CASTNET
2018 Annual Report

Prepared for:

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List of Acronyms and Abbreviations

% diff	percent difference
A/D	analog to digital converter
AQS	Air Quality System
ARS	Air Resource Specialists, Inc.
ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
BLM-WSO	Bureau of Land Management-Wyoming State Office
CASTNET	Clean Air Status and Trends Network
CFR	Code of Federal Regulation
CMAQ	Community Multi-scale Air Quality
DAS	data acquisition system
DC	direct current
DEP	Department of Environmental Protection
deg	degree
DQO	data quality objectives
DVM	digital voltmeter
ECCC	Environment and Climate Change Canada
EEMS	Environmental, Engineering & Measurement Services, Inc.
EPA	U.S. Environmental Protection Agency
ESC	Environmental Systems Corporation
FSAD	Field Site Audit Database
g-cm	gram centimeter
GPS	goblal positioning system
k	kilo (1000)
km	kilometer
lpm	liters per minute
MLM	Multilayer Model
m/s	meters per second
mv	millivolt
NADP	National Atmospheric Deposition Program
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPAP	National Performance Audit Program
NPS	National Park Service
OAQPS	Office of Air Quality Planning and Standards
PE	Performance Evaluation
ppb	parts per billion
ppm	parts per million

PSD	Prevention of Significant Deterioration
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RH	relative humidity
RTD	Resistance Temperature Detector
SJRWMD	Saint John's Water Management District
SLAMS	State or Local Air Monitoring Stations
SOP	standard operating procedure
SRP	standard reference photometer
SSRF	Site Status Report Forms
STP	standard temperature and pressure
TEI	Thermo Environmental Instruments
TTP	Through The Probe
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USNO	United States Naval Observatory
V	volts
VDC	volts direct current
Wood	Wood Environment and Infrastructure Solutions
WRR	World Radiation Reference

1.0 Introduction

The Clean Air Status and Trends Network (CASTNET) is a national air monitoring program established in 1988 by the US EPA. Nearly all CASTNET sites measures weekly concentrations of acidic gases and particles to provide accountability for EPA's emission reduction programs. Most sites measure ground-level ozone as well as supplemental measurements such as meteorology and/or other trace gas concentrations.

Ambient concentrations are used to estimate deposition rates of the various pollutants with the objective of determining relationships between emissions, air quality, deposition, and ecological effects. In conjunction with other national monitoring networks, CASTNET data are used to determine the effectiveness of national emissions control programs and to assess temporal trends and spatial deposition patterns in atmospheric pollutants. CASTNET data are also used for long-range transport model evaluations and critical loads research.

Historically, CASTNET pollutant flux measurements have been reported as the aggregate product of weekly measured concentrations and model-estimated deposition velocities. The Multi-layer Model (MLM) was used to derive deposition velocity estimates from on-site meteorological parameters, land use types, and site characteristics. In 2011, EPA discontinued meteorological measurements at most EPA-sponsored CASTNET sites.

Currently, CASTNET pollutant flux estimates are calculated as the aggregate product of weekly measured chemical concentrations and gridded model-estimated deposition velocities. Total deposition is assessed using the NADP's Total Deposition Hybrid Method (TDEP; EPA, 2015c; Schwede and Lear, 2014), which combines data from established ambient monitoring networks and chemical-transport models. To estimate dry deposition, ambient measurement data from CASTNET and other networks were merged with dry deposition rates and flux output from the Community Multiscale Air Quality (CMAQ) modeling system.

Since 2011 nearly all CASTNET ozone monitors have adhered to the requirements for State or Local Air Monitoring Stations (SLAMS) as specified by the EPA in 40 CFR Part 58. As such, the ozone data collected must meet the requirements in 40 CFR Part 58 Appendix A, which defines the quality assurance (QA) requirements for gaseous pollutant ambient air monitoring. The audits performed by EEMS under this contract fulfilled the requirement for annual performance evaluation audits of pollutant monitors in the network. The QA requirements can be found at:
https://www3.epa.gov/ttn/amtic/files/ambient/pm25/qa/APP_D%20validation%20template%20version%2003_2017_for%20AMTIC%20Rev_1.pdf

Currently 81 sites at 79 distinct locations measure ground-level ozone concentrations. Annual performance evaluation ozone audit QA data are submitted to the Air Quality System (AQS) database.

As of December 2018, the network is comprised of 95 active rural sampling sites across the United States and Canada, cooperatively operated by the Environmental Protection Agency (EPA), the National Park Service (NPS), Bureau of Land Management – Wyoming State Office (BLM-WSO) and several independent partners. Wood Environment and Infrastructure Solutions (Wood) is responsible for operating the EPA sponsored sites, and Air Resource Specialist, Inc. (ARS) is responsible for operating the NPS and BLM-WSO sponsored sites.

2.0 Project Objectives

The objectives of this project are to establish an independent and unbiased program of performance and systems audits for all CASTNET sampling sites. Ongoing QA programs are an essential part of any long-term monitoring network.

Performance audits verify that all reported parameters are consistent with the accuracy goals as defined in the CASTNET Quality Assurance Project Plan (QAPP). The acceptance criteria have changed over the years and EEMS relies on the CASTNET contractor to provide updates to the acceptance criteria. The current criteria are included in Table 2-1.

Due to budgetary necessity, the meteorological measurements were shifted to operating on an as-funded basis. The meteorological sensors were audited on an as directed basis.

Table 2-1. Performance Audit Challenge and Acceptance Criteria

Sensor	Parameter	Audit Challenge	Acceptance Criteria
Precipitation	Response	10 manual tips	1 DAS count per tip
Precipitation	Accuracy	2 introductions of known amounts of water	≤ ±10.0% of input amount
Relative Humidity	Accuracy	Compared to reference instrument or standard solution	≤ ±10.0%
Solar Radiation	Accuracy	Compared to WRR traceable standard	≤ ±10.0% of daytime average
Surface Wetness	Response	Distilled water spray mist	Positive response
Surface Wetness	Sensitivity	1% decade resistance	N/A
Shelter Temperature	Average Difference	Comparison to RTD at 3 observed points	2 °C
Temperature	Accuracy	Comparison to 3 NIST measured baths (~ 0° C, ambient, ~ full-scale)	≤ ± 0.5° C

Sensor	Parameter	Audit Challenge	Acceptance Criteria
Delta Temperature	Accuracy	Comparison to temperature sensor at same test point	≤ ± 0.50° C
Wind Direction	Orientation Accuracy	Parallel to alignment rod/crossarm, or sighted to distant point	≤ ±5° from degrees true
Wind Direction	Linearity	Eight cardinal points on test fixture	≤ ±5° mean absolute error
Wind Direction	Response Threshold	Starting torque tested with torque gauge	< 10 g-cm Climatronics; < 20 g-cm R. M. Young
Wind Speed	Accuracy	Shaft rotational speed generated and measured with certified synchronous motor	≤ ±0.5 mps below 5.0 mps input; ≤ ±5.0% of input at or above 5.0 mps
Wind Speed	Starting Threshold	Starting torque tested with torque gauge	< 0.5 g-cm
Mass Flow Controller	Flow Rate	Comparison with Primary Standard	≤ ± 5.0% of designated rate
Ozone	Slope	Linear regression of multi-point test gas concentration as measured with a certified transfer standard	0.9000 ≤ m ≤ 1.1000
	Intercept		-5.0 ppb ≤ b ≤ 5.0 ppb
	Correlation Coefficient		0.9950 ≤ r
	Percent Difference	Comparison with Standard Concentration	≤ ±15.1% of test gas concentration and ≤ ± 0.003 ppm actual difference*
DAS	Accuracy	Comparison with certified standard	≤ ± 0.003 VDC

* The CASTNET QAPP differs from the EPA OAQPS SLAMS for the Acceptance Criterion for Ozone Percent Difference. The EPA OAQPS for SLAMS criterion is ≤ ±10.0% of test gas concentration.

In addition to the accuracy goals defined in the CASTNET QAPP the ozone monitors fall under the requirements of 40 CFR, Part 58 Appendix A, for quality assurance. To comply with

Appendix A, the CASTNET audit program includes annual independent ozone performance evaluations (PE). The EEMS field scientists who conduct ozone PE maintain annual certification from the Office of Air Quality Planning and Standards (OAQPS). Audit methods and procedures used are compliant with the National Performance Audit Program (NPAP). EEMS personnel performed the NPAP Through-The-Probe (TTP) pollutant monitor audits following EPA's Quality Assurance Guidance Document – Method Compendium – Field Standard Operating Procedures (SOP) for the Federal $PM_{2.5}$ Performance Evaluation Program and NPAP-TTP Audit Standard Operating Procedures (SOP). All procedures and guidance documents used to perform these audits can be found at the EPA OAQPS website:
https://www3.epa.gov/ttn/amtic/npepqa.html

The NPAP is a QA program implemented by the OAQPS to conduct audits of gaseous air pollutant monitors by standard methods throughout each region of the U.S. The method includes introduction of National Institute of Standards and Traceability (NIST) audit gases to the station monitors through the ambient sample inlet, including all filters and fittings. This method evaluates measurement system accuracy through the entire sample train. The audit gas concentrations are also measured and verified with an audit analyzer on-site. For gases other than ozone the audit analyzer is calibrated at the time of the audit.

Performance audits are conducted using standards that are certified as currently traceable to the NIST or another authoritative organization. All standards are certified annually with the exception of ozone standards which are verified as level 2 standards at EPA regional labs at least twice per year.

