

	AMBIENT ANALYZER	GAS DILUTION SYSTEM
Manufacturer	Thermo	Teledyne-API
Model	43i-TLE	700EU
Serial Number	0820430687	957
SO2 Coefficient	.914	
SO2 Background	3.40	
Internal Temp (°C)	35.9	
Chamber Temp (°C)	45.2	
Pressure (mmHg)	698.1	
Sample Flow (LPM)	.430	
Lamp Intensity (%)	69%	

CALIBRATION GAS	
Cylinder S/N	CC506134
Expiration Date	9/10/2022
Cylinder Pressure	1100
Delivery Pressure	30
Tank Conc. (ppm)	12.69

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	5%
Maximum Absolute Difference (%)	5%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	10%
Maximum Absolute Difference (%)	10%

Full Scale (ppb)	200

		GAS DILUTION SYSTEM			SO_2			
POINT	TARGET	ACTUAL	Z-air Flow	Gas Flow	DAS	Diff	%Diff	LINEAR%
ZERO	0	0.0	6000	0.00	0.2705	0.2705	N/A	-0.2%
1	160	156.3	5994	74.73	153.7	-2.6	-1.6%	-0.3%
2	120	119.4	5925	56.30	116.9	-2.5	-2.1%	0.0%
3	90	99.8	5932	47.01	96.9	-2.9	-2.9%	0.4%
4	60	80.2	5942	37.77	78.44	-1.7	-2.1%	0.0%
5	30	35.9	6053	17.15	34.62	-1.2	-3.4%	0.2%
ZERO	0	0.0	6000	0.00	0.1038	0.1038	N/A	-0.1%

Mean ABS % Difference	2.4%	PASS
Max ABS % Difference	3.4%	PASS

Slope	0.980
Y-Intercept	-0.12
Correlation	1.0000

Analog Test	DAS Conc.
Zero	na
Full Scale	na

NOTES: Rebuilt the pump.

Air Resource SPECIALISTS

SO_2 ANALYZER VERIFICATION & CALIBRATION (AS LEFT)

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Belchley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

AS LEFT

	AMBIENT ANALYZER	GAS DILUTION SYSTEM
Manufacturer	Thermo	Teledyne-API
Model	43i-TLE	700EU
Serial Number	0820430687	957
SO2 Coefficient	.989	CALIBRATION GAS
SO2 Background	3.1	Cylinder S/N: CC506134
Internal Temp (°C)	35.5	Expiration Date: 9/10/2022
Chamber Temp (°C)	45.4	Cylinder Pressure: 1100
Pressure (mmHg)	696.6	Delivery Pressure: 30
Sample Flow (LPM)	.429	Tank Conc. (ppm): 12.69
Lamp Intensity (%)	69%	

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	5%
Maximum Absolute Difference (%)	5%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	10%
Maximum Absolute Difference (%)	10%

Full Scale (ppb)	200

		GAS DILUTION SYSTEM			SO_2			
POINT	TARGET	ACTUAL	Z-air Flow	Gas Flow	DAS	Diff	%Diff	LINEAR%
ZERO	0	0.0	6000	0.00	0.4608	0.4608	N/A	-0.3%
1	160	156.2	5997	74.76	157.8	1.6	1.0%	-1.2%
2	120	119.4	5925	56.30	117.5	-1.9	-1.6%	0.6%
3	90	99.8	5931	47.01	97.9	-1.9	-1.9%	0.7%
4	60	80.1	5941	37.74	78.54	-1.6	-2.0%	0.5%
5	30	39.7	6053	19.00	39.49	-0.2	-0.6%	-0.1%
ZERO	0	0.0	6000	0.00	0.34	0.34	N/A	-0.3%

Mean ABS % Difference	1.4%	PASS
Max ABS % Difference	2.0%	PASS

Slope	0.996
Y-Intercept	-0.20
Correlation	0.9997

Analog Test	DAS Conc.
Zero	
Full Scale	

NOTES: Rebuilt the pump and adjusted the PMT.

Air Resource SPECIALISTS

CO ANALYZER VERIFICATION & CALIBRATION (AS FOUND)

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

AS FOUND

	AMBIENT ANALYZER	GAS DILUTION SYSTEM
Manufacturer	Thermo	Teledyne-API
Model	48i-TLE	700EU
Serial Number	0832633181	957
CO Coefficient	1.031	CALIBRATION GAS
CO Background	1.111	Cylinder S/N: CC506134
Internal Temp (°C)	40.9	Expiration Date: 9/10/2022
Bench Temp (°C)	44.2	Cylinder Pressure: 1100
Pressure (mmHg)	715	Delivery Pressure: 30
Sample Flow (LPM)	.550	Tank Conc. (ppm): 315.70
Sample/Reference Ratio	1.1467303	
AGC Intensity (Hz)	196943	
Motor Speed (%)	100.02	

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	5%
Maximum Absolute Difference (%)	5%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	10%
Maximum Absolute Difference (%)	10%

Full Scale (ppm)	5

		GAS DILUTION SYSTEM			CO			
POINT	TARGET	ACTUAL	Z-air Flow	Gas Flow	DAS	Diff	%Diff	LINEAR%
ZERO	0	0.000	6000	0.00	0.0024	0.002	N/A	-0.6%
1	4.00	3.888	5994	74.73	3.903	0.015	0.4%	-0.9%
2	3.00	2.972	5925	56.30	2.92	-0.052	-1.7%	0.5%
3	2.00	2.482	5932	47.01	2.423	-0.059	-2.4%	0.6%
4	1.00	1.994	5942	37.77	1.955	-0.039	-2.0%	0.2%
5	0.75	0.892	6053	17.15	0.861	-0.031	-3.5%	0.1%
ZERO	0	0.000	6000	0.00	-0.029	-0.029	N/A	0.1%

Mean ABS % Difference	2.0%	PASS
Max ABS % Difference	3.5%	PASS

Slope	0.999
Y-Intercept	-0.03
Correlation	0.9998

Analog Test	DAS Conc.
Zero	na
Full Scale	na

NOTES:

Air Resource SPECIALISTS

CO ANALYZER VERIFICATION & CALIBRATION (AS LEFT)

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

AS LEFT

	AMBIENT ANALYZER	GAS DILUTION SYSTEM
Manufacturer	Thermo	Teledyne-API
Model	48i-TLE	700EU
Serial Number	0832633181	957
CO Coefficient	1.034	
CO Background	-.013	
Internal Temp (°C)	40.9	
Bench Temp (°C)	44.2	
Pressure (mmHg)	712	
Sample Flow (LPM)	.550	
Sample/Reference Ratio	1.1500131	
AGC Intensity (Hz)	196786	
Motor Speed (%)	100.1%	

CALIBRATION GAS	
Cylinder S/N	CC506134
Expiration Date	9/10/2022
Cylinder Pressure	1100
Delivery Pressure	30
Tank Conc. (ppm)	315.70

CALIBRATION ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	5%
Maximum Absolute Difference (%)	5%

DATA ACCEPTANCE CRITERIA (<=)	
Mean Absolute Difference (%)	10%
Maximum Absolute Difference (%)	10%

Full Scale (ppm)	5

		GAS DILUTION SYSTEM			CO			
POINT	TARGET	ACTUAL	Z-air Flow	Gas Flow	DAS	Diff	%Diff	LINEAR%
ZERO	0	0.000	6000	0.00	0.0091	0.009	N/A	0.2%
1	4.00	3.887	5997	74.76	3.94	0.053	1.4%	-0.6%
2	3.00	2.972	5925	56.30	2.977	0.005	0.2%	0.4%
3	2.00	2.483	5931	47.01	2.491	0.008	0.3%	0.3%
4	1.00	1.993	5941	37.74	2.004	0.011	0.6%	0.2%
5	0.75	0.988	6053	19.00	1.015	0.027	2.7%	-0.1%
ZERO	0	0.000	6000	0.00	0.041	0.041	N/A	-0.4%

Mean ABS % Difference	1.0%	PASS
Max ABS % Difference	2.7%	PASS

Slope	1.001
Y-Intercept	0.02
Correlation	0.9999

Analog Test	DAS Conc.
Zero	
Full Scale	

NOTES: Performed the pre-amb board and the S/R ratio calibration.

Air Resource SPECIALISTS

SITE INFORMATION

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

		Deg	Min	Sec		Decimal
LATITUDE	North	37	11	11	--CALCULATE->	37.1864
LONGITUDE	West	86	2	28		86.0411

Decimal		Deg	Min	Sec
	--CALCULATE->			

	Meters		Feet
ELEVATION		--CALCULATE->	

Feet		Meters
	--CALCULATE->	

Photo Documentation Completed?	☐ Yes	☐ No	☐ N/A

	Protocol?	Carrier?	# of Bars?	Signal Strength?
Cellular Phone Coverage				-X dBm
Cellular Phone Coverage				-X dBm

DAY	TIME IN	TIME OUT
5/15/2020	~1800	~2030
5/16/2020	~930	~2030
5/17/2020	~1000	~1400

Please verify site standards used by the site operator

SITE STANDARDS	MANUFACTURER	MODEL	SERIAL #	Calibration Expiration Date
PM Flow Reference				

NOTES:

Air Resource SPECIALISTS

CALIBRATION AND VERIFICATION STANDARDS

ABBR.	MACA-HM				
CLIENT	National Park Service	FIELD SPECIALIST	Dave Beichley	DATE	5/15/2020
SITE NAME	Mammoth Cave NP - Houchin Meadow			DATE OF LAST VISIT	11/5/2019

	MANUFACTURER	MODEL	SERIAL #	Calibration Expiration Date
Ozone Transfer Standard	Thermo	49i	1130450197	2/24/2021
MFC High Flow Reference	BIOS	Definer 220H	122997	6/18/2020
MFC Low Flow Reference	BIOS	Definer 220L	123077	6/18/2020
Temperature Reference	Eutechnics	4400	308287	9/18/2020
AT/RH Sensor Reference	Rotronic	HC2S3	20039891	11/13/2020
Barometric Pressure Reference	Druck	DPI705	70573705	8/22/2020
Wind Speed Reference (high rpm)	RM Young	18820A	CA 03358	6/20/2020
Wind Speed Reference (low rpm)				
Wind Speed Torque Gauge	RM Young	18310	na	
Wind Direction Alignment Reference	Brunton	5006LM	5060408265	
Wind Direction Linearity Reference	Wilson Machinery	8 point disc	#31	
Wind Direction Torque Gauge	RM Young	18310	na	
Solar Radiation Reference				
Multiplier	CSI	Pyranometer	68694	8/20/2020
UV Radiation Reference				
Multiplier				
Precipitation Reference				
Volume 930 mL	RM Young	62260	na	
Voltage Measurement Reference				
Voltage Source				

PM Flow Standard #1	BIOS	Definer 220H	122997	6/18/2020
PM Flow Standard #2				
PM Flow Standard #3				
PM Flow Standard #4				

PM Temperature Standard #1				
PM Temperature Standard #2				
PM Temperature Standard #3				
PM Temperature Standard #4				

PM Barometric Pressure Standard #1				
PM Barometric Pressure Standard #2				
PM Barometric Pressure Standard #3				
PM Barometric Pressure Standard #4				

TEOM MTV Standard				

HiVol Direct Flow Standard				
HiVol Orifice Plate				
Orifice Manometer				
Stagnation Manometer				

PRAXAIR
Making our planet more productive

DocNumber: 258456

Praxair Distribution, Inc.
5700 S. Alameda Street
Los Angeles CA 90058
Tel: 323-585-2154
Fax: 714-542-6689
PGVP ID: F22019

CERTIFICATE OF ANALYSIS / EPA PROTOCOL GAS

Customer & Order Information

AIR RESOURCE SPECIALISTS INC
1901 SHARP POINT DR STE F
FORT COLLINS CO 80525-4402

Certificate Issuance Date: 09/10/2019
Praxair Order Number: 86675463
Part Number: NI CO324NS1E-AS
Customer PO Number: A33391

Fill Date: 08/29/2019
Lot Number: 70088924105
Cylinder Style & Outlet: AS CGA 660
Cylinder Pressure and Volume: 2000 psig 140 ft3

Certified Concentration

Expiration Date:	09/10/2022	NIST Traceable
Cylinder Number:	CC506134	Expanded Uncertainty
315.7 ppm	Carbon monoxide	± 0.4 %
12.92 ppm	Nitric oxide	± 0.7 %
12.69 ppm	Sulfur dioxide	± 1.2 %
Balance	Nitrogen	

ProSpec EZ Cert

For Reference Only: NOx 12.97 ppm

Certification Information: Certification Date: 09/10/2019 Term: 36 Months Expiration Date: 09/10/2022

This cylinder was certified according to the 2012 EPA Traceability Protocol, Document #EPA-600/R-12/531, using Procedure G1.
Do Not Use this Standard if Pressure is less than 100 PSIG.