Site systems audits are intended to provide a qualitative appraisal of the total measurement system. Site planning, organization, and operation are evaluated to ensure that good Quality Assurance/Quality Control (QA/QC) practices are being applied. At a minimum the following audit issues are addressed at each site systems audit:

- Site locations and configurations match those provided in the CASTNET QAPP.
- Meteorological instruments are in good physical and operational condition and are sited to meet EPA ambient monitoring guidelines (EPA-600/4-82-060).
- Sites are accessible, orderly, and if applicable, compliant with OSHA safety standards.
- Sampling lines are free of leaks, kinks, visible contamination, weathering, and moisture.
- Site shelters provide adequate temperature control.
- All ambient air quality instruments are functional, being operated in the appropriate range, and the zero air supply desiccant is unsaturated.
- All instruments are in current calibration.

- Site documentation (maintenance schedules, on-site SOPs, etc.) is current and log book records are complete.
- All maintenance and on-site SOPs are performed on schedule.
- Corrective actions are documented and appropriate for required maintenance/repair activity.
- Site operators demonstrate an adequate knowledge and ability to perform required site activities, including documentation and maintenance activities.

3.0 CASTNET Sites Visited in 2018

This report covers the CASTNET sites audited in 2018. Only those variables that were supported by the CASTNET program were audited. From March through December 2018, EEMS conducted field performance and systems audits at 37 monitoring sites. Meteorological sensors at four of the sites were also audited. The locations, sponsor agency and dates of the audits along with states and EPA Regions are presented in Table 3-1.

Table 3-1. Site Audits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
GRB411	NPS	Great Basin NP	NV / R9	3/26/2018
CAN407	NPS	Canyonlands NP	UT / R8	4/3/2018
JOT403	NPS	Joshua Tree NM	CA / R9	4/5/2018
IRL141	EPA	Indian River Lagoon	FL / R4	4/10/2018
SUM156	EPA	Sumatra	FL / R4	4/12/2018
PET427	NPS	Petrified Forest NP	AZ / R9	4/16/2018
GRC474	NPS	Grand Canyon NP	AZ / R9	4/17/2018
CHA467	NPS	Chiricahua NM	AZ / R9	4/19/2018
GAS153	EPA	Georgia Station	GA / R4	5/10/2018
SND152	EPA	Sand Mountain	AL / R4	5/11/2018
ESP127	EPA	Edgar Evins St. Park	TN / R4	5/12/2018
SPD111	EPA	Speedwell	TN / R4	5/13/2018
DIN431	NPS	Dinosaur NM	UT / R8	5/17/2018
FOR605	EPA	Fortification Creek	WY / R8	6/6/2018
NPT006	EPA	Nez Perce Tribe	ID / R10	7/3/2018
MEV405	NPS	Mesa Verde NP	CO / R8	8/7/2018
ARE128	EPA	Arendtsville	PA / R3	8/18/2018
MKG113	EPA	M. K. Goddard St. Park	PA / R3	8/20/2018
KEF112	EPA	Kane Experimental Forest	PA / R3	8/21/2018

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
PSU106	EPA	Penn State University	PA / R3	8/22/2018
ANA115	EPA	Ann Arbor	MI / R5	9/10/2018
HOX148	EPA	Hoxeyville	MI / R5	9/11/2018
UVL124	EPA	Unionville	MI / R5	9/12/2018
CTH110	EPA	Connecticut Hill	NY / R2	9/25/2018
HWF187	EPA	Huntington Wildlife Forest	NY / R2	9/30/2018
HOW191	EPA	Howland AmeriFlux	ME / R1	10/2/2018
ASH135	EPA	Ashland	ME / R1	10/4/2018
WST109	EPA	Woodstock	NH / R1	10/8/2018
DEN417	NPS	Denali NP	AK / R10	10/10/2018
RED004	EPA	Red Lake Nation	MN / R5	10/22/2018
SAL133	EPA	Salamonie Reservoir	IN / R5	10/27/2018
CAT175	EPA	Claryville	NY / R2	11/7/2018
ABT147	EPA	Abington	CT / R1	11/8/2018
PNF126	EPA	Cranberry	NC / R4	11/15/2018
BEL116	EPA	Beltsville	MD / R3	11/17/2018
DUK008	EPA	Duke Forest	NC / R4	12/5/2018
COW137	EPA	Coweeta	NC / R4	12/6/2018

In addition to the sites listed in Table 3-1 that were visited for complete systems and performance audits, the 40 sites listed in Table 3-2 were visited to conduct TTP ozone and other pollutant gas PE.

Table 3-2. Site Ozone PE Visits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
PAL190	EPA	Palo Duro	TX / R6	3/9/2018
ZIO433	NPS	Zion NP Dalton's Wash	UT / R8	4/6/2018
BBE401	NPS	Big Bend NP	TX / R6	4/23/2018
ALC188	EPA	Alabama-Coushatta	TX / R6	4/26/2018
BAS601	EPA	Basin	WY / R8	6/4/2018
NEC602	EPA	Newcastle	WY / R8	6/7/2018
CVL151	EPA	Coffeeville	MS / R4	6/15/2018
CAD150	EPA	Caddo Valley	AR / R6	6/16/2018
CHE185	EPA	Cherokee Nation	OK / R6	6/17/2018
CDZ171	EPA	Cadiz	KY / R4	6/23/2018
YEL408	NPS	Yellowstone NP	WY / R8	7/5/2018
GLR468	NPS	Glacier NP	MT / R8	7/6/2018
PND165	EPA	Pinedale	WY / R8	7/23/2018
PED108	EPA	Prince Edward	VA / R3	7/30/2018
VPI120	EPA	Horton Station	VA / R3	7/31/2018
CDR119	EPA	Cedar Creek St. Park	WV / R3	8/1/2018
PAR107	EPA	Parsons	WV / R3	8/1/2018
CKT136	EPA	Crockett	KY / R4	8/2/2018
MCK131	EPA	Mackville	KY / R4	8/3/2018
MCK231	EPA	Mackville (precision site)	KY / R4	8/3/2018
CHC432	NPS	Chaco NHP	NM / R6	8/6/2018
CNT169	EPA	Centennial	WY / R8	8/30/2018
PRK134	EPA	Perkinstown	WI / R5	9/17/2018
ACA416	NPS	Acadia NP	ME / R1	10/3/2018
VIN140	EPA	Vincennes	IN / R5	10/19/2018
ALH157	EPA	Alhambra	IL / R5	10/20/2018
VOY413	NPS	Voyageurs NP	MN / R5	10/23/2018

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
STK138	EPA	Stockton	IL / R5	10/25/2018
SAN189	EPA	Santee Sioux	NE / R7	10/26/2018
OXF122	EPA	Oxford	OH / R5	10/28/2018
LRL117	EPA	Laurel Hill St. Park	PA / R3	11/10/2018
BVL130	EPA	Bondville	IL / R5	11/11/2018
MAC426	NPS	Mammoth Cave NP	KY / R4	11/13/2018
DCP114	EPA	Deer Creek St. Park	OH / R5	11/14/2018
GRS420	NPS	Great Smoky Mountains NP	TN / R4	11/14/2018
BWR139	EPA	Blackwater NWR	MD / R3	11/16/2018
SHN418	NPS	Shenandoah NP - Big Meadows	VA / R3	11/19/2018
WSP144	EPA	Washington Crossing St. Park	NJ / R2	12/1/2018
QAK172	EPA	Quaker City	OH / R5	12/4/2018
CND125	EPA	Candor	NC / R4	12/5/2018

4.0 Performance Audit Results

This section provides the summarized performance evaluation (audit) results of each variable challenged at each station visited except for trace gas audit results. CASTNET operates trace gas monitors at several sites including three sites that are part of the NCORE Network (GRS420, MAC426, and BVL130). Performance evaluation audits of the CASTNET trace gas monitors were performed at BVL130, ROM206, PND165, HWF187, MAC426, GRS420, and PNF126 in 2018. Results of the NO_y, CO, and SO_2 monitor audits for those sites have been uploaded to the EPA AQS database and are not included in this report. All PE results for all monitors were within acceptance limits.

Performance audit results are discussed for each variable in the following sections. Tables are included to summarize the average and maximum error between the audit challenges and site results as recorded by the on-site Data Acquisition System (DAS). Linear regression and percent difference (% diff) calculation results are included where appropriate. Results that are outside the CASTNET QAPP acceptance criteria are shaded in the tables.

The errors presented in the tables in the following sections are reported as the difference of the measurement recorded by the DAS and the audit standard. Where appropriate, negative values indicate readings that were lower than the standard, and positive values indicate readings that were above the standard value. The errors appear to be random and without bias. The results are also arranged by audit date. Viewing the results in this order helps to detect any errors that could have been caused by the degradation or drift of the audit standards during the year. The audit standards are transported and handled with care, and properly maintained to help prevent such occurrences. No known problems with the standards were apparent during the year. All standards were within specifications when re-certified at the end of the year.

Detailed reports of the field site audits, which contain all of the test points for each variable at each site, can be found in the Appendices of each of the 2018 Quarterly reports. The variable specific data forms included in Appendix A of each quarter's report contain the challenge input values, the output of the DAS, additional relevant information pertaining to the variable and equipment, and all available means of identification of the sensors and equipment for each site.

Table 4.1 summarizes the number of test failures by variable tested. All station data are recorded from the station’s primary datalogger.

Table 4-1. Performance Audit Results by Variable Tested

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Ozone	73	1	1.4
Flow Rate	37	2	5.4
Shelter Temperature (average)	35	1	2.8
Wind Direction Orientation Average Error	4	0	0.0
Orientation Maximum Error	4	1	25
Wind Direction Linearity Average Error	4	0	0.0
Linearity Maximum Error	4	1	25
Wind Direction Starting Torque	3	0	0.0
Wind Speed Low Range Average Error	3	0	0.0
Low Range Maximum Error	3	1	33.3
Wind Speed High Range Average Error	3	1	33.3
High Range Maximum Error	3	1	33.3
Wind Speed Starting Torque	3	1	33.3
All Temperature Sensors	40	4	10
Relative Humidity	4	0	0.0
Solar Radiation	4	0	0.0
Precipitation	4	0	0.0
DAS Analog to Digital	33	0	0.0

4.1 Ozone

Seventy three ozone monitor audits were performed in 2018. All ozone challenges were conducted to comply with the OAQPS NPAP-TTP Standard Operating Procedures (SOP) which can be found at https://www3.epa.gov/ttn/amtic/npapsop.html. Each ozone monitor was challenged with ozone-free air and four up-scale concentrations. The ozone test gas concentrations were generated and measured with a NIST-traceable photometer that was verified as a level 2 standard by USEPA. The results of the ozone audits were uploaded to the AQS database at the end of each quarter.

Results of all ozone audits performed are included in Table 4-2. Only one monitor (MEV405) tested failed the annual PE with a level 2 test point difference above ± 3 ppb. It was noted that there were wildfires in the area at the time of the audit and that the ozone inlet filter was visibly contaminated. Tests with audit gas introduced upstream and downstream of the filter indicated a large pressure drop across the filter and that audit gas was scrubbed by the filter.

Some monitors responded low to ozone-free air which may also contribute to low response at the level 2 audit point.

Table 4-2. Performance Audit Results for Ozone

Site ID	Actual Difference for Level 2	Ozone Average (% diff) for Levels 3, 4 and 6	Ozone Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	Standard	Date
PAL190	0.29	0.5	0.7	0.99943	0.50033	0.99998	1110	3/9/2018
GRB411	-1.28	-2.2	-4.3	1.00068	-1.01085	0.99992	1110	3/26/2018
CAN407	-0.56	-0.8	-1.5	0.99814	-0.26156	0.99998	1110	4/3/2018
JOT403	0.25	1	1.3	1.00731	0.20872	0.99999	1110	4/5/2018
ZIO433	0.54	1.2	1.9	1.00431	0.28805	0.99998	1110	4/6/2018
PET427	-0.27	-1.2	-1.8	0.99262	-0.14499	0.99999	1110	4/16/2018
GRC474	-0.49	-1.7	-2.2	0.99403	-0.42301	0.99995	1110	4/17/2018
CHA467	-1.13	-4	-5.6	0.98088	-0.96843	0.99997	1110	4/19/2018
DIN431	0.43	-0.5	-1.3	0.9845	0.64081	0.99995	1110	5/17/2018
BAS601	-0.19	0.4	0.7	1.00258	0.02374	0.99999	1110	6/4/2018
NEC602	-1.79	-1.6	-3.9	1.01187	-1.41665	0.99994	1110	6/7/2018
NPT006	0.7	4.4	4.8	1.04879	-0.21685	0.99999	1110	7/3/2018
YEL408	0.41	8.1	9.3	1.09919	-0.95554	0.99997	1110	7/5/2018
GLR468	0.18	2	3	1.01182	0.37141	0.99997	1110	7/6/2018
PND165	-0.46	-2.7	-3.6	0.97782	-0.04803	0.99997	1110	7/23/2018
CHC432	-0.03	0.8	0.9	1.00902	-0.06102	1	1110	8/6/2018

Site ID	Actual Difference for Level 2	Ozone Average (% diff) for Levels 3, 4 and 6	Ozone Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	Standard	Date
MEV405	-5.76	-6.3	-10.7	0.98879	-2.76421	0.99885	1110	8/7/2018
CNT169	-0.08	2.2	3.1	1.03442	-0.47485	0.99997	1110	8/30/2018
IRL141	0.11	-0.6	-1.1	0.99181	0.26706	0.99998	1113	4/10/2018
BBE401	-1.46	-2.3	-3.9	0.99145	-0.70388	0.99993	1113	4/23/2018
ALC188	-0.68	-2	-3.6	1.00068	-0.87301	0.99996	1113	4/26/2018
SUM156	-0.73	-1.6	-2.3	1.00155	-1.06424	0.99998	1113	4/28/2018
GAS153	-2.46	-9.3	-11.8	0.93379	-1.32697	0.99996	1113	5/10/2018
SND152	-0.71	-1.4	-1.8	0.99526	-0.53683	0.99999	1113	5/11/2018
ESP127	-0.51	-2	-2.6	0.98976	-0.44844	0.99999	1113	5/12/2018
SPD111	0.17	-0.3	-1.3	0.99197	0.14502	0.99996	1113	5/13/2018
CVL151	-1.41	-1.6	-4.5	1.01283	-1.14547	0.99984	1113	6/15/2018
CAD150	-1.43	-5	-6.7	0.97654	-1.28958	0.99996	1113	6/16/2018
CHE185	0.17	-5	-5.6	0.94545	0.6716	0.99994	1113	6/17/2018
CDZ171	-0.96	-2.2	-3.9	0.99861	-1.01538	0.99999	1113	6/23/2018
PED108	-0.66	-2.3	-3.5	0.99518	-0.86871	0.99998	1113	7/30/2018
VPI120	-0.41	-0.4	-0.9	1.00707	-0.63289	1	1113	7/31/2018
CDR119	-0.69	-1.9	-2.6	0.98984	-0.45756	1	1113	8/1/2018
PAR107	-1.08	-2.4	-3.5	0.9906	-0.75436	0.99999	1113	8/1/2018
CKT136	-0.49	-2	-3	0.98748	-0.32891	0.99999	1113	8/2/2018
MCK131	-0.94	-1.6	-2	0.99623	-0.77359	1	1113	8/3/2018
MCK231	-0.53	-2.3	-3.2	0.98809	-0.56309	0.99999	1113	8/3/2018
ARE128	-0.52	-0.9	-2.2	1.00136	-0.47127	0.99999	1113	8/18/2018
MKG113	-0.12	-1.2	-1.5	0.98818	0.13975	0.99998	1113	8/20/2018
KEF112	-0.84	-2.5	-3.5	0.98924	-0.64896	0.99998	1113	8/21/2018
PSU106	-1.13	-5.1	-7.2	0.97946	-1.22536	0.99981	1113	8/22/2018
DEN417	-0.54	-0.8	-1.3	1.00172	-0.78036	0.99995	1113	10/10/2018
SAN189	-1.2	-2.6	-3.2	0.98377	-1.01678	0.99983	1113	10/26/2018
ANA115	0.36	2	2.2	1.01785	0.03993	1	1114	9/10/2018
UVL124	-0.45	-1.7	-2.1	0.98778	-0.12076	0.99998	1114	9/12/2018
HOX148	-0.64	0.2	1.5	1.01978	-0.80351	0.99996	1114	9/13/2018
PRK134	0.14	0.8	1.2	1.01014	-0.05475	0.99998	1114	9/17/2018
VIN140	0.22	1.9	2.4	1.01647	0.04168	0.99998	1114	10/19/2018
ALH157	-0.05	-0.2	1.2	0.98941	0.29214	0.99997	1114	10/20/2018
VOY413	-0.1	0	-0.4	1.00442	-0.24024	1	1114	10/23/2018
STK138	-0.24	-2.7	-2.8	0.97103	0.13936	1	1114	10/25/2018
SAL133	0.48	3.7	4.1	1.04441	-0.41066	1	1114	10/27/2018
OXF122	-0.17	1.2	1.4	1.01638	-0.2987	0.99999	1114	10/28/2018

Site ID	Actual Difference for Level 2	Ozone Average (% diff) for Levels 3, 4 and 6	Ozone Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	Standard	Date
DCP114	-0.59	-4.2	-4.6	1.01609	0.37187	0.99997	1114	11/14/2018
QAK172	-0.05	-0.4	-1	0.99049	0.12281	0.99998	1114	12/4/2018
COW137	-0.29	-0.2	-0.5	0.99914	-0.12425	0.99999	1114	12/7/2018
CTH110	0.41	-1	-2	0.97547	0.59409	0.99997	1115	9/25/2018
HWF187	-0.1	-3.1	-3.5	0.96137	0.40858	1	1115	9/30/2018
HOW191	-0.24	-2.3	-2.6	0.97614	-0.04959	0.99999	1115	10/2/2018
ACA416	1.15	6.4	7.5	1.05148	0.62233	0.99999	1115	10/3/2018
ASH135	-0.44	-2.1	-2.4	0.97553	0.19571	0.99998	1115	10/4/2018
WST109	0.7	-2.1	-3.5	0.95382	1.30927	0.99999	1115	10/8/2018
ABT147	0.02	1.1	1.8	1.00265	0.47031	0.99995	1115	11/8/2018
LRL117	-0.63	-2.3	-3.2	0.99021	-0.71289	1	1115	11/10/2018
BVL130	-0.83	-2.9	-3.7	0.98685	-0.87873	0.99999	1115	11/11/2018
MAC426	-0.63	-1.3	-1.9	0.99643	-0.55514	1	1115	11/13/2018
GRS420	1.17	2.1	2.3	0.96669	-0.34372	0.99997	1115	11/14/2018
PNF126	-0.15	1.3	3	1.01013	-0.33327	0.99988	1115	11/15/2018
BWR139	-1.39	0.3	2	1.03497	-1.85768	0.99998	1115	11/16/2018
BEL116	-0.58	-1.6	-2.5	0.99399	-0.56529	1	1115	11/17/2018
SHN418	0.78	-0.4	-0.8	0.98746	0.55993	0.99998	1115	11/19/2018
WSP144	-1.5	-3.1	-4.6	0.99263	-1.43695	1	1115	12/1/2018
CND125	-0.07	-2.6	-3.2	0.97813	-0.17465	0.99997	1115	12/5/2018

4.1.1 Ozone Bias

EEMS is aware of the EPA *Technical Assistance Document* "Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone" *October 2013* which can be found at the AMTIC website:
https://www3.epa.gov/ttn/amtic/files/ambient/qaqc/OzoneTransferStandardGuidance.pdf.