Analytical Data: (R=Reference Standard, Z=Zero Gas, C=Gas Candidate)

1. **Component:** Carbon monoxide

Requested Concentration: 324 ppm
Certified Concentration: 315.7 ppm
Instrument Used: Horiba VIA-510 S/N 576876015
Analytical Method: NDIR
Last Multipoint Calibration: 08/20/2019

First Analysis Data: Date 09/03/2019

Z: 0	R: 497.4	C: 315.5	Conc: 315.6		
R: 497.2	Z: 0	C: 315.7	Conc: 315.8		
Z: 0	C: 315.6	R: 497.3	Conc: 315.7		

UOM: ppm Mean Test Assay: 315.7 ppm

Reference Standard: Type / Cylinder #: GMIS / SA1882
Concentration / Uncertainty: 497.4 ppm ±0.41%
Expiration Date: 04/26/2025
Traceable to: SRM # / Sample # / Cylinder #: SRM 1680b / 2-J-15 / CAL016072
SRM Concentration / Uncertainty: 490.4 PPM / ±2.0 PPM
SRM Expiration Date: 09/20/2021

Second Analysis Data: Date

Z: 0	R: 0	C: 0	Conc: 0		
R: 0	Z: 0	C: 0	Conc: 0		
Z: 0	C: 0	R: 0	Conc: 0		

UOM: ppm Mean Test Assay: ppm

2. **Component:** Nitric oxide

Requested Concentration: 13 ppm
Certified Concentration: 12.92 ppm
Instrument Used: Thermo Electron 42i-LS S/N 1030645077
Analytical Method: Chemiluminescence
Last Multipoint Calibration: 08/13/2019

First Analysis Data: Date 09/03/2019

Z: 0	R: 19.91	C: 12.92	Conc: 12.92		
R: 19.92	Z: 0	C: 12.93	Conc: 12.93		
Z: 0	C: 12.93	R: 19.91	Conc: 12.93		

UOM: ppm Mean Test Assay: 12.92 ppm

Reference Standard: Type / Cylinder #: GMIS / CC321695
Concentration / Uncertainty: 19.91 ppm ±0.66%
Expiration Date: 05/22/2022
Traceable to: SRM # / Sample # / Cylinder #: APEX1161149 / N/A / APEX1161149
SRM Concentration / Uncertainty: 20.03 ppm / ± 0.10 ppm
SRM Expiration Date: 01/27/2020

Second Analysis Data: Date 09/10/2019

Z: 0	R: 19.91	C: 12.92	Conc: 12.93		
R: 19.9	Z: 0	C: 12.9	Conc: 12.91		
Z: 0	C: 12.89	R: 19.89	Conc: 12.9		

UOM: ppm Mean Test Assay: 12.91 ppm

3. **Component:** Sulfur dioxide

Requested Concentration: 13 ppm
Certified Concentration: 12.69 ppm
Instrument Used: Ametek 921CE S/N AW-921-S321
Analytical Method: UV Spectrometry
Last Multipoint Calibration: 08/12/2019

First Analysis Data: Date 09/03/2019

Z: 0	R: 48.6	C: 12.6	Conc: 12.6		
R: 48.6	Z: 0	C: 12.7	Conc: 12.7		
Z: 0	C: 12.7	R: 48.5	Conc: 12.7		

UOM: ppm Mean Test Assay: 12.67 ppm

Reference Standard: Type / Cylinder #: NTRM / CC72596
Concentration / Uncertainty: 48.56 ppm ±1.02%
Expiration Date: 03/30/2020
Traceable to: SRM # / Sample # / Cylinder #: NTRM#CC72596 / 1207n1111 /
SRM Concentration / Uncertainty: 48.58 PPM / ±0.50 PPM
SRM Expiration Date: 03/30/2020

Second Analysis Data: Date 09/10/2019

Z: 0	R: 48.5	C: 12.7	Conc: 12.71		
R: 48.5	Z: 0	C: 12.7	Conc: 12.71		
Z: 0	C: 12.7	R: 48.6	Conc: 12.71		

UOM: ppm Mean Test Assay: 12.71 ppm

Analyzed By: Henry Koung

Certified By: Leeanna Flores

LEVEL 2 RE-VERIFICATION REPORT

U. S. Environmental Protection Agency
Office of Research and Development
Center for Environmental Measurement amd Modeling
Air Methods and Characterization Division Metrology Laboratory
109 T.W. Alexander Drive
RTP, NC 27711

Primary Standard		Guest Information	
Agency:	EPA RTP	**Owner:**	ARS Inc.
Contact:	Scott Moore	**Contact:**	Randy Kechter
Make:	NIST	**Make:**	Thermo Scientific
Model:	SRP	**Model:**	49i
S/N:	61	**S/N:**	1130450197
MLID:	01182	**MLID:**	00535
NIST Validation	3/28/2019	**Re-Verification Date:**	2/25/2020
SRP Template V1-3 02/12/2020		**Status:**	**PASS**

	Slope	Intercept	R^2
Average:	0.9943	-0.0870	0.9999996
Upper Acceptance Limit:	1.0300	3.00	NA
Lower Acceptance Limit	0.9700	-3.00	NA

Start		End		File	Slope	Intercept	R^2
02/24/20	18:18	02/24/20	20:05	R2020022403.xls	0.9943	-0.0102	0.99999941
02/24/20	20:06	02/24/20	21:56	R2020022404.xls	0.9947	-0.1759	0.99999950
02/24/20	21:57	02/24/20	23:44	R2020022405.xls	0.9942	-0.0731	0.99999963
02/24/20	23:45	02/25/20	1:32	R2020022406.xls	0.9944	-0.0482	0.99999956
02/25/20	1:33	02/25/20	3:21	R2020022407.xls	0.9943	-0.1012	0.99999972
02/25/20	3:21	02/25/20	5:09	R2020022408.xls	0.9942	-0.1130	0.99999978
02/25/20	5:10	02/25/20	6:57	R2020022409.xls	0.9942	-0.0876	0.99999962

Authority: All ozone instruments are run in accordance with the Code of Federal Regulations 40 Part 50 (https://www3.epa.gov/ttn/amtic/40cfr50.html), EPA SRP SOP (SRP Standard Operating Procedure, Sept 18, 2015 Revision(PDF) (1pg, 5242 KB) - November 2016) and EPAs Technical Assistance Document (Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone (PDF) (67pp, 820 KB) - May 31, 2009) or as specified in a project specific EPA Quality Assurance Project Plan (QAPP).

Adjustments: None

Repairs: None

Comments: SRP-61 generating ozone.

Next Due By: February 25, 2021

Number of Cycles: 7
Number of Points: 12

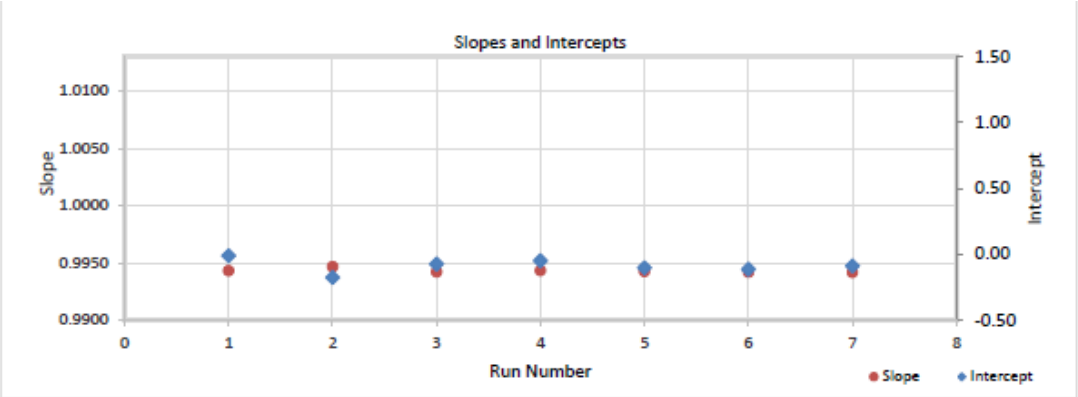
	Concentration nmol/mol	Uncertainty (2K) nmol/mol
High Point:	508	±5.6
Ozone NAAQS:	70	±0.83
Low Point:	17	±0.36

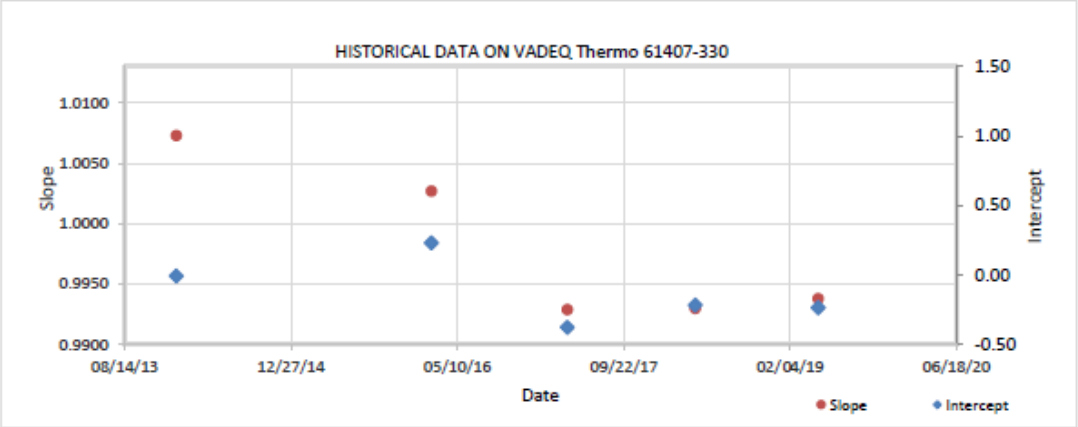
Analyst: DATE: March 3, 2020

Joshua Varga | U.S. EPA, 4930 Old Page Rd., RTP, NC 27709 | (919) 541-3722 | varga.joshua@epa.gov

Reviewer: DATE: March 3, 2020

Scott Moore | U.S. EPA, 4930 Old Page Rd., RTP, NC 27709 | (919) 541-5104 | moore.scott@epa.gov





HISTORICAL DATA ON Thermo Scientific 1130450197

	Date	Slope	Intercept	R^2
Re-Verification	04/30/19	0.9938	-0.24	0.9999998
	04/25/18	0.9930	-0.22	0.999999
	04/06/17	0.9929	-0.38	0.999999
	02/22/16	1.0027	0.23	0.999999
	01/16/14	1.0073	-0.01	0.999998

MesaLabs

NVLAP Lab Code 200661-0
Calibration

Calibration Certificate

CertificateNo.	316435	**Sold To:**	Air Resource Specialists, Inc.
Product	200-220H Definer 220 High Flow		1901 Sharp Point Drive Ste F
Serial No.	122997		Fort Collins, CO 80525
Cal. Date	18-Jun-2019		US

All calibrations are performed at Mesa Laboratories, Inc., 10 Park Place, Butler, NJ, 07405, an ISO 17025:2005 accredited laboratory through NVLAP of NIST. This report shall not be reproduced except in full without the written approval of the laboratory. Results only relate to the items calibrated. This report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the Federal Government.