The document provides the rationale for standard photometer designation and the procedures required to ensure photometer stability. The process involves comparisons to a higher level standard (in this case a regional EPA level 1 standard) and also multiple comparisons on separate days, known as "6x6 verification". As described in the document, once the transfer standard comparison relationship with the level 1 standard has been established and the stability requirements are met, the actual ozone concentration is calculated by:

$$Std.O_3\ conc. = \frac{1}{\bar{m}}\ (Indicated\ O_3\ conc. - \bar{I})$$

Where:
$\bar{m}$ = average slope
$\bar{I}$ = average intercept

EEMS used this equation prior to 2017 with a rolling 6x6 average slope and intercept to correct level 2 standard photometer measurements back to the regional EPA level 1 standard reference photometer (SRP) for ozone PE audits. Since the technical assistance document also states that if any adjustments are made to the transfer standard a new 6x6 verification is required, EEMS did not adjust the physical settings (background and span) of the level 2 standards unless the photometer did not meet the criteria (+/- 3 %) comparison to the level 1 standard. Thereby only mathematical corrections were applied to the level 2 standard photometers.

Review of data prior to 2017 indicated that this procedure may have introduced a bias to the standard since the level 2 standards are only compared to the level 1 SRP two or three times per year. The rolling 6x6 slope and intercept averages may not have reflected the current relationship between the level 2 and the level 1 standards. This bias was observed in the data from the 2016 ozone PE audits.

In 2017, EEMS elected to deviate from the EPA Technical Assistance Document and began correcting the level 2 standard photometer using the most recent verification results rather than the rolling 6x6 results. Ozone PE audit data are presented in Figures 4-1 and 4-2 which show the actual concentration difference for level 2 audits, and the average percent differences of the ozone PE audits greater than level 2 performed in 2018.

Figure 4-1. 2018 Ozone PE Actual Difference Level 2 Audits

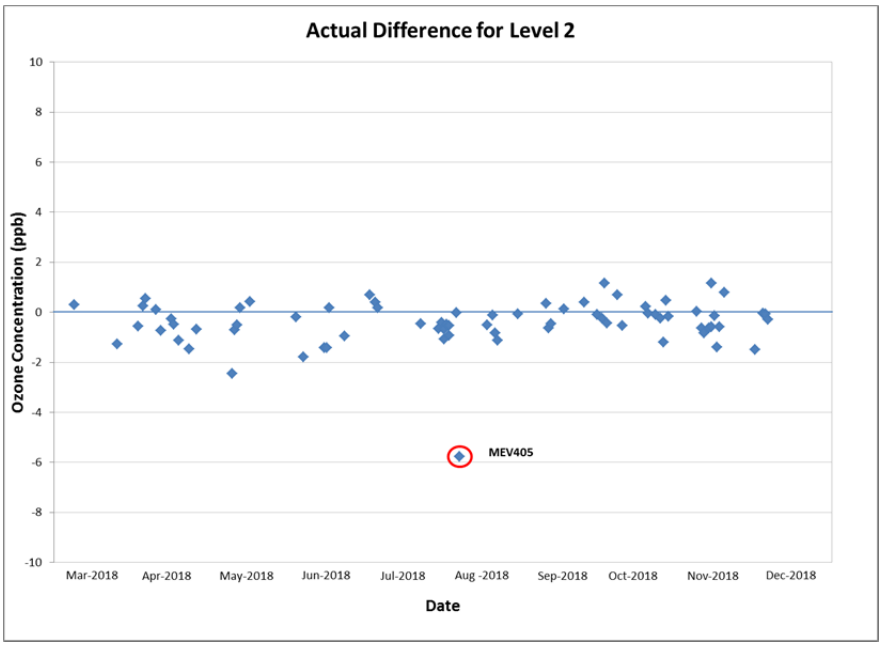
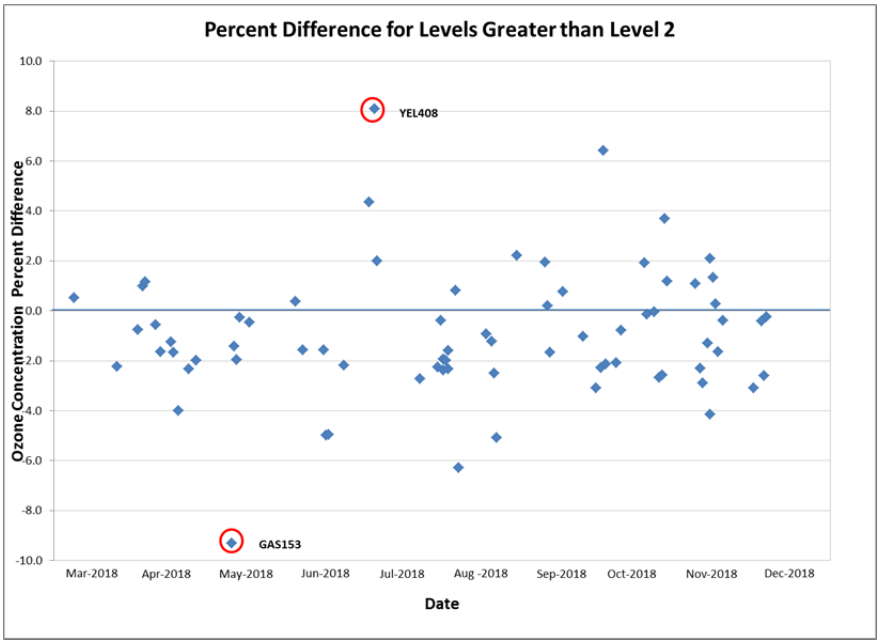


Figure 4-2. 2018 Average % Difference Ozone Audits Greater Than Level 2



When compared to 2017 data (Figures 4-3 and 4-4) the 2018 results appear to have a slight negative bias.

Figure 4-3. 2017 Ozone PE Actual Difference Level 2 Audits

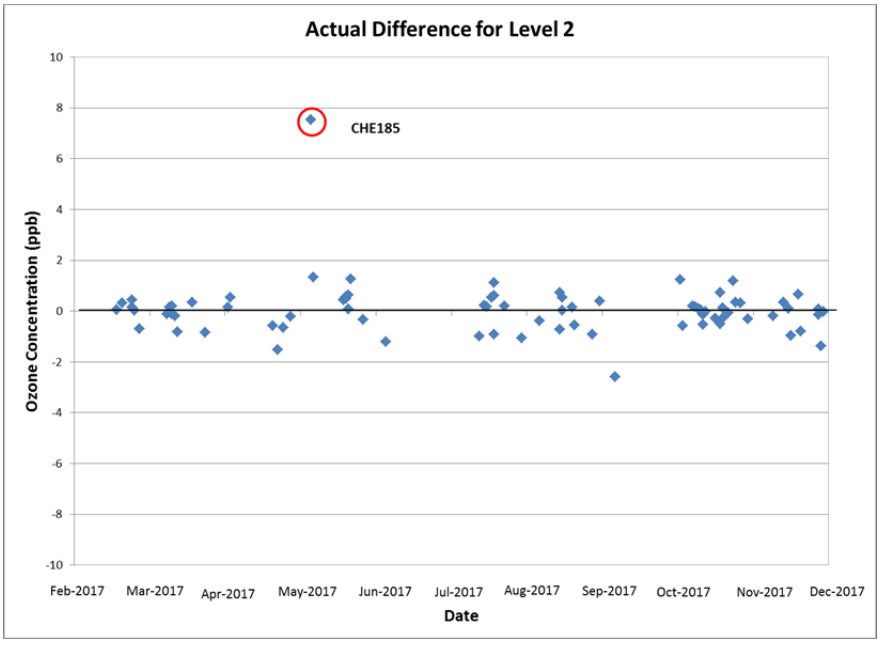
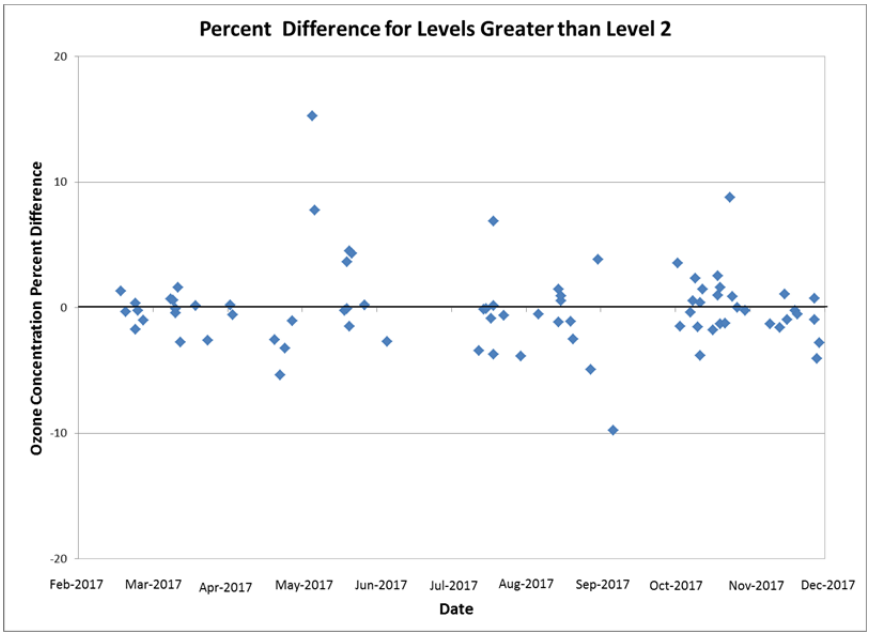


Figure 4-4. 2017 Average % Difference Ozone Audits Greater Than Level 2



As further investigation, EEMS has compiled ozone audit results from audits performed for clients other than CASTNET. The monitors include both SLAMS and Prevention of Significant Deterioration (PSD) stations.