As Received Calibration Data

Technician

Lab. Pressure mmHg
Lab. Temperature 22.6 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
sccm	sccm		1.00%	
sccm	sccm		1.00%	
sccm	sccm		1.00%	
°C	°C	-	± 0.8°C	
mmHg	mmHg	-	± 3.5 mmHg	

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
Percision Thermometer			
Precision Barometer			

MesaLabs

NVLAP Lab Code 200661-0
Calibration

As Shipped Calibration Data

Certificate No	316435	**Lab. Pressure**	750 mmHg
Technician	Lilianna Malinowska	**Lab. Temperature**	22.6 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
25398.3 sccm	25289.4 sccm	0.43%	1.00%	In Tolerance
5147.75 sccm	5116.58 sccm	0.61%	1.00%	In Tolerance
1588.54 sccm	1575.92 sccm	0.8%	1.00%	In Tolerance
22.4 °C	22.4 °C	-	± 0.8°C	In Tolerance
750 mmHg	750 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	03-May-2019	02-May-2020
Percision Thermometer	305460	02-Oct-2018	02-Oct-2019
Precision Barometer	2981392	18-Jul-2018	18-Jul-2019

Calibration Notes

The expanded uncertainty of flow, temperature, and pressure measurements all have a coverage factor of k = 2 for a confidence interval of approximately 95%.

Flow testing is in accordance with our test number PR18-13 with an expanded uncertainty of 0.18% using high-purity nitrogen or filtered laboratory air. Flow readings in sccm are performed at STP of 21.1°C and 760 mmHg.

Pressure testing is in accordance with our test number PR18-11 with an expanded uncertainty of 0.16 mmHg.

Temperature testing is in accordance with our test number PR18-12 with an expanded uncertainty of 0.04 °C.

Traceability to the International System of Units (SI) is verified by accreditation to ISO/IEC 17025 by NVLAP under NVLAP Code 200661-0.

Technician Notes:

By:

Mohammed Aziz
Director of Engineering
Mesa Laboratories, Inc., Butler, NJ

MesaLabs

NVLAP Lab Code 200661-0
Calibration

Calibration Certificate

CertificateNo.	317765	**Sold To:**	Air Resource Specialists, Inc.
Product	200-220L Definer 220 Low Flow		1901 Sharp Point Drive Ste F
Serial No.	123077		Fort Collins, CO 80525
Cal. Date	18-Jun-2019		US

All calibrations are performed at Mesa Laboratories, Inc., 10 Park Place, Butler, NJ, 07405, an ISO 17025:2005 accredited laboratory through NVLAP of NIST. This report shall not be reproduced except in full without the written approval of the laboratory. Results only relate to the items calibrated. This report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the Federal Government.

As Received Calibration Data

Technician Lilianna Malinowska

Lab. Pressure 750 mmHg
Lab. Temperature 21.9 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
0 sccm	479.38 sccm	-100.0%	1.00%	Out of Tolerance
0 sccm	108.35 sccm	-100.0%	1.00%	Out of Tolerance
0 sccm	33.59 sccm	-100.0%	1.00%	Out of Tolerance
21.9 °C	22.1 °C	-	± 0.8°C	In Tolerance
749 mmHg	749 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-10	105329	21-Dec-2018	21-Dec-2019
Percision Thermometer	305460	02-Oct-2018	02-Oct-2019
Precision Barometer	2981392	18-Jul-2018	18-Jul-2019

MesaLabs

NVLAP Lab Code 200661-0
Calibration

As Shipped Calibration Data

Certificate No	317765	**Lab. Pressure**	750 mmHg
Technician	Lilianna Malinowska	**Lab. Temperature**	21.9 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
483.31 sccm	479.65 sccm	0.76%	1.00%	In Tolerance
108.69 sccm	108.41 sccm	0.26%	1.00%	In Tolerance
33.62 sccm	33.56 sccm	0.18%	1.00%	In Tolerance
22.4 °C	22.4 °C	-	± 0.8°C	In Tolerance
750 mmHg	750 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-10	105329	21-Dec-2018	21-Dec-2019
Percision Thermometer	305460	02-Oct-2018	02-Oct-2019
Precision Barometer	2981392	18-Jul-2018	18-Jul-2019

Calibration Notes

The expanded uncertainty of flow, temperature, and pressure measurements all have a coverage factor of k = 2 for a confidence interval of approximately 95%.

Flow testing is in accordance with our test number PR18-13 with an expanded uncertainty of 0.18% using high-purity nitrogen or filtered laboratory air. Flow readings in sccm are performed at STP of 21.1°C and 760 mmHg.

Pressure testing is in accordance with our test number PR18-11 with an expanded uncertainty of 0.16 mmHg.

Temperature testing is in accordance with our test number PR18-12 with an expanded uncertainty of 0.04 °C.

Traceability to the International System of Units (SI) is verified by accreditation to ISO/IEC 17025 by NVLAP under NVLAP Code 200661-0.

Technician Notes:

By:

Mohammed Aziz
Director of Engineering
Mesa Laboratories, Inc., Butler, NJ

MICRO PRECISION CALIBRATION INC
12071 Tejon Street Suite # 100
Westminster Colorado 80234
720-535-4470

Certificate of Calibration

Date: Sep 18, 2019 **Cert No. 551220083220468**

Customer:
AIR RESOURCE SPECIALISTS
1901 SHARP POINT DRIVE, SUITE F
FORT COLLINS CO 80525

Work Order #: N/A

MPC Control #:	CH2797	Serial Number:	308287
Asset ID:	CH2797	Department:	N/A
Gage Type:	DIGITAL THERMOMETER	Performed By:	JERROD SALAZAR
Manufacturer:	EUTECHNICS	Received Condition:	IN TOLERANCE
Model Number:	4400	Returned Condition:	IN TOLERANCE
Size:	-20 TO 130 DEG C	Cal. Date:	September 18, 2019
Temp/RH:	21.5°C / 34.0%	Cal. Interval:	12 MONTHS
Location:	Calibration performed at MPC facility	Cal. Due Date:	September 18, 2020

Calibration Notes:
Updated the vendor information from MPC-GV to MPC-DEN. This Cert Replaces Cert # 551220083220438.

Test Points

Seq.	Description	Standard	Tolerance -	Tolerance +	As Found	As Left	UOM	Result	Uncertainty
1	TEST POINT	-10.00	-10.05	-9.95	-10.02	-10.02	C	Passed	0.014
2	TEST POINT	0.00	-0.05	0.05	0.02	0.02	C	Passed	0.014
3	TEST POINT	10.00	9.95	10.05	9.98	9.98	C	Passed	0.014
4	TEST POINT	65.00	64.95	65.05	65.00	65.00	C	Passed	0.014
5	TEST POINT	120.00	119.95	120.05	119.99	119.99	C	Passed	0.014

Standards Used to Calibrate Equipment

I.D.	Description.	Model	Serial	Manufacturer	Cal. Due Date	Traceability #
DR3160	DRY WELL CALIBRATOR	9107	A23273	HART SCIENTIFIC	Sep 30, 2020	551220083197861
DR9852	THERMOMETER READOUT W/PROBE	1529 W/5162	B25661	FLUKE	Aug 31, 2020	551220083156238

Calibrating Technician: JERROD SALAZAR

QC Approval: ROBERT MEANS

Statements of Pass or Fail Conformance: The uncertainty of measurement has been taken into account when determining compliance with specification, as per ILAC-G8:09/2009. All measurements and test results guard banded to ensure the probability of false-accept does not exceed 2% in compliance with ANSI/NCSL Z540.3-2006.
The status of compliance with the acceptance criteria is reported as:
PASS - Compliant with specification; .
FAIL - Not compliant with specification.
FAIL² - The measured value is not within the acceptance limits. However, a portion of the expanded uncertainty of measurement at 95% is within the specified tolerance.
PASS² - The measured value is within acceptance limits. However, a portion of the expanded uncertainty of measurement at 95% exceeds the specified tolerance.
The expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%, unless otherwise stated. This calibration report complies with ISO/IEC 17025:2017 and ANSI/NCSL Z540.3 Method 5-Guard Bands based on Test Uncertainty Ratio. Calibration cycles and resulting due dates were submitted/approved by the customer. Any number of factors may cause an instrument to drift out of tolerance before the next scheduled calibration. Recalibration cycles should be based on frequency of use, environmental conditions and customer's established systematic accuracy. All standards are traceable to SI through the National Institute of Standards and Technology (NIST) and/or recognized national or international standards laboratories. Services rendered include proper manufacturer's service instruction and are warranted for no less than forty (30) days. The information on this report pertains only to the instrument identified, this may not be reproduced in part or in a whole without the prior written approval of the issuing MP Calibration Laboratory.

MICRO PRECISION CALIBRATION INC
12071 Tejon Street Suite # 100
Westminster Colorado 80234
720-535-4470

Certificate of Calibration

Date: Sep 18, 2019 **Cert No. 551220083220468**

Procedures Used in this Event

Procedure Name	Description
MPC-TEM-001 Rev. 02	Temperature Sensors and Indicators, General

Calibrating Technician: JERROD SALAZAR

QC Approval: ROBERT MEANS

Statements of Pass or Fail Conformance: The uncertainty of measurement has been taken into account when determining compliance with specification, as per ILAC-G8:03/2009. All measurements and test results guard banded to ensure the probability of false-accept does not exceed 2% in compliance with ANSI/NCSL Z540.3-2006.
The status of compliance with the acceptance criteria is reported as:
PASS - Compliant with specification; .
FAIL - Not compliant with specification.
FAIL* - The measured value is not within the acceptance limits. However, a portion of the expanded uncertainty of measurement at 95% is within the specified tolerance.
PASS* - The measured value is within acceptance limits. However, a portion of the expanded uncertainty of measurement at 95% exceeds the specified tolerance.
The expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%, unless otherwise stated. This calibration report complies with ISO/IEC 17025:2017 and ANSI/NCSL Z540.3 Method 5-Guard Bands based on Test Uncertainty Ratio. Calibration cycles and resulting due dates were submitted/approved by the customer. Any number of factors may cause an instrument to drift out of tolerance before the next scheduled calibration. Recalibration cycles should be based on frequency of use, environmental conditions and customer's established systematic accuracy. All standards are traceable to SI through the National Institute of Standards and Technology (NIST) and/or recognized national or international standards laboratories. Services rendered include proper manufacturer's service instruction and are warranted for no less than thirty (30) days. The information on this report pertains only to the instrument identified, this may not be reproduced in part or in a whole without the prior written approval of the issuing MP Calibration Laboratory.

rotronic

MEASUREMENT SOLUTIONS
135 Engineers Rd Suite 150
Hauppauge, NY 11788

CERTIFICATE of CALIBRATION
A 5804

ACCREDITED
CERT #5622.01

Product:	HC2-S3	**Customer:**	Air Resource Specialists
S/N:	20039891		1901 Sharp Point Dr
Manufacturer:	Rotronic AG		Fort Collins CO 80525-4429
Specifications	See report below		
Lab. Conditions	23 ± 2 °C / 40 ± 25 %RH	**Account:**	002356 **Order:** 100030

The above mentioned instrument was calibrated in compliance with ISO/IEC 17025 and ANSI/NCSL Z540-1 using Rotronic Instrument Corp laboratory procedures. All measurements are traceable to the International System of Units (SI) through NIST or other national metrology institutes. The measurement uncertainty values (U k=2) reported were estimated for a coverage factor of k=2, which approximates a 95% confidence level. The Test Uncertainty Ratio (TUR) is reported for each calibration point on this certificate. The Limit value represents the specified instrument performance. When calculating the Limit value for As Found data the specified drift value for 1 year is used. The measurement uncertainty has been taken into account when stating compliance to the Limit value. A guardband calculation is performed to limit the False Accept Risk to less than 2%. Calibration results relate only to the instrument calibrated.

Parameter	Unit	Generator	Run Type	Ref.	UUT	Error	U (k=2)	Limit	Result	TUR
Temperature	°C	T00	AsFound	24.43	24.41	-0.02	± 0.07	±0.18	P	2.6:1
Humidity	%RH	T00	AsFound	0.31	0.09	-0.22	± 0.29	±1.51	P	5.2:1
Humidity	%RH	T10	AsFound	11.03	10.69	-0.34	± 0.30	±1.51	P	5.0:1
Humidity	%RH	T35	AsFound	35.09	34.63	-0.46	± 0.35	±1.52	P	4.3:1
Humidity	%RH	T80	AsFound	79.94	79.38	-0.56	± 0.59	±1.59	P	2.7:1
Temperature	°C	T00	AsLeft	24.29	24.26	-0.03	± 0.07	±0.14	P	2.0:1
Humidity	%RH	T00	AsLeft	0.32	0.32	0.00	± 0.29	±0.97	P	3.3:1
Humidity	%RH	T10	AsLeft	11.10	11.12	0.02	± 0.30	±0.97	P	3.2:1
Humidity	%RH	T35	AsLeft	35.11	35.20	0.09	± 0.35	±0.99	P	2.8:1
Humidity	%RH	T80	AsLeft	79.97	79.96	-0.01	± 0.59	±1.10	P	1.9:1

NOTE: In the Result column P indicates Pass, F indicates Fail, I indicates Indeterminate. Indeterminate results are error values which are less than the specified limit but exceed the guardband limit.
999.00 in UUT column indicates UUT failure. Disregard all measured values for that calibration point.

Calibration References: see Generator column in the above report for each individual calibration point

T00 to T80: Temperature measured with Fluke Digital Thermometer mod. 1504 S/N A86637 (due Feb. 24, 2020) and Fluke Bead Probe mod. 5611A S/N B9225036 (due March 4, 2020).T00 to T80: Dew or frost point measured with RH Systems Dew Point Mirror mod. 973 S/N 16-0116 (due May 6, 2020)

By: Gary Boney
Calibration Technician

Date 11/13/2019

MICRO PRECISION

MICRO PRECISION CALIBRATION INC
12071 Tejon Street Suite # 100
Westminster Colorado 80234
720-535-4470

Certificate of Calibration

Date: Aug 22, 2019 **Cert No. 551220083177209**

Customer:
AIR RESOURCE SPECIALISTS
1901 SHARP POINT DRIVE, SUITE F
FORT COLLINS CO 80525

		Work Order #:	DEN-1500087
		Purchase Order #:	A33366
MPC Control #:	DF4663	Serial Number:	70573705
Asset ID:	N/A	Department:	N/A
Gage Type:	DIGITAL PRESSURE INDICATOR	Performed By:	JERROD SALAZAR
Manufacturer:	DRUCK INC	Received Condition:	IN TOLERANCE
Model Number:	DPI 705	Returned Condition:	IN TOLERANCE
Size:	30 PSIA	Cal. Date:	August 22, 2019
Temp/RH:	20.8°C / 42.0%	Cal. Interval:	12 MONTHS
Location:	Calibration performed at MPC facility	Cal. Due Date:	August 22, 2020

Calibration Notes:

Standards Used to Calibrate Equipment

I.D.	Description.	Model	Serial	Manufacturer	Cal. Due Date	Traceability #
DC4100	AIR DATA CALIBRATOR	3682	9121	KING NUTRONICS	Aug 31, 2019	551220081517429

Procedures Used in this Event

Procedure Name	Description
MPC-00062 Rev. 04	Pressure and Vacuum, General, June-23-2016 rev04

Calibrating Technician: JERROD SALAZAR

QC Approval: BRIAN GOLD

Statements of Pass or Fail Conformance: The uncertainty of measurement has been taken into account when determining compliance with specification, as per ILAC-G8:09/2009. All measurements and test results guard banded to ensure the probability of false-accept does not exceed 2% in compliance with ANSI/NCSL Z540.3-2006.
The status of compliance with the acceptance criteria is reported as:
PASS - Compliant with specification.
FAIL - Not compliant with specification.
FAIL* - The measured value is not within the acceptance limits. However, a portion of the expanded uncertainty of measurement at 95% is within the specified tolerance.
PASS* - The measured value is within acceptance limits. However, a portion of the expanded uncertainty of measurement at 95% exceeds the specified tolerance.
The expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%, unless otherwise stated. This calibration report complies with ISO/IEC 17025:2017 and ANSI/NCSL Z540.3 Method 5-Guard Bands based on Test Uncertainty Ratio. Calibration cycles and resulting due dates were submitted/approved by the customer. Any number of factors may cause an instrument to drift out of tolerance before the next scheduled calibration. Recalibration cycles should be based on frequency of use, environmental conditions and customer's established systematic accuracy. All standards are traceable to SI through the National Institute of Standards and Technology (NIST) and/or recognized national or international standards laboratories. Services rendered include proper manufacturer's service instruction and are warranted for no less than thirty (30) days. The information on this report pertains only to the instrument identified, this may not be reproduced in part or in a whole without the prior written approval of the issuing MP Calibration Laboratory.

(CERT, Rev 6)

R.M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA

CERTIFICATE OF CALIBRATION AND TESTING

Model: 18802
Serial Number: CA03358

Description: Anemometer Drive - 200 to 15000 RPM
(Comprised of 18820A Control Unit and 18830A Motor Assembly)

R. M. Young Company certifies that the above equipment was inspected and calibrated prior to shipment in accordance with established manufacturing and testing procedures. Standards established by R.M. Young Company for calibrating the measuring and test equipment used in controlling product quality are traceable to the National Institute of Standards and Technology.

Nominal Motor RPM RPM	27106D Output Frequency Hz (1)	Calculated RPM (2)	Indicated RPM (3)
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10200	1700	10200	10200
12600	2100	12600	12600
15000	2500	15000	15000
☑ Clockwise and Counterclockwise rotation verified.			

(1) Measured output frequency of YOUNG model 27106D standard anemometer attached to motor shaft.
(2) YOUNG model 27106D produces 10 pulsed per revolution of the anemometer shaft.
(3) Indicated on the Control Unit LCD.

* Indicates out of tolerance.

☐ New Unit ☑ Service / Repair Unit ☐ As found
☑ No calibration adjustments required ☐ As left

Traceable frequency meter used for calibration:
Model: 34405A Serial Number: TW46290020

Date: 20 June 2019
Calibration Interval: One year

Tested By : EC

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

apogee
INSTRUMENTS
721 West 1800 North
Logan, UT 84321

Certificate of Calibration
Apogee Instruments Pyranometer
Model SP-100/200/400 Series

Serial Number	:	SP-110-SS_68694
Calibration Date	:	Aug-2019
Recommended Recalibration Date	:	Aug-2021
Calibration Uncertainty	:	± 5 %
Measurement Repeatability	:	< 1 %
Non-stability (Long-term Drift)	:	< 2 % per year

Calibration Procedure

Calibration is based on a side-by-side comparison under high intensity discharge metal halide lamps using the mean of (4) Apogee transfer standard pyranometers. Apogee transfer standards are calibrated to the mean of at least (2) ISO-classified reference pyranometers under sunlight (clear sky conditions) in Logan, Utah. Each of the four ISO-classified reference pyranometers are recalibrated on an alternating year schedule (two instruments per year) at the National Renewable Energy Laboratory (NREL) in Golden, Colorado. NREL reference standards are calibrated to the World Radiometric Reference (WRR) in Davos, Switzerland.

Traceability

Reference Instrument	Serial Number	ISO 9060 Classification
EKO Instruments MS80*	S16088044	Spectrally Flat Class A
Kipp & Zonen CM11	060089	Spectrally Flat Class A
Kipp & Zonen CMP11	101625	Spectrally Flat Class A
Hukseflux SR20	2497	Spectrally Flat Class A
Apogee SP-110	TS1	Fast Response Class C
Apogee SP-110	TS2	Fast Response Class C
Apogee SP-110	TS3	Fast Response Class C
Apogee SP-110	TS4	Fast Response Class C

*MS80 purchased new in 2017. Initial calibration conducted by EKO Instruments with traceability to the World Radiometric Reference.

Technical Manager : Jacob Bingham Date : 20-Aug-2019

Please keep this document for your records

Website: www.apogeeinstruments.com E-mail: techsupport@apogeeinstruments.com Ph: (435)792-4700 Fax: (435)787-8268

MesaLabs

NVLAP Lab Code 200661-0
Calibration

Calibration Certificate

CertificateNo.	316435	**Sold To:**	Air Resource Specialists, Inc.
Product	200-220H Definer 220 High Flow		1901 Sharp Point Drive Ste F
Serial No.	122997		Fort Collins, CO 80525
Cal. Date	18-Jun-2019		US

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As Received Calibration Data

Technician

Lab. Pressure mmHg
Lab. Temperature 22.6 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
sccm	sccm		1.00%	
sccm	sccm		1.00%	
sccm	sccm		1.00%	
°C	°C	-	± 0.8°C	
mmHg	mmHg	-	± 3.5 mmHg	

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
Percision Thermometer			
Precision Barometer			

MesaLabs

NVLAP Lab Code 200661-0
Calibration

As Shipped Calibration Data

Certificate No	316435	**Lab. Pressure**	750 mmHg
Technician	Lilianna Malinowska	**Lab. Temperature**	22.6 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
25398.3 sccm	25289.4 sccm	0.43%	1.00%	In Tolerance
5147.75 sccm	5116.58 sccm	0.61%	1.00%	In Tolerance
1588.54 sccm	1575.92 sccm	0.8%	1.00%	In Tolerance
22.4 °C	22.4 °C	-	± 0.8°C	In Tolerance
750 mmHg	750 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	03-May-2019	02-May-2020
Percision Thermometer	305460	02-Oct-2018	02-Oct-2019
Precision Barometer	2981392	18-Jul-2018	18-Jul-2019

Calibration Notes

The expanded uncertainty of flow, temperature, and pressure measurements all have a coverage factor of k = 2 for a confidence interval of approximately 95%.