Similar to Figure 4-1, Figure 4-5 is a plot of the actual difference for audit level 2 concentrations for audits performed at non-CASTNET sites in 2017 and 2018.

Figure 4-5. Level 2 Actual Difference for Non-CASTNET Data Collected

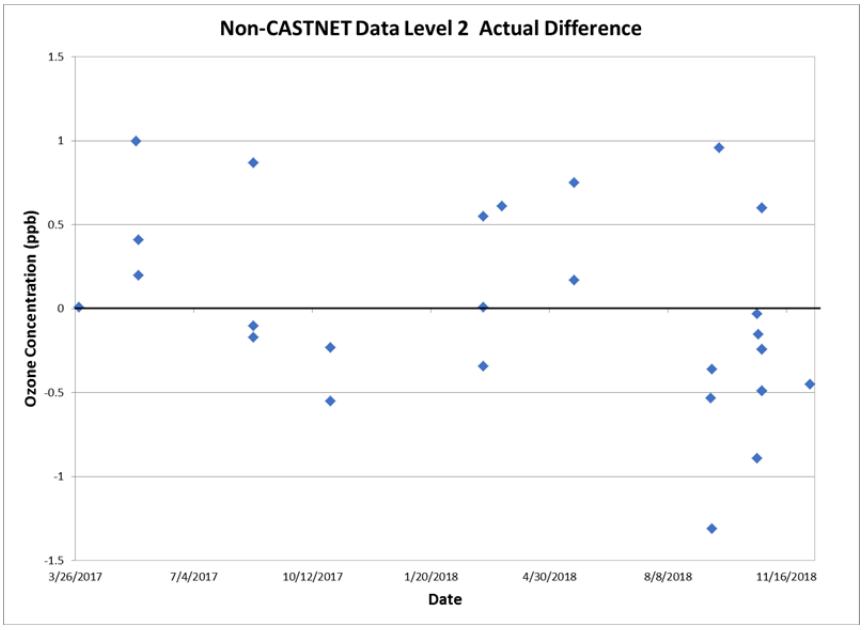
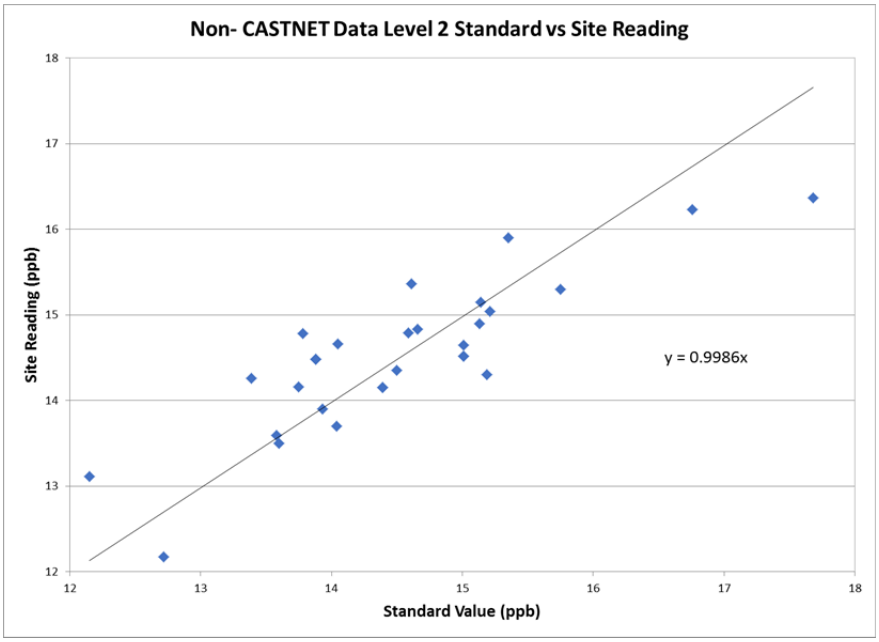


Figure 4-6 is a plot of the correlation between the EEMS standard and the site monitors for the level 2 audit points at non-CASTNET sites for 2017 and 2018.

Figure 4-6. Correlation between Level 2 Data for Non-CASTNET Sites



The data indicate that there is no apparent bias at level 2 audit points at sites that are not part of CASTNET. Figure 4-7 is a chart of the comparison of the EEMS standard to the site monitors for all points greater than level 2. Again, there appears to be no bias.

Figure 4-7. Correlation between Levels Greater than Level 2 for Non-CASTNET Sites

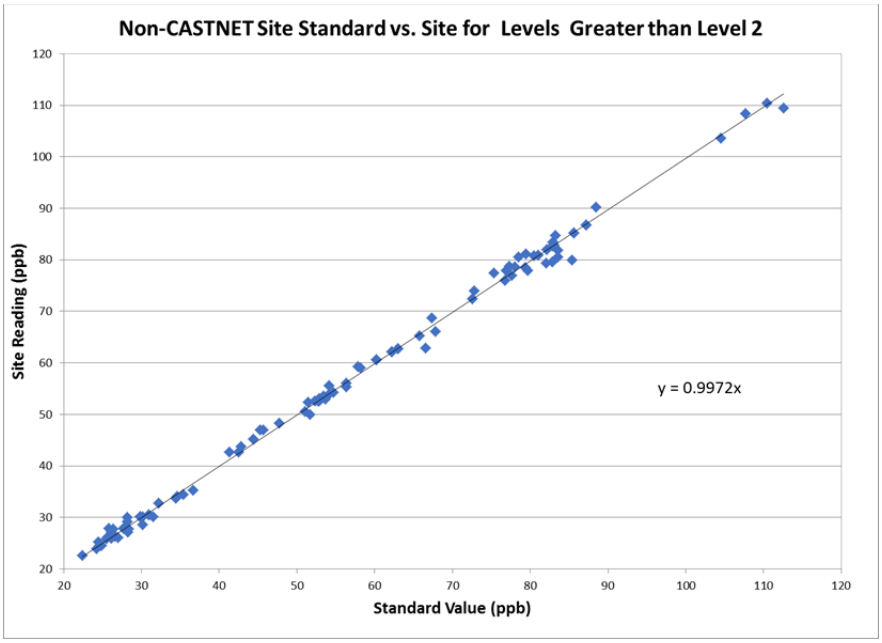
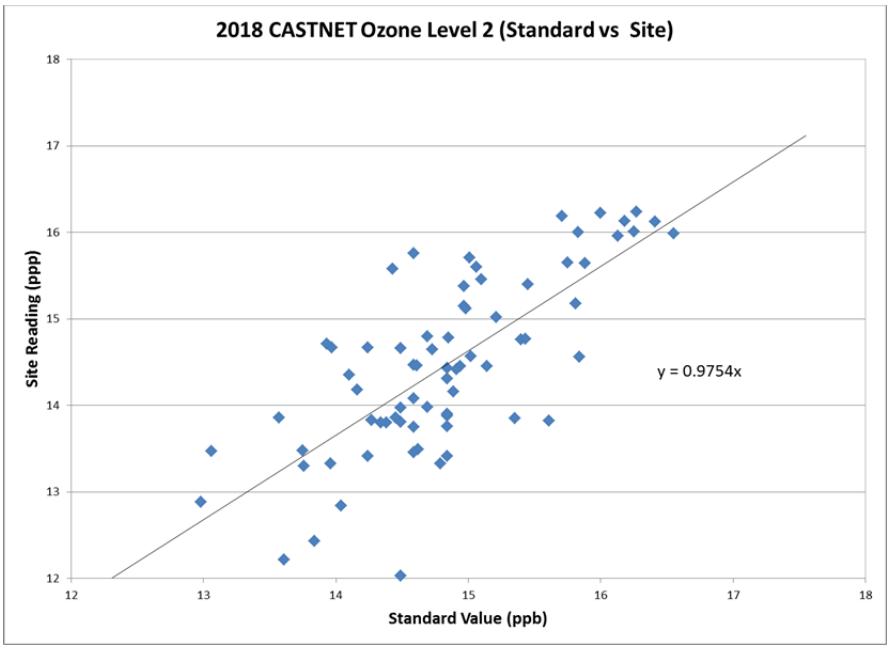


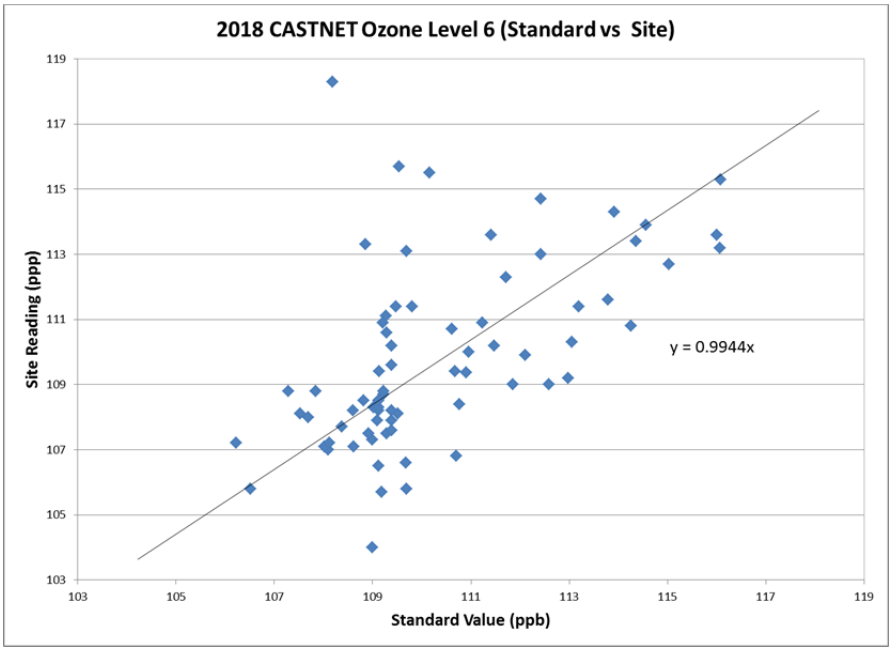
Figure 4-8 is the chart that compares the EEMS standard to the CASTNET monitors for all audits in 2018 at audit level 2. This chart (similar to Figure 4-1) indicates that there may be a slight negative bias with a slope of 0.9754.