Flow testing is in accordance with our test number PR18-13 with an expanded uncertainty of 0.18% using high-purity nitrogen or filtered laboratory air. Flow readings in sccm are performed at STP of 21.1°C and 760 mmHg.

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Temperature testing is in accordance with our test number PR18-12 with an expanded uncertainty of 0.04 °C.

Traceability to the International System of Units (SI) is verified by accreditation to ISO/IEC 17025 by NVLAP under NVLAP Code 200661-0.

Technician Notes:

By:

Mohammed Aziz
Director of Engineering
Mesa Laboratories, Inc., Butler, NJ

APPENDIX E

EEMS PE Audit of the
Mammoth Cave National Park (MAC426) Site

PRELIMINARY PE THROUGH-THE-PROBE AUDIT REPORT

EEMS Van-3

OZONE REPORT

Site Name: MAC426 — Airs ID: 210610501
Auditor: Korey Devins (EEMS) — Audit Date: 08/19/20
Station Manager: Mike Slate (ARS) / Johnathan Jernigan (operator)

MOBILE PE LAB INSTRUMENTS

	Ozone	CO
Instrument:		
Manufacturer:	Thermo	0
Model:	49i-A1ZCA	0
Serial Number:	1180030022	0
Calibration Date:	01/14/20	1/0/1900
Slope:	0.9995	0
Intercept (PPM):	0.0002901	0

STATION INSTRUMENT INFORMATION

Instrument:	Ozone	
Manufacturer/Model #:	TEI	49i-A3NAA
Property Number:	1030745085	
Calibration Date:	05/16/20	
Slope/Intercept (PPB):	0.0000	0.0000
Indicated Flow (LPM):	0.77 / 0.77	
In-Line Filter Change:	08/18/20	
Manifold Type:	1/4 " Teflon	

PRELIMINARY OZONE AUDIT RESULTS

Mobile Lab O3 Concentration (ppm)	Site Response (ppm)	Percent Difference
0.10957	0.10865	-0.8
0.06589	0.06520	-1.0
0.03316	0.03278	-1.1
0.01419	0.01406	-0.9
0.00001	0.00033	

	Pass/Fail	Warning
O3 Audit Level 6	Pass	
O3 Audit Level 4	Pass	
O3 Audit Level 3	Pass	
O3 Audit Level 2	Pass	
O3 Audit Level 1	N/A	

Auditor: Korey Devins (Print)
Korey M. Devins (Signature)
Tim Sharac
EPA person notified in case of audit failure

Audit Limits

Pass	Bias < ±15.1% OR difference from actual concentration < 24 hour allowable drift (0.003 ppm)
Fail	Bias > ±15.1% AND difference from actual concentration > 24 hour allowable drift (0.003 ppm)
Warning	Bias > ±10% AND difference from actual concentration > 0.0015 ppm

APPENDIX F

EEMS Field Systems Audit (FSA) of the
Mammoth Cave National Park (MAC426) Site

Extracted from the 4th quarter audit report available at:
https://www.epa.gov/sites/production/files/2020-03/documents/2019-4th_quarter_report_0.pdf

Site Inventory by Site Visit

	Site Visit Date	Parameter	Mfg	Owner ID	Model Number	Serial Number
MAC426-Eric Hebert-10/17/2019						
1	10/17/2019	Computer	Hewlett Packard	none	6560 b	5CB1520H70
2	10/17/2019	DAS	Environmental Sys Corp	none	8832	unknown4
3	10/17/2019	Elevation	Elevation	None	1	None
4	10/17/2019	Filter pack flow pump	Thomas	none	107CAB18B	070000012920
5	10/17/2019	Flow Rate	Tylan	none	FC280	AW02213005
6	10/17/2019	Infrastructure	Infrastructure	none	none	none
7	10/17/2019	Met tower	Climatronics	none	illegible	illegible
8	10/17/2019	MFC power supply	Tylan	03677	RO-32	illegible
9	10/17/2019	Ozone	ThermoElectron Inc	none	49i A3NAA	1030745085
10	10/17/2019	Ozone Standard	ThermoElectron Inc	none	49i A1NAA	1015543061
11	10/17/2019	Sample Tower	Aluma Tower	none	B	none
12	10/17/2019	Shelter Temperature	ARS	60	none	none
13	10/17/2019	Siting Criteria	Siting Criteria	None	1	None
14	10/17/2019	Temperature2meter	RM Young	none	41342	15104
15	10/17/2019	Zero air pump	Werther International	none	PC70/4	606489

DAS Data Form

DAS Time Max Error: 0.73

Mfg	Serial Number	Site	Technician	Site Visit Date	Parameter	Use Desc.
Environmental Sys	unknown4	MAC426	Eric Hebert	10/17/2019	DAS	Primary

Das Date: 10/17/2019 **Audit Date** 10/17/2019
Das Time: 10:45:16 **Audit Time** 10:46:00
Das Day: 290 **Audit Day** 290

Low Channel:		High Channel:	
Avg Diff:	**Max Diff:**	**Avg Diff:**	**Max Diff:**
0.0000	0.0001	0.0000	0.0001

Mfg	Fluke	**Parameter**	DAS
Serial Number	95740135	**Tfer Desc.**	DVM
Tfer ID	01311		
Slope	1.00000	**Intercept**	0.00000
Cert Date	1/25/2019	**CorrCoff**	1.00000

Mfg	Datel	**Parameter**	DAS
Serial Number	15510194	**Tfer Desc.**	Source generator (D
Tfer ID	01320		
Slope	1.00000	**Intercept**	0.00000
Cert Date	2/13/2012	**CorrCoff**	1.00000

Channel	Input	DVM Output	DAS Output	InputUnit	OutputUnit	Difference
1	0.0000	0.0000	0.0000	V	V	0.0000
1	0.1000	0.0998	0.0999	V	V	0.0001
1	0.3000	0.2997	0.2997	V	V	0.0000
1	0.5000	0.4996	0.4996	V	V	0.0000
1	0.7000	0.6995	0.6995	V	V	0.0000
1	0.9000	0.8994	0.8993	V	V	-0.0001
1	1.0000	0.9992	0.9992	V	V	0.0000

Flow Data Form

Mfg	Serial Number Tag	Site	Technician	Site Visit Date	Parameter	Owner ID
Tylan	AW02213005	MAC426	Eric Hebert	10/17/2019	Flow Rate	none

Mfg	Tylan
SN/Owner ID	illegible 03677
Parameter:	MFC power supply

Mfg	BIOS	Parameter	Flow Rate
Serial Number	148613	Tfer Desc.	BIOS 220-H
Tfer ID	01421		
Slope	1.00000	Intercept	0.00000
Cert Date	3/4/2019	CorrCoff	1.00000

DAS 1:		DAS 2:		
A Avg % Diff:	A Max % Dif	A Avg %Diff	A Max % Dif	
5.03%	5.03%			

Cal Factor Zero	0.032
Cal Factor Full Scale	10.98
Rotometer Reading:	1.65

Desc.	Test type	Input l/m	Input Corr	MfcDisp.	OutputSignal	Output S E	InputUnit	OutputSignalU	PctDifference
primary	pump off	0.000	0.000	-0.13	0.0000	-0.08	l/m	l/m	
primary	leak check	0.000	0.000	-0.03	0.0000	0.03	l/m	l/m	
primary	test pt 1	1.594	1.590	1.34	0.0000	1.51	l/m	l/m	-5.03%
primary	test pt 2	1.594	1.590	1.34	0.0000	1.51	l/m	l/m	-5.03%
primary	test pt 3	1.593	1.590	1.34	0.0000	1.51	l/m	l/m	-5.03%

Sensor Component		Condition		Status	
Sensor Component	Leak Test	Condition		Status	pass
Sensor Component	Tubing Condition	Condition	Good	Status	pass
Sensor Component	Filter Position	Condition	Poor	Status	Fail
Sensor Component	Rotometer Condition	Condition	Clean and dry	Status	pass
Sensor Component	Moisture Present	Condition	See comments	Status	pass
Sensor Component	Filter Distance	Condition	7.0 cm	Status	pass
Sensor Component	Filter Depth	Condition	-2.0 cm	Status	Fail
Sensor Component	Filter Azimuth	Condition	Not tested	Status	pass
Sensor Component	System Memo	Condition		Status	pass

Ozone Data Form

Mfg	Serial Number Tag	Site	Technician	Site Visit Date	Parameter	Owner ID
ThermoElectron Inc	1030745085	MAC426	Eric Hebert	10/17/2019	Ozone	none

Slope:	0.98781	Slope:	0.00000
Intercept	2.24646	Intercept	0.00000
CorrCoff:	0.99999	CorrCoff:	0.00000

Mfg	ThermoElectron Inc	Parameter	ozone
Serial Number	1180030022	Tfer Desc.	Ozone primary stan
Tfer ID	01114		
Slope	0.99840	Intercept	0.27090
Cert Date	6/11/2019	CorrCoff	1.00000

DAS 1:		DAS 2:	
A Avg % Diff:	A Max % Dif	A Avg %Diff	A Max % Dif
0.0%	0.0%		

UseDescription	ConcGroup	Tfer Raw	Tfer Corr	Site	Site Unit	RelPerDif	AbsDif
primary	1	0.40	0.12	2.50	ppb		2.38
primary	2	14.16	13.91	15.77	ppb		1.86
primary	3	31.86	31.63	33.47	ppb	5.65	
primary	4	68.28	68.11	69.70	ppb	2.31	
primary	5	115.42	115.33	116.10	ppb	0.67	

Sensor Component	Condition	Status
Sample Train	Good	pass
22.5 degree rule		pass
Inlet Filter Condition	Moderately clean	pass
Battery Backup	N/A	pass
Offset	-3.1	pass
Span	1.005	pass
Zero Voltage	N/A	pass
Fullscale Voltage	N/A	pass
Cell A Freq.	122.4 kHz	pass
Cell A Noise	0.9 ppb	pass
Cell A Flow	0.78 lpm	pass
Cell A Pressure	731.2 mmHg	pass
Cell A Tmp.	34.0 C	pass
Cell B Freq.	99.3 kHz	pass
Cell B Noise	0.6 ppb	pass
Cell B Flow	0.78 lpm	pass
Cell B Pressure	730.6 mmHg	pass
Cell B Tmp.	N/A	pass
Line Loss	< 1 %	pass
System Memo		pass

2 Meter Temperature Data Form

Calc. Difference

Mfg	Serial Number Tag	Site	Technician	Site Visit Date	Parameter	Owner ID
RM Young	15104	MAC426	Eric Hebert	10/17/2019	Temperature2meter	none