Figure 4-8. Correlation between Level 2 Data for 2018 CASTNET Sites



Charts for each audit level were generated that compare the EEMS standard to the CASTNET monitors. At each increasing audit level, the slope of the comparison also increased. Figure 4-9 is the comparison for audit level 6.

Figure 4-9. Correlation between Level 6 Data for 2018 CASTNET Sites



This seems to indicate that there is little to no bias at level 6. It has been observed that many CASTNET monitors respond low when challenged with ozone-free air. In some cases, the EEMS standard may respond with a measurement slightly above zero when measuring ozone-free air. The data seem to indicate that the differences seen when measuring ozone-free air may be contributing to the bias at the lower audit levels.

It is important to note that none of the audit results (with the exception of MEV405 discussed separately) were above the acceptance criteria. It is also important to note that any observed bias is approaching the noise level of the monitors and may not be significant.

4.2 Flow Rate

The controlled flow rate operated by the CASTNET filter pack system was audited at 37 sites in 2018. Two sites (UVL124 and ABT147) were outside the acceptance criterion of ± 5.0%. All flow rates are in standard temperature and pressure (at 25 ^{o}C) (STP). A NIST-traceable dry-piston primary flow rate device was used for the tests. The readings obtained from this primary standard are the STP flow rate observed, while the DAS flow rate was read from the on-site data logger.

4.3 Shelter Temperature

At each site reporting ozone concentrations to AQS, the hourly average shelter temperature must be maintained between 20 and 30 degrees C. Shelter temperature was audited at 35 of the sites visited. All but one (CHC432) of the shelter temperature data accuracy results were found to be within the acceptance limit. The method consisted of placing the audit standard in close proximity (in situ) to the shelter temperature sensor and recording either instantaneous observations of both sensors, or averages from both sensors. A Resistance Temperature Detector (RTD) was used as the audit standard.

Nearly all of the site sensors were observed to lag behind the audit sensor during the rapid changes in temperature inside the shelter as the air conditioning or heating cycled on and off. In most instances the shelter temperature sensors never reached the minimum or maximum temperature measured with the audit standard. This is not likely to add a large error to the hourly averaged shelter temperature measurements. However, since the output of the shelter temperature sensors follow a sine wave curve but the actual shelter temperature does not change following a sine wave curve, if the shelter temperature is set near the lower or higher allowable limits (20 to 30 degrees C) the actual hourly averages may be lower or higher than those measured by the site sensors.

The CASTNET QAPP does not make a distinction between shelter temperature and any other temperature sensor regarding accuracy criteria. However the sensors were evaluated using a 2 degree C acceptance criterion. This criterion better follows the EPA OAQPS guidelines.

The shelter temperature and flow rate audit results are summarized in Table 4-3. Flow rate and shelter temperature data are reported only for the sites that were visited for complete systems and performance audits.

Table 4-3. Performance Audit Results Shelter Temperature, and Flow Rate

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)
GRB411	0.03	0.19	3.01	3.00	-0.33
CAN407	0.72	1.10	2.93	3.01	2.73
JOT403	0.58	0.69	2.96	3.01	1.57
IRL141	0.40	0.83	1.52	1.50	-1.10
SUM156	0.02	1.39	1.53	1.50	-2.17
PET427	-0.18	-0.79	3.00	3.01	0.34

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)
GRC474	0.76	0.95	2.97	3.02	1.43
CHA467	0.50	0.99	3.01	3.02	0.49
GAS153	0.53	1.08	1.55	1.50	-3.02
SND152	0.11	-0.77	1.52	1.50	-1.32
ESP127	0.24	0.37	1.54	1.50	-2.38
SPD111	0.34	0.89	1.52	1.50	-1.32
DIN431	0.31	0.57	3.00	3.00	-0.16
FOR605			3.07	3.05	-0.39
NPT006	0.25	0.47	2.95	3.00	1.66
CHC432	3.34	3.51			
MEV405	-0.77	-1.80	2.92	3.03	3.74
ARE128	0.34	0.36	1.56	1.50	-3.85
MKG113	0.15	0.70	1.51	1.50	-0.88
KEF112	-0.04	-0.54	1.53	1.50	-2.39
PSU106	0.32	0.44	1.54	1.50	-2.81
ANA115	-0.19	-0.53	1.52	1.50	-1.53
HOX148	-0.08	0.58	1.47	1.50	2.27
UVL124	0.17	0.42	2.02	1.50	-25.74
CTH110	1.13	1.42	1.53	1.50	-2.17
HWF187	-0.32	-0.42	1.55	1.50	-3.23
HOW191	0.77	1.03	1.53	1.53	0.00
ACA416	-0.24	-0.39			
ASH135	0.60	0.66	1.52	1.50	-1.10
WST109	-0.42	-0.64	1.51	1.50	-0.44
DEN417	0.58	0.97	2.96	3.01	1.93
RED004			3.06	3.01	-1.53
SAL133	-0.10	-1.12	1.57	1.50	-4.67
CAT175			1.52	1.50	-0.99
ABT147	-0.08	-0.17	2.03	1.50	-26.11
PNF126	0.03	0.07	1.50	1.50	0.00

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)
BEL116	-0.10	-0.11	1.48	1.50	1.12
DUK008			1.48	1.50	1.35
COW137	-0.31	1.16	1.54	1.50	-2.60

4.4 Wind Speed

The wind speed sensors at three sites equipped for meteorological measurements were audited. The wind speed data accuracy results at ACA416 were above the acceptance limit. The results of the wind speed performance audits are presented in Table 4-4. The state of Maine operates the meteorological sensors at ACA416. Audits in previous years have indicated similar results. The sensor appears to be accurate up to speeds above 20 m/s (over 45 mph) and then fails at higher speeds. It is likely that the sensor is not tested by the state at high wind speeds and this is not a concern.

4.4.1 Wind Speed Starting Threshold

The condition of the wind speed bearings were evaluated as part of the performance audits. The data acceptance criterion for wind speed bearing torque is not defined in the QAPP. However, ***Appendix 1: CASTNET Field Standard Operating Procedures***, states that the wind speed bearing torque should be ≤ 0.2 g-cm. To establish the wind speed bearing torque criterion for audit purposes the rational described in the QAPP for data quality objectives (DQO) was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically field criteria are set at approximately one-half the DQO. Therefore, 0.5 g-cm was used for the acceptance limit for audit purposes. This value is within the manufacturers' specifications for a properly maintained system. One of the systems (BEL116) was found to be above the acceptance limit.

4.5 Wind Direction

Two separate tests were performed to evaluate the accuracy of each wind direction sensor:

- A linearity test was performed to evaluate the ability of the sensor to function properly and accurately throughout the range from 1 to 360 degrees. This test evaluates the sensor independently of orientation and can be performed with the sensor mounted on a test fixture.

- An orientation test was used to determine if the sensor was aligned properly when installed to measure wind direction accurately in degrees true. An audit standard compass was used to perform the orientation tests.

The results of the wind direction performance audits are presented in Table 4-4. The average errors for all sensors were within the acceptance limits.

4.5.1 Wind Direction Starting Threshold

The condition of the wind direction bearings were evaluated as part of the performance audits. The data acceptance criterion for wind direction bearing torque is not defined in the QAPP. However, ***Appendix 1: CASTNET Field Standard Operating Procedures***, states that the wind direction bearing torque should be ≤ 10 g-cm for R. M. Young sensors. The manufacturer states that a properly maintained sensor will be accurate up to a starting threshold of 11 g-cm. To establish the wind direction bearing torque criterion for audit purposes the rational described in the QAPP for data quality objectives (DQO) was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically field criteria are set to approximately one-half the DQO. For audit purposes 20 g-cm was used for the acceptance limit for R. M. Young sensors. Climatronics sensors typically have a lower starting torque. For audit purposes a threshold of 10 g-cm was selected for Climatronics sensors. None of the sensors tested were outside of acceptance limits for wind direction starting threshold. The test results are provided in Table 4-4.

Table 4-4. Performance Audit Results for Wind Sensors

	Wind Direction					Wind Speed				
	Orientation Error		Linearity Error		Starting Torque (g-cm)	Low Range Error		High Range Error		Starting Torque (g-cm)
Site	Ave (deg)	Max (deg)	Ave (deg)	Max (deg)		Ave (m/s)	Max (m/s)	Ave (% diff)	Max (% diff)	
FOR605	3.0	5								
CHC432	2.0	4	1.00	3	5	-0.04	-0.2	0.3	1.0	0.3
ACA416	3.8	6	1.88	5.6	8.5	0.13	0.6	-6.5	-26.3	0.2
BEL116	3.5	5	0.93	2.1	10	-0.04	-0.2	-0.1	-0.7	0.55

* Note: The wind systems acceptance criteria were applied to the average of the results. The data validation section of the CASTNET QAPP states that if any wind direction or wind speed challenge result is outside the acceptance criterion the variable is flagged.

4.6 Temperature and Two-Meter Temperature

With the exception of DUK008, the EPA sponsored site temperature measurement systems consist of a temperature sensor mounted on a tower approximately 9 meters above ground-level. Sites operated by the Park Service have moved the temperature sensors to approximately two meters above the ground (2-meter temperature). The DUK008 sensor is mounted on a walk-up tower above treetop canopy at approximately 30 meters above ground.