Mfg	Extech	Parameter	Temperature
Serial Number	H232734	Tfer Desc.	RTD
Tfer ID	01227		
Slope	1.00733	Intercept	0.14497
Cert Date	2/12/2019	CorrCoff	1.00000

DAS 1:		DAS 2:	
Abs Avg Err	Abs Max Err	Abs Avg Err	Abs Max Err
0.22	0.57		

UseDescription	Test type	InputTmpRaw	InputTmpCorrected	OutputTmpSignal	OutputSignalEng	OSE Unit	Difference
primary	Temp Low Rang	0.20	0.05	0.0000	0.62	C	0.57
primary	Temp Mid Range	27.28	26.94	0.0000	26.87	C	-0.07
primary	Temp High Rang	48.29	47.79	0.0000	47.82	C	0.03

Sensor Component	Properly Sited	Condition	Properly sited	Status	pass
Sensor Component	Shield	Condition	Moderately clean	Status	pass
Sensor Component	Blower	Condition	Functioning	Status	pass
Sensor Component	Blower Status Switch	Condition	N/A	Status	pass
Sensor Component	System Memo	Condition		Status	pass

Shelter Temperature Data For

Mfg	Serial Number Tag	Site	Technician	Site Visit Date	Parameter	Owner ID
ARS	none	MAC426	Eric Hebert	10/17/2019	Shelter Temperature	60

DAS 1:		DAS 2:	
Abs Avg Err	Abs Max Err	Abs Avg Err	Abs Max Err
0.32	0.53		

Mfg	Extech	Parameter	Shelter Temperature
Serial Number	H232734	Tfer Desc.	RTD
Tfer ID	01227		
Slope	1.00733	Intercept	0.14497
Cert Date	2/12/2019	CorrCoff	1.00000

UseDesc.	Test type	InputTmpRaw	InputTmpCorr.	OutputTmpSignal	OutputSignalEng	OSE Unit	Difference
primary	Temp Mid Range	26.18	25.85	0.000	25.7	C	-0.11
primary	Temp Mid Range	25.31	24.98	0.000	25.5	C	0.53

Sensor Component	System Memo	Condition		Status	pass

Infrastructure Data For

Site ID	MAC426	Technician	Eric Hebert	Site Visit Date	10/17/2019

Shelter Make	Shelter Model	Shelter Size
custom	N/A	1536 cuft

Sensor Component		Condition		Status	
Sensor Component	Sample Tower Type	Condition	Type B	Status	pass
Sensor Component	Conduit	Condition	Good	Status	pass
Sensor Component	Met Tower	Condition	Good	Status	pass
Sensor Component	Moisture Trap	Condition	Installed	Status	pass
Sensor Component	Power Cables	Condition	Good	Status	pass
Sensor Component	Shelter Temp Control	Condition	Functioning	Status	pass
Sensor Component	Rotometer	Condition	Installed	Status	pass
Sensor Component	Sample Tower	Condition	Good	Status	pass
Sensor Component	Shelter Condition	Condition	Good	Status	pass
Sensor Component	Shelter Door	Condition	Good	Status	pass
Sensor Component	Shelter Roof	Condition	Good	Status	pass
Sensor Component	Shelter Floor	Condition	Good	Status	pass
Sensor Component	Signal Cable	Condition	Good	Status	pass
Sensor Component	Tubing Type	Condition	3/8 teflon	Status	pass
Sensor Component	Sample Train	Condition	Good	Status	pass

Site Visit Comments

Parameter	Site	Technician	S.V. Date	Component	Mfg	Serial No.	Hazard	Problem
Flow Rate	MAC426	Eric Hebert	10/17/2019	Moisture Present	Tylan	4410	☐	☐

The filter sample tubing has drops of moisture in low sections outside the shelter.

Field Systems Comments

1 **Parameter:** SiteOpsProcComm

The site operator is very knowledgeable with air quality monitoring. He is doing a very good job with site activities and filter handling.

2 **Parameter:** SitingCriteriaCom

Bowling Green is within 40 km of the site. The site is in a hay field which is harvested twice per year. The area to the west and south is comprised of livestock farms including cattle and poultry.

3 **Parameter:** ShelterCleanNotes

The shelter is well maintained, clean, neat, and well organized.

Field Systems Data Form

F-02058-1500-S1-rev002

Site ID	MAC426	**Technician**	Eric Hebert	**Site Visit Date**	10/17/2019

Site Sponsor (agency)	NPS	**USGS Map**	Rhoda
Operating Group	NPS	**Map Scale**	
AQS #	21-061-0501	**Map Date**	
Meteorological Type	Climatronics		
Air Pollutant Analyzer	Ozone, SO2, NOy, Hg, IMPROVE, PM	**QAPP Latitude**	37.2806
Deposition Measurement	dry, wet, Hg	**QAPP Longitude**	-86.2639
Land Use	agriculture, woodland - mixed	**QAPP Elevation Meters**	236
Terrain	rolling	**QAPP Declination**	3
Conforms to MLM	Marginally	**QAPP Declination Date**	12/27/2004
Site Telephone	(270) 758-2136	**Audit Latitude**	37.131794
Site Address 1	Alfred Cook Road	**Audit Longitude**	-86.142953
Site Address 2		**Audit Elevation**	230
County	Edmonson	**Audit Declination**	-4.0
City, State	Smiths Grove, KY		**Present**
Zip Code	42171	**Fire Extinguisher**	☑ inspected March 2011
Time Zone	Eastern	**First Aid Kit**	☑
Primary Operator		**Safety Glasses**	☐
Primary Op. Phone #		**Safety Hard Hat**	☐
Primary Op. E-mail		**Climbing Belt**	☑
Backup Operator		**Security Fence**	☑
Backup Op. Phone #		**Secure Shelter**	☑
Backup Op. E-mail		**Stable Entry Steps**	☑

Shelter Working Room ☑ **Make** custom **Model** N/A **Shelter Size** 1536 cuft

Shelter Clean ☑ **Notes** The shelter is well maintained, clean, neat, and well organized.

Site OK ☑ **Notes**

Driving Directions From Bowling Green go east on 31W. Turn left (north) on 442 toward Pig. At the stop sign in Pig, turn right on route 259, or Brownsville Road. Continue approximately 1 mile, just past two churches (one on each side of the road). Take the 2nd left past the church on the left onto Chaumount Road. Then take the first left onto Doyle Road. Continue straight onto Alfred Cook Road. The site will be on the left approximately 0.6 miles.

Field Systems Data Form

F-02058-1500-S3-rev002

Site ID	MAC426	Technician	Eric Hebert	Site Visit Date	10/17/2019

1	Are wind speed and direction sensors sited so as to avoid being influenced by obstructions?	☑	N/A
2	Are wind sensors mounted so as to minimize tower effects? (i.e. wind sensors should be mounted atop the tower or on a horizontally extended boom >2x the max diameter of the tower into the prevailing wind)	☑	N/A
3	Are the tower and sensors plumb?	☑	N/A
4	Are the temperature shields pointed north or positioned to avoid radiated heat sources such as buildings, walls, etc?	☑	
5	Are temperature and RH sensors sited to avoid unnatural conditions? (i.e. ground below sensors should be natural surface and not steeply sloped. Ridges, hollows, and areas of standing water should be avoided)	☑	
6	Is the solar radiation sensor plumb?	☑	N/A
7	Is it sited to avoid shading, or any artificial or reflected light?	☑	N/A
8	Is the rain gauge plumb?	☑	N/A
9	Is it sited to avoid sheltering effects from buildings, trees, towers, etc?	☑	N/A
10	Is the surface wetness sensor sited with the grid surface facing north?	☑	N/A
11	Is it inclined approximately 30 degrees?	☑	N/A

Provide any additional explanation (photograph or sketch if necessary) regarding conditions listed above, or any other features, natural or man-made, that may affect the monitoring parameters:

Field Systems Data Form

F-02058-1500-S2-rev002

Site ID MAC426 **Technician** Eric Hebert **Site Visit Date** 10/17/2019

Potential Interferent	Minimum Distance From Measurement Apparatus	Distance	Pass = Checked
Large Point Source of SO2 or NOx	20 to 40 km		☑
Major industrial complex	10 to 20 km		☑
City > 50,000 population	40 km	35 km	☐
City 10,000 to 50,000 population	10 km		☑
City 1,000 to 10,000 population	5 km		☑
Major highway, airport or rail yard	2 km		☑
Secondary road, heavily traveled	500 m		☑
Secondary road, lightly traveled	200 m		☑
Feedlot operations	500 m		☑
Intensive agricultural ops (including aerial spraying)	500 m		☑
Limited agricultural operations	200 m	10 m	☐
Large parking lot	200 m		☑
Small parking lot	100 m		☑
Tree line	50 m		☑
Obstacles to wind	10 times obstacle height		☑

Siting Distances OK ☑

Siting Criteria Comment

Bowling Green is within 40 km of the site. The site is in a hay field which is harvested twice per year. The area to the west and south is comprised of livestock farms including cattle and poultry.

Field Systems Data Form

F-02058-1500-S4-rev002

Site ID MAC426 **Technician** Eric Hebert **Site Visit Date** 10/17/2019

1	Do all the meterological sensors appear to be intact, in good condition, and well maintained?	☑	2 meter Temperature only
2	Are all the meteorological sensors operational online, and reporting data?	☑	2 meter Temperature only
3	Are the shields for the temperature and RH sensors clean?	☑	
4	Are the aspirated motors working?	☑	
5	Is the solar radiation sensor's lens clean and free of scratches?	☑	N/A
6	Is the surface wetness sensor grid clean and undamaged?	☑	N/A
7	Are the sensor signal and power cables intact, in good condition, and well maintained?	☑	
8	Are the sensor signal and power cable connections protected from the elements and well maintained?	☑	

Provide any additional explanation (photograph or sketch if necessary) regarding conditions listed above, or any other features, natural or man-made, that may affect the monitoring parameters:

Field Systems Data Form

F-02058-1500-S6-rev002

Site ID MAC426 **Technician** Eric Hebert **Site Visit Date** 10/17/2019

DAS, sensor translators, and peripheral equipment operations and maintenance

1	Do the DAS instruments appear to be in good condition and well maintained?	☑	
2	Are all the components of the DAS operational? (printers, modem, backup, etc)	☑	
3	Do the analyzer and sensor signal leads pass through lightning protection circuitry?	☑	Met sensors only
4	Are the signal connections protected from the weather and well maintained?	☑	
5	Are the signal leads connected to the correct DAS channel?	☑	
6	Are the DAS, sensor translators, and shelter properly grounded?	☑	
7	Does the instrument shelter have a stable power source?	☑	
8	Is the instrument shelter temperature controlled?	☑	

		Stable	Grounded
9	Is the met tower stable and grounded?	☑	☑
10	Is the sample tower stable and grounded?	☑	☑
11	Tower comments?		

Provide any additional explanation (photograph or sketch if necessary) regarding conditions listed above, or any other features, natural or man-made, that may affect the monitoring parameters:

Field Systems Data Form

F-02058-1500-S5-rev002

Site ID	MAC426	Technician	Eric Hebert	Site Visit Date	10/17/2019

Siting Criteria: Are the pollutant analyzers and deposition equipment sited in accordance with 40 CFR 58, Appendix E

1	Do the sample inlets have at least a 270 degree arc of unrestricted airflow?	☑	
2	Are the sample inlets 3 - 15 meters above the ground?	☑	
3	Are the sample inlets > 1 meter from any major obstruction, and 20 meters from trees?	☑	

Pollutant analyzers and deposition equipment operations and maintenance

1	Do the analyzers and equipment appear to be in good condition and well maintained?	☑	
2	Are the analyzers and monitors operational, on-line, and reporting data?	☑	
3	Describe ozone sample tube.		1/4 teflon by 10 meters
4	Describe dry dep sample tube.		3/8 teflon by 12 meters
5	Are in-line filters used in the ozone sample line? (if yes indicate location)	☑	At inlet only
6	Are sample lines clean, free of kinks, moisture, and obstructions?	☑	
7	Is the zero air supply desiccant unsaturated?	☑	
8	Are there moisture traps in the sample lines?	☑	
9	Is there a rotometer in the dry deposition filter line, and is it clean?	☑	Clean and dry

Provide any additional explanation (photograph or sketch if necessary) regarding conditions listed above, or any other features, natural or man-made, that may affect the monitoring parameters:

Field Systems Data Form

F-02058-1500-S8-rev002

Site ID	MAC426	Technician	Eric Hebert	Site Visit Date	10/17/2019

Site operation procedures

1	Has the site operator attended a formal CASTNET training course? If yes, when and who instructed?	☑	Receives training every 6 months during calibration visits
2	Has the backup operator attended a formal CASTNET training course? If yes, when and who instructed?	☑	Receives training every 6 months during calibration visits
3	Is the site visited regularly on the required Tuesday schedule?	☑	
4	Are the standard CASTNET operational procedures being flollowed by the site operator?	☑	
5	Is the site operator(s) knowledgeable of, and able to perform the required site activities? (including documentation)	☑	

Are regular operational QA/QC checks performed on meteorological instruments?

QC Check Performed		Frequency	Compliant
Multipoint Calibrations	☑	Semiannually	☑
Visual Inspections	☑	Weekly	☑
Translator Zero/Span Tests (climatronics)	☐	N/A	☑
Manual Rain Gauge Test	☑	Monthly	☑
Confirm Reasonableness of Current Values	☑	Weekly	☑
Test Surface Wetness Response	☑	N/A	☑

Are regular operational QA/QC checks performed on the ozone analyzer?

QC Check Performed		Frequency	Compliant
Multi-point Calibrations	☑	Semiannually	☑
Automatic Zero/Span Tests	☑	Daily	☑
Manual Zero/Span Tests	☑	Monthly	☑
Automatic Precision Level Tests	☑	Daily	☑
Manual Precision Level Test	☐	N/A	☑
Analyzer Diagnostics Tests	☑	Alarm values only	☑
In-line Filter Replacement (at inlet)	☑	Monthly	☑
In-line Filter Replacement (at analyze	☐	N/A	☑
Sample Line Check for Dirt/Water	☑	Weekly	☑
Zero Air Desiccant Check	☑	Weekly	☑

1	Do multi-point calibration gases go through the complete sample train including all filters?	☑	
2	Do automatic and manual z/s/p gasses go through the complete sample train including all filters?	☑	
3	Are the automatic and manual z/s/p checks monitored and reported? If yes, how?	☑	DataView

Provide any additional explanation (photograph or sketch if necessary) regarding conditions listed above, or any other features, natural or man-made, that may affect the monitoring parameters:

Field Systems Data Form

F-02058-1500-S7-rev002

Site ID: MAC426 Technician: Eric Hebert Site Visit Date: 10/17/2019

Documentation

Does the site have the required instrument and equipment manuals?

	Yes	No	N/A		Yes	No	N/A
Wind speed sensor	☑	☐	☐	Data logger	☑	☐	☐
Wind direction sensor	☑	☐	☐	Data logger	☐	☐	☑
Temperature sensor	☑	☐	☐	Strip chart recorder	☐	☐	☑
Relative humidity sensor	☐	☑	☐	Computer	☐	☑	☐
Solar radiation sensor	☑	☐	☐	Modem	☐	☑	☐
Surface wetness sensor	☐	☑	☐	Printer	☐	☑	☐
Wind sensor translator	☑	☐	☐	Zero air pump	☐	☑	☐
Temperature translator	☐	☑	☐	Filter flow pump	☐	☑	☐
Humidity sensor translator	☐	☐	☑	Surge protector	☐	☐	☑
Solar radiation translator	☑	☐	☐	UPS	☐	☐	☑
Tipping bucket rain gauge	☑	☐	☐	Lightning protection device	☐	☑	☐
Ozone analyzer	☑	☐	☐	Shelter heater	☐	☑	☐
Filter pack flow controller	☑	☐	☐	Shelter air conditioner	☑	☐	☐
Filter pack MFC power supply	☑	☐	☐				

Does the site have the required and most recent QC documents and report forms?

	Present		Current
Station Log	☑	DataView2	☑
SSRF	☑		☑
Site Ops Manual	☑		☑
HASP	☐		☐
Field Ops Manual	☐		☐
Calibration Reports	☑		☑
Ozone z/s/p Control Charts	☐		☐
Preventive maintenance schedule	☐		☐

1	Is the station log properly completed during every site visit?	☑	DataView
2	Are the Site Status Report Forms being completed and current?	☑	
3	Are the chain-of-custody forms properly used to document sample transfer to and from lab?	☑	
4	Are ozone z/s/p control charts properly completed and current?	☐	Control charts not used

Provide any additional explanation (photograph or sketch if necessary) regarding conditions listed above, or any other features, natural or man-made, that may affect the monitoring parameters:

Field Systems Data Form

F-02058-1500-S9-rev002

Site ID MAC426 **Technician** Eric Hebert **Site Visit Date** 10/17/2019

Site operation procedures

1	Is the filter pack being changed every Tuesday as scheduled?	☑	Filter changed various times
2	Are the Site Status Report Forms being completed and filed correctly?	☑	
3	Are data downloads and backups being performed as scheduled?	☐	No longer required
4	Are general observations being made and recorded? How?	☑	SSRF, logbook
5	Are site supplies on-hand and replenished in a timely fashion?	☑	
6	Are sample flow rates recorded? How?	☑	SSRF
7	Are samples sent to the lab on a regular schedule in a timely fashion?	☑	
8	Are filters protected from contamination during handling and shipping? How?	☑	Clean gloves on and off
9	Are the site conditions reported regularly to the field operations manager or staff?	☐	

QC Check Performed		Frequency	Compliant
Multi-point MFC Calibrations	☑	Semiannually	☑
Flow System Leak Checks	☑	Weekly	☑
Filter Pack Inspection	☐		☐
Flow Rate Setting Checks	☑	Weekly	☑
Visual Check of Flow Rate Rotometer	☑	Weekly	☑
In-line Filter Inspection/Replacement	☑	Semiannually and as needed	☑
Sample Line Check for Dirt/Water	☑	Weekly	☑

Provide any additional explanation (photograph or sketch if necessary) regarding conditions listed above, or any other features, natural or man-made, that may affect the monitoring parameters:

The site operator is very knowledgeable with air quality monitoring. He is doing a very good job with site activities and filter handling.

Field Systems Data Form

F-02058-1500-S10-rev002

Site ID MAC426 **Technician** Eric Hebert **Site Visit Date** 10/17/2019

Site Visit Sensors

Parameter	Manufacturer	Model	S/N	Client ID
Computer	Hewlett Packard	6560 b	5CB1520H70	none
DAS	Environmental Sys Corp	8832	unknown4	none
Elevation	Elevation	1	None	None
Filter pack flow pump	Thomas	107CAB18B	070000012920	none
Flow Rate	Tylan	FC280	AW02213005	none
Infrastructure	Infrastructure	none	none	none
Met tower	Climatronics	illegible	illegible	none
MFC power supply	Tylan	RO-32	illegible	03677
Ozone	ThermoElectron Inc	49i A3NAA	1030745085	none
Ozone Standard	ThermoElectron Inc	49i A1NAA	1015543061	none
Sample Tower	Aluma Tower	B	none	none
Shelter Temperature	ARS	none	none	60
Siting Criteria	Siting Criteria	1	None	None
Temperature2meter	RM Young	41342	15104	none
Zero air pump	Werther International	PC70/4	606489	none

APPENDIX G

State Audit (NPAP) of the
Mammoth Cave National Park (MAC426) Site

ANDY BESHEAR
GOVERNOR

REBECCA W. GOODMAN
SECRETARY

ANTHONY R. HATTON
COMMISSIONER

ENERGY AND ENVIRONMENT CABINET
DEPARTMENT FOR ENVIRONMENTAL PROTECTION

300 SOWER BOULEVARD
FRANKFORT, KENTUCKY 40601
TELEPHONE: 502-564-2150
TELEFAX: 502-564-4245

February 6, 2020

Johnathan Jernigan,
Office of Science and Management
P.O. Box 7
Mammoth Cave National Park
Mammoth Cave, Kentucky 42259

Dear Mr. Jernigan:

On January 22, 2020, personnel from the Kentucky Division for Air Quality's (KDAQ) Technical Services Branch conducted performance audits of the air monitors located at the Houchin Meadows site. The monitoring site is operated by the National Park Service at Mammoth Cave National Park.

The trace-level NO/NO_x analyzer, trace level SO_2 analyzer, CO analyzer, ozone analyzer, and continuous $PM_{2.5}$ TEOM all responded within EPA-recommended control limits.

The next audit of the Houchin Meadows site is scheduled to occur in April 2020. If you have any questions prior to that time, please feel free to contact me at (502) 782-6708.

Sincerely,

Jennifer F. Miller

Jennifer F. Miller, Manager
Technical Services Branch

JFM/tcm
Enclosures

CC: Mr. Timothy Pinion

Commonwealth of Kentucky
Energy and Environment Cabinet
Department for Environmental Protection
DIVISION FOR AIR QUALITY

SO_2 PERFORMANCE AUDIT FORM

ANALYZER

Manufacturer:	Thermo
Model Number:	43i
Inv./Ser. Number:	0820430687
Range:	200 ppb
Date Last Calibrated:	November 7, 2019
Last Cal. Slope:	0.958
Last Cal. Intercept:	3.540
Offline Time:	n/a
Online Time:	n/a

SITE

AQS Site ID:	21-061-0501
Location:	Mammoth Cave
Site Operator:	Jernigan
Auditor:	Martin TLM
Audit Date:	January 22, 2020
Site Temperature:	25.5
Audit Temperature:	26.2
Site Cylinder S/N:	CC506134
Site Cylinder PSI:	1800
Site Cyl. Exp. Date:	September 10, 2022

PASS

AUDIT SYSTEM

CALIBRATOR

Manufacturer:	Environics
Model Number:	6100
Inventory Number:	NR24458
Flow Certification Date:	October 14, 2020

ZERO AIR UNIT

Manufacturer:	Teledyne API
Model Number:	751H
Inventory Number:	RM7702
Last Service Date:	January 13, 2020

CYLINDER

Manufacturer:	Airgas
Serial Number:	CAL16439
Concentration:	4.894 PPM
Cylinder PSI:	1350
Expiration Date:	March 21, 2023

TEMPERATURE STANDARD

Standard ID No.:	904
Certification Date:	August 20, 2019

CALIBRATOR					ANALYZER RESPONSE					PASS / FAIL
Audit Levels (PPM)	Flowrate Total	Flowrate Dilution	Flowrate Span Gas	Conc. PPM	Chart Percent	KAMS Voltage	KAMS PPM	Indicated PPM	L1: Diff L5-6: %D	
Zero	4972.4	4972.4	0.000	0.0000			0.0000	N/A	N/A	N/A
Level 1 (0.0003-0.0029)	8954.5	8949.9	4.567	0.0025			0.0020	0.0020	0.0005	PASS
Level 5 (0.0200-0.0499)	4966.1	4935.6	30.471	0.0300			0.0271	0.0271	-9.7	FAIL
Level 6 (0.0500-0.0999)	4968.1	4891.8	76.331	0.0752			0.0684	0.0684	-9.0	FAIL

AUDIT Slope: 0.911 Intercept: 0.000

Comments: All points responded within EPA's limit of 15% or 1.5 ppb (whichever is greater).