The BLM has recently upgraded the temperature sensors at their sites to submersible RTD sensors. However, the sensor operating at CHC432 is a combined relative humidity and temperature sensors and not standalone RTD or encased thermistor temperature sensor. Due to the design of the RH/Temperature sensor, it cannot be submerged in water baths in order to challenge the sensor at different temperature audit levels. For that reason, the combination RH/Temperature sensor was audited by placing the sensor in a watertight chamber (RH salt chamber) and then placing the chamber in an ice-water bath, ambient bath, and hot water bath. Therefore, the temperature audit results for site CHC432 are not directly comparable to audit results of RTD or encased thermistor sensors.

All sites use shields to house the sensors that are either mechanically aspirated with forced air, or naturally aspirated. In all cases the sensors were removed from the sensor shields, and placed in a uniform temperature bath with a precision NIST-traceable RTD, during the audit.

A total of forty temperature sensors were tested, and four were found to be above acceptance criterion. It should be noted that one of those sensors (CHC432) is a combination RH/Temperature sensor as described above and cannot be submersed in a water-bath. The average errors for all sensors are presented in Table 4-5.

4.6.1 Temperature Shield Blower Motors

All fourteen of the temperature systems with sensor shield blower motors (forced-air aspiration) encountered during the site audits conducted during 2018 were found to be functioning.

4.7 Relative Humidity

The four relative humidity systems that were audited were tested with a combination of primary standard salt solutions, and a NIST traceable transfer standard relative humidity probe. The results of the average and maximum errors throughout the measurement range of approximately 30% to 95% are presented in Table 4-5. All humidity sensors were within the acceptable limits.

As in previous years, operation of both temperature and humidity sensors with respect to natural or forced-air aspiration can vary between sites. At most EPA sponsored sites temperature and humidity sensors are operating in naturally aspirated shields. At most NPS sponsored sites temperature and humidity sensors are operating in shields designed to be mechanically aspirated with forced-air blowers.

During humidity audit tests with the primary standard salt solutions, the sensors were removed from the shields and placed in a temperature-controlled enclosure. During audit tests with the transfer standard probe, the sensor and transfer were placed in the same ambient conditions. Therefore the audit tests do not account for differences in the operation of the sensors due to the different shield configurations.

Table 4-5. Performance Audit Results for Temperature and Relative

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity	
			Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
GRB411		0.00		
CAN407		-0.15		
JOT403		-0.13		
IRL141	-0.24			
SUM156	-0.03			
PET427		0.66		
GRC474		0.09		
CHA467		0.39		
GAS153	-0.02			
SND152	-0.04			
ESP127	0.28			
SPD111	-0.02			
DIN431		0.01		
FOR605	0.00		-1.5	-3.9
NPT006	-0.25			
CHC432		-2.50	-3.1	-4.5

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity	
			Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
MEV405		0.20		
ARE128	-0.32			
MKG113	-0.14			
KEF112	-0.07			
PSU106	0.01			
ANA115	-0.13			
HOX148	-0.09			
UVL124	-0.04			
CTH110	-0.01			
HWF187	0.09			
HOW191	0.01			
ACA416		-0.04	2.4	3.7
ASH135	-0.03			
WST109	-0.04			
DEN417		-0.18		
RED004	-1.38			
SAL133	0.03			
CAT175	-0.15			
ABT147	-0.11			
PNF126	-0.06			
BEL116	-0.36	-0.08	2.6	5
DUK008	-0.53			
COW137	0.00			

4.8 Solar Radiation

The ambient conditions encountered during the audit visits were suitable (high enough light levels) for accurate comparisons of solar radiation measurements. A World Radiation Reference (WRR) traceable Eppley PSP radiometer and translator or a model 8-48 were used as the audit standard system.

Four sites were tested. All sites had daytime average results that were within the acceptance criterion. The results of the individual tests for each site are included in Table 4-6. The percent difference of the maximum single-hour average solar radiation value observed during each site audit is also reported in Table 4-6 although this criterion is not part of the CASTNET data quality indicators. All maximum values were also within ±10%.

4.9 Precipitation

The four sites audited used a tipping bucket rain gauge for obtaining precipitation measurement data. The audit challenges consisted of entering multiple amounts of a known volume of water into the tipping bucket funnel at a rate equal to approximately 2 inches of rain per hour. Equivalent amounts of water entered were compared to the amount recorded by the DAS. The results are summarized in Tables 4-6. All sensors were within the acceptance criteria.

Table 4-6. Performance Audit Results for Solar Radiation and Precipitation

Site	Solar Radiation Error				Precipitation Ave. Error (% diff)
	Daytime Ave. (% diff)	Std. Max. Value (w/m2)	Site Max. Observed (w/m2)	Max. Value (% diff)	
FOR605	-6.2	975	903	-7.4	-2.1
CHC432	-0.1	1029	1014	-1.5	1.8
ACA416	0.8	376	366	-2.7	-6.0
BEL116	4.6	494	512.3	3.7	2.0

4.10 Data Acquisition Systems (DAS)

All of the NPS sponsored sites visited utilized an ESC logger as the primary and only DAS. All EPA sites visited operated Campbell Scientific loggers as their only DAS. The results presented in table 4-7 include the tests performed on the logger at each site. The BLM sites utilize a

Campbell Scientific CR1000. The CR1000 and some of the other loggers encountered are not configured to allow analog tests.

4.10.1 Analog Test

The accuracy of each logger was tested on two different channels (if two channels were available to be used) with a NIST-traceable Fluke digital voltmeter. At the EPA sponsored sites the channels above analog channel 8 could not be tested since there were no empty channels available to test. All data loggers were within the acceptance criterion of ± 0.003 volts.

4.10.2 Functionality Tests

Other performance tests used to evaluate the DAS included the verification of the date and time., All site data loggers were found to be set to the correct date and within ±5 minutes per the acceptance criterion for time. The NPS sponsored site data loggers were found to be set to the correct date and within ±5 minutes of the acceptance criterion for time. However, most of the NPS clocks were found to be 1 to 3 minutes different than the standard, whereas the EPA sponsored site clocks were all within 2-3 seconds. The Campbell Scientific logger clocks at the EPA sites are synchronized with the internet, whereas the ESC loggers at the NPS sites are not.

Table 4-7. Performance Audit Results for Data Acquisition Systems

Date	Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
		Low Channel		High Channel			
		Average	Maximum	Average	Maximum		
3/26/2018	GRB411					Y	-1.38
4/3/2018	CAN407	0.0001	0.0002			Y	1.00
4/5/2018	JOT403			0.0000	0.0002	Y	-0.95
4/10/2018	IRL141			0.0000	-0.0002	Y	0.00
4/12/2018	SUM156			0.0000	0.0001	Y	0.00
4/16/2018	PET427	0.0000	0.0003			Y	-0.33
4/17/2018	GRC474	0.0003	0.0006			Y	-1.37
4/19/2018	CHA467	0.0003	0.0004			Y	0.25
5/10/2018	GAS153			0.0001	0.0003	Y	0.00
5/11/2018	SND152			0.0000	0.0001	Y	0.00
5/12/2018	ESP127			-0.0001	-0.0002	Y	0.00

Date	Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
		Low Channel		High Channel			
		Average	Maximum	Average	Maximum		
5/13/2018	SPD111			-0.0001	-0.0002	Y	0.00
5/17/2018	DIN431	0.0002	0.0003			Y	1.57
8/6/2018	CHC432	0.0003	0.0008			Y	-0.60
8/7/2018	MEV405	-0.0003	-0.0004			Y	-0.22
8/18/2018	ARE128			0.0000	0.0001	Y	0.00
8/20/2018	MKG113			-0.0001	-0.0002	Y	0.00
8/21/2018	KEF112			0.0000	0.0001	Y	0.00
8/22/2018	PSU106			0.0000	-0.0002	Y	0.00
9/10/2018	ANA115			0.0002	0.0005	Y	0.00
9/11/2018	HOX148			0.0001	0.0002	Y	0.03
9/12/2018	UVL124			0.0000	0.0001	Y	0.00
9/25/2018	CTH110			-0.0001	-0.0002	Y	0.00
9/30/2018	HWF187					Y	-0.25
10/2/2018	HOW191			0.0000	0.0001	Y	-0.02
10/3/2018	ACA416	-0.0003	-0.0004			Y	-1.33
10/4/2018	ASH135			0.0000	0.0001	Y	0.07
10/8/2018	WST109			-0.0001	-0.0002	Y	-0.03
10/10/2018	DEN417			0.0001	0.0002	Y	2.67
10/22/2018	RED004			-0.0017	-0.0021	Y	0.00
10/27/2018	SAL133			-0.0001	-0.0002	Y	0.00
11/8/2018	ABT147			-0.0001	-0.0001	Y	0.02
11/15/2018	PNF126			-0.0001	-0.0001	Y	0.00
11/17/2018	BEL116			0.0000	-0.0001	Y	0.05
12/6/2018	COW137			-0.0001	-0.0005	Y	-0.02

5.0 Systems Audit Results

The following sections summarize the site systems audit findings and provide information observed regarding the measurement processes at the sites. Conditions that directly affect data accuracy have been reported in the previous sections. Other conditions that affect data quality and improvements to some measurement systems or procedures are suggested in the following sections.

5.1 Siting Criteria

All of the sites that were visited have undergone changes during the period of site operation which include population growth, road construction, and foresting activities. None of those changes were determined to have a significant impact on the siting criteria that did not exist when the site was initially established.

Some sites that are located in state and national parks are not in open areas, and have trees within the 50 meter criterion established in the QAPP. Given the land use and aesthetic concerns, these sites are acceptable and represent an adequate compromise with regard to siting criteria and the goal of long-term monitoring. For sites that measure ozone data designated as NAAQS compliant, these sites may violate recommended siting criteria in 40 CFR Part 58.

The CASTNET QAPP is currently being revised to more closely follow 40 CFR Part 58 Appendix E. The audit program will incorporate those changes when they are implemented.