Verified By: _____ Date: 1/24/20

Commonwealth of Kentucky
Energy and Environment Cabinet
Department for Environmental Protection
DIVISION FOR AIR QUALITY

OZONE AUDIT FORM

ANALYZER

Manufacturer:	Thermo
Model Number:	49i
Inv./Ser. Number:	1160770010
Range:	500 ppb
Date Last Cal.:	n/a
Last Cal. Slope:	n/a
Last Cal. Intercept:	n/a
Offline Time:	n/a
Online Time:	n/a

SITE

AQS Site No.:	21-061-0501
Location:	Mammoth Cave
Operator:	Jernigan
Auditor:	Martin TCM
Audit Date:	22-Jan-20
Site Temperature:	25.5
Audit Temperature:	26.2

AUDIT SYSTEM

OZONE CALIBRATOR & PHOTOMETER

Manufacturer:	Environics
Calibrator Model:	6103
Inventory Number:	CB52004398
Gertification Date:	21-Jan-20
Photometer Model:	6103
Inventory Number:	CB52004398
Certification Date:	21-Jan-20

ZERO AIR

Manufacturer:	Teledyne API
Model Number:	751H
Inventory Number:	RM7699
Flow Rate:	5-9 LPM
Last Service Date:	17-Jan-20

TEMPERATURE STANDARD

Standard ID#:	904
Gertification Date:	8/20/19

OZONE GENERATION				MONITOR RESPONSE						
AUDIT POINTS	METER READING	Zero Offset	Actual PPM	Chart Percent	KAMS Voltage	KAMS PPM	Indicated PPM	% d (± 7)	Action Limit (± 7)	Void Data (± 10)
Zero	-0.001	-0.001	0.000			0.000				
Level 2/3 (.006-0.036)	0.030	-0.001	0.031			0.031	0.031	0.0		
Level 4 (0.04-0.069)	0.060	-0.001	0.061			0.059	0.059	-3.3	Pass	Valid
Level 5 (0.07-0..089)	0.080	-0.001	0.081			0.081	0.081	0.0	Pass	Valid
Level 8 (0.21-0.30)	0.160	-0.001	0.161			0.158	0.158	-1.9	Pass	Valid
Level x	0.015	-0.001	0.016			0.015	0.015	-6.3		

Comments: Regular analyzer was removed from site for maintenance. S/N 1160770010 installed while regular analyzer is being repaired.
Calibration information was not available on-site for S/N 1160770010

Verified By: _____ **Date:** 1/24/20

DAQ Revised January 2014

Commonwealth of Kentucky
Energy and Environment Cabinet
Department for Environmental Protection
DIVISION FOR AIR QUALITY

CO AUDIT FORM

INSTRUMENT

Manufacturer	Thermo
Model Number	48i-TLE
Inv./Ser. Number	0823633181
Range	5 ppm
Date Last Cal	November 7, 2019
Last Cal Slope	1.031
Cylinder PSI	1800

SITE

Site No.	n/a
AIRS Site No.:	21-061-0501
Location	Mammoth Cave
Operator	Jernigan
Auditor	Martin TCM
Audit Date	January 22, 2020
Site Temperature:	25.5
Audit Temperature:	26.2

AUDIT CALIBRATOR

Manufacturer	Environics
Model Number	6100
Inventory Number	NR24458
Certification Date	October 14, 2019

AUDIT CYLINDER

Manufacturer	Airgas
Serial Number	FF19662
Concentration PPM	251.7 PPM
Certification Date	March 26, 2022

CALIBRATOR						MONITOR RESPONSE				
AUDIT POINTS	Total Flowrate	Dilution Flowrate	Span Flowrate	Conc. PPM		Chart Percent	KAMS Voltage	KAMS PPM	Indicated PPM	% d
Zero	4968.4	4968.4	0.000	0.00				0.04	0.00	
Level 3	8954.4	8948.9	5.496	0.15				0.19	0.15	0.0
Level 4	4965.3	4950.1	15.209	0.77				0.82	0.78	1.3
Level 5	4966.6	4910.6	55.986	2.84				2.92	2.88	1.4

Audit:	Slope	1.014	Intercept	0.0

Comments: Audit conducted for levels 4, 3, and 2 due to audit cylinder concentration and audit calibrator flow rates.

Verified By: _____ Date: 1/24/20

DAQ, Revised 7/30/08

KENTUCKY DIVISION FOR AIR QUALITY

NO-NO_2 AUDIT FORM

MONITORING SYSTEM

INSTRUMENT

Manufacturer:	Thermo
Model Number:	42i-y
Inv./Ser. Number:	734025663
Range:	200 ppb
Last Calibration Date:	November 7, 2019
Last Cal. Slope NO:	1.007
Last Cal. Int. NO:	3.46
Last Cal. Slope NO_2:	1.039 (diff)
Last Cal. Int. NO_2:	3.85 (diff)
Offline Time:	n/a
Online Time:	n/a

SITE

AQS Site NO.:	21-061-0501
Location:	Mammoth Cave
Operator:	Jernigan
Auditor:	Martin TLM
Audit Date:	January 22, 2020
Site Cylinder S/N:	CC506134
Site Cylinder PSI:	1800

AUDIT SYSTEM

CALIBRATOR

Manufacturer:	Environics
Model Number:	6100
Inventory Number:	NR24458
Certification Date:	10/14/2019

GAS CYLINDER

Manufacturer:	Airgas
Serial Number:	FF19662
Conc. NO PPM:	9.782
Conc. NO_X PPM:	9.847
Certification Date:	March 26, 2019

ZERO AIR

Manufacturer:	Teledyne API
Model Number:	751II
Inventory Number:	RM7702
Flow Rate:	5-9 LPM
Last Service Date:	January 13, 2020

TEMPERATURE STANDARD

Standard ID #:	Streamline Pro 904
Certification Date:	August 20, 2019
Site Temperature:	25.5
Audit Temperature:	26.2

NO-NO_X

	Calibrator					Monitor Response							
	Total Air Flow	Dilution Flow	Span Gas Flow	NO_X PPM	NO PPM	NO_X Chart Percent	NO Chart Percent	NO_X PPM	NO_2 PPM	NO PPM	Indicated NO PPM	Audit % d
L0	4968.4	4968.4	0.000	0.000	0.000			0.000	0.000	0.000		
L4	4968.1	4960.5	7.625	0.015	0.015			0.015	0.000	0.015	0.015	0.0
L5	4965.3	4950.1	15.209	0.030	0.030			0.030	0.000	0.030	0.030	0.0
L7	4966.6	4910.6	55.986	0.111	0.110			0.114	0.001	0.112	0.112	1.8
LX												

Audit	NO_X	NO
Intercept	0.000	0.000
Slope	1.029	1.020

NO_2

	Calibrator Flows						Monitor Response (Values From Datalogger)										
	Total Flow	Dilution Flow	Span Gas Flow	NO_X Calculated	NO Calculated	NO_2 Calculated	NO_X GPTPS	NO_2 GPTPS Corrected	NO_X GPT PPM	NO GPT PPM	NO_X PPM	NO PPM	Actual NO_2 PPM	KAMS Voltage	NO_2 KAMS PPM	Indicated NO_2 PPM	Audit % d
L0	0.0			#DIV/0!	#DIV/0!	#DIV/0!					0.000	0.000	#DIV/0!				
L3	0.0			#DIV/0!	#DIV/0!	#DIV/0!		0.000			0.000	0.000	#DIV/0!			0.000	#DIV/0!
L4	0.0			#DIV/0!	#DIV/0!	#DIV/0!		0.000			0.000	0.000	#DIV/0!			0.000	#DIV/0!
L5	0.0			#DIV/0!	#DIV/0!	#DIV/0!		0.000			0.000	0.000	#DIV/0!			0.000	#DIV/0!
LX																	
																C.E. =	#DIV/0!

TEST FUNCTIONS

Parameters	Values	Acceptable Limits	
Sample Flow		500 cc/min ± 50	OUT
Ozone Flow		80 cc/min ± 15	OUT
Reel Temp		50°C ± 1°C	OUT
PMT Temp		7°C ± 2°C	OUT
NOX Slope		1.0 ± 0.3	OUT
NO Slope		1.0 ± 0.3	OUT

Note Actual NO2 values must be between the following ranges for each audit point:

L3	0.0080 - 0.0199 ppm
L4	0.0200 - 0.0499 ppm
L5	0.1000 - 0.2990 ppm

Comments: #DIV/0!

No drift on final zero

Place holder for revision date

Verified By: _____ Date: 1/24/20

Commonwealth of Kentucky
Energy and Environment Cabinet
Department for Environmental Protection
DIVISION FOR AIR QUALITY

TEOM AUDIT FORM

ANALYZER

Manufacturer:	Thermo
Model No.:	1405
Inv./Ser. No.:	RM7697

AUDIT DEVICES

Flow Device:	Streamline Pro
Serial Number:	904
Cert Date:	August 22, 2019

TEMPERATURE PROBE

Cert Date:	August 20, 2019

SITE

AQS Site No.:	
Location:	Mammoth Cave
Operator:	Jernigan Martin
Auditor:	Tom
Audit Date:	January 22, 2020
Offline Time:	10:24
Online Time:	*see notes
Shelter Temperature:	25.5
Audit Temperature:	26.2

FLOW RATE

Measured Flows	Displayed Monitor Flows	Audit Flows Actual (LPM)	Target Flowrate	Comparison of Audit Flows to Target Flows (% d)	Comparison of Audit Flows to Displayed
Total Flow	16.67	16.73	16.7 ± 5%	-0.18	-0.36
Main Flow	3.00	2.93	3.0 ± 5%	2.39	2.39
Aux. Flow	13.67				

LEAK CHECK

Leak Check	Monitor Displayed Value	NOV Value Previously Determined	Actual Leak Value (LPM)	Acceptable Leak Limits	Comments
Zero (Main)	0.02		0.02	≤ .15 LPM	OK
Zero (Aux.)	0.00		0.00	≤ .60 LPM	OK

TEMPERATURE AND PRESSURE

	Monitor Display	Audit Reading	Acceptable Limits	Comparison to Acceptable Limits	Comments
Temperature	0.3	0.4	± 2.0 °C	0.1	OK
Pressure	0.981	0.984	± 0.013 atm (1 atm = 760 mm Hg)	0.003	OK

Comments: TEOM was shutdown following audit.

Verified By: _____ **Date:** 1/24/20

DAQ Revised 5-2014