5.2 Sample Inlets

With consideration given to the siting criteria compromises described in the previous section, all but four sites (LAV410, YEL408, VOY413, and CDR119) visited in 2018 have ozone monitor sample trains that are sited properly and in accordance with the CASTNET QAPP. All ozone sample inlets are currently being evaluated with respect to obstructions above the inlet. The acceptance criterion requires that there should be no obstructions (including trees) within a 22.5 degree angle (object distance must be at least two times the height) above the ozone inlet. There are trees that violate the 22.5 degree sample inlet requirement at the four sites listed above.

Ozone sample inlets are between 3 and 15 meters. With the exception of one site (WNC429) Teflon tubing of the proper diameter is used for the ozone inlets. The ozone sample train at WNC429 is primarily glass with an exhaust fan downstream of the ozone sample port. The ozone analyzer at WNC429 (South Dakota) is operated by the State.

With the exception of WNC429, the ozone zero, span, and precision calibration test gases are introduced at the ozone sample inlet, through all filters and the entire sample train. All sample trains are comprised of only Teflon fittings and materials. Sample inlet particulate filters of 5 micron are present at most sites.

The dry deposition filter packs are designed to sample from 10 meters. Most of the filter pack sample lines are also Teflon. Inline filters are present in the sample trains to prevent moisture and particulates from damaging the flow rate controller.

5.3 Infrastructure

Sites continue to be improved by repairing the site shelters which had deteriorated throughout the years of operation. The installation and upgrade of the data loggers and replacement of degrading signal cables, has been very beneficial to the network. A few of the site shelters are still in need of repair, but overall the condition of the sites has improved again during the past year.

5.4 Site Operators

Generally the site operators are very conscientious and eager to complete the site activities correctly. They are willing to, and have performed sensor replacements and repairs at the sites with support provided by the Wood and ARS field operations centers. In some cases, where replacements or repairs were made, documentation of the activities was not complete, and did not include serial numbers of the removed and installed equipment.

Many of the CASTNET site operators also perform site operator duties for the National Atmospheric Deposition Program (NADP). Many of the NPS site operators also perform other air, or environmental quality functions within their park. All are a valuable resource for the program.

Still many of the site operators have not been formally trained to perform the CASTNET duties by either Wood or ARS. They had been given instructions by the previous site operators and over the phone instructions from the field operation centers at Wood and ARS.

5.5 Documentation

There were some documentation problems with the Site Status Report Forms (SSRF) completed by the site operators each week during the regular site visits. Common errors included improper reporting of "initial flow", "final flow", and "leak check" values.

The NPS site operator procedures are well developed and readily accessible at all of the NPS sites visited. There is an electronic interface (DataView 2) available to view, analyze, and print site data. There are electronic "checklists" for the site operator to complete during the site visits; however, all of the CASTNET filter pack procedures are not included in the "checklists". Flow rates and leak check results are not recorded electronically.

An electronic logbook is included in the interface software. This system permits easy access to site documentation data. Complete calibration reports have been added to the system and accessible through the site computer, however the reports available on-site are not up to date.

5.6 Site Sensor and FSAD Identification

Continued improvement has also been made in the area of documentation of sensors and systems used at the sites. It is important to maintain proper sensor identification for the purposes of site inventory and to properly identify operational sensors for data validation procedures. Many sensors have had new numbers affixed for proper identification.

Where possible the identification numbers assigned (serial numbers and barcodes) are used within the field site audit database for all the sensors encountered during the site audits. The records are used for both the performance and systems audits. If a sensor is not assigned a serial number by the manufacturer, that field is entered as "none". If it is unknown whether an additional client ID number is assigned to a sensor, and a number is not found, the client ID is also entered as "none". If it is typical for a manufacturer and/or client ID number to be assigned to a sensor, and that number is not present, the field is entered as "missing". If either the serial number or the client ID numbers cannot be read, the field is entered as "illegible". An auto-number field is assigned to each sensor in the database in order to make the records unique.

6.0 Summary and Recommendations

The CASTNET Site Audit Program has been successful in evaluating the field operations of the sites. The results of performance and systems audits are recorded and archived in a relational database, the Field Site Audit Database (FSAD). CASTNET site operations are generally acceptable and continue to improve. Some differences between actual site operations and operations described in the QAPP have been identified and described. Procedural differences between EPA and NPS sponsored sites have also been described.

As discussed previously the shelters have received some much needed attention. It was also observed that improvements were made to the shelter temperature control systems. As a requirement in 40 CFR Part 58 for ozone monitoring, shelter temperature is an important variable. Additional improvement could be made to accurately measure and report shelter temperature.

The previous paragraphs and sections included some recommendations for improving the field operations systems. One recommendation for improving the audit program is presented in the following section.

6.1 In Situ Comparisons

An improvement to the audit procedures designed to evaluate the differences in measurement technique would be to develop an "In Situ" audit measurement system. This would require a suite of sensors that would be collocated with the site sensors. Ideally the audit sensors would address the inconsistent sensor installations observed throughout the network. By deploying a suite of certified NIST traceable sensors installed and operating as recommended by the manufacturer and to EPA guidelines, subtle differences in the operation of the existing CASTNET measurement systems could be evaluated. The "In Situ" sensors would be operated at each site for a 24 hour period and the measurements would be compared to the CASTNET measurements. A portable system of meteorological sensors would be beneficial for meteorological measurement evaluations particularly at BLM sponsored sites. EEMS is still pursuing this type of audit system.

7.0 References

Office of Air Quality and Planning Standards AMTIC website, SOP and guidance documents: www.epa.gov/ttn/amtic/

Quality Assurance Handbook for Air Pollution Measurement Systems: Volume II - Ambient Air Specific Methods – EPA.

Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV - Meteorological Measurements – EPA.

Clean Air Status and Trends Network (CASTNET) Quality Assurance Project Plan (2003) – EPA.

Quality Assurance Handbook for Air Pollution Measurement Systems: Volume I: - A Field Guide To Environmental Quality Assurance – EPA.

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Sensitivity of the National Oceanic and Atmospheric Administration multilayer model to instrument error and parameterization uncertainty: Journal of Geophysical Research, Vol. 105. No. D5, March 16, 2000.

Wind System Calibration, Recommended Calibration Interval, Procedure, and Test Equipment: November 1999, R. M. Young Company

Bowker, G.E., Schwede, D.B.; Lear, G.G.; Warren-Hicks, W.J., and Finkelstein, P.L., 2011. Quality assurance decisions with air models: a case study of imputation of missing input data using EPA's multi-layer model. Water, Air, and Soil Pollution 222, 391e402.

APPENDIX 1

Audit Standards Certifications

FINAL SUMMARY AUDIT REPORT FLOW BASED
EEMS Van-2

Site Name: EPA-07 Audit Date: 10/30/2018

Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Actual Difference (ppm)	Pass/Fail	Warning
Ozone						
Pre Zero	0.0000	0.0000	0.0	0.0000		
Audit Level 6					N/A	
Audit Level 4					N/A	
Audit Level 3					N/A	
Audit Level 2					N/A	
Post Zero						
Carbon Monoxide						
Pre Zero	-0.002	0.014		0.0161	Pass	
CO Audit level 4	2.203	2.203	0.0	0.0005	Pass	
CO Audit level 4	1.521	1.528	0.5	0.0070	Pass	
CO Audit level 3	0.606	0.610	0.6	0.0037	Pass	
CO Audit level 2	0.092	0.127	38.0	0.0351	Pass	Warning
CO Audit level 1	0.033	0.031	-7.0	-0.0023	Pass	
Post Zero	-0.002	0.004		0.0061	Pass	
Oxides of Nitrogen						
Pre Zero	0.0000	0.0003		0.0003	Pass	
NO Audit Point #1	0.0649	0.0654	0.8	0.0005	Pass	
NO Audit Point #2	0.0448	0.0452	0.8	0.0004	Pass	
NO Audit Point #3	0.0179	0.0181	1.1	0.0002	Pass	
NO Audit Point #4	0.0027	0.0038	40.7	0.0011	Pass	
NO Audit Point #5	0.0010	0.0010	0.0	0.0000	Pass	
Post Zero	-0.0001	0.0001		0.0002	Pass	
Pre Zero	0.0000	0.0004		0.0004	Pass	
NOx Audit Point #1	0.0649	0.0652	0.5	0.0003	Pass	
NOx Audit Point #2	0.0448	0.0450	0.3	0.0001	Pass	
NOx Audit Point #3	0.0179	0.0179	0.0	0.0000	Pass	
NOx Audit Point #4	0.0027	0.0038	40.7	0.0011	Pass	
NOx Audit Point #5	0.0010	0.0010	0.0	0.0000	Pass	
Post Zero	-0.0001	0.0002		0.0003	Pass	
Pre Zero	0.0000	0.0004		0.0004		
NO2 Audit level 5	0.0438	0.0432	-1.3	-0.0006	Pass	
NO2 Audit level 4	0.0017	0.0187	-1.6	0.0170	Pass	
NO2 Audit level 2	0.0045	0.0044	-2.2	-0.0001	Pass	
NO2 Audit level 1	0.0000	0.0000	0.0	0.0000	Pass	
Post Zero	-0.0001	0.0002		0.0003	Pass	
Converter Efficiency NO2 level 5	99.2%				Pass	
Converter Efficiency NO2 level 4	99.7%				Pass	
Converter Efficiency NO2 level 2	102.2%				Pass	
Converter Efficiency NO2 level 1	100.0%				Pass	
Sulfur Dioxide						
Pre Zero	-0.0001	-0.0004		-0.0003	Pass	
SO2 Audit level 6	0.0664	0.0647	-2.6	-0.0017	Pass	
SO2 Audit level 5	0.0459	0.0451	-1.8	-0.0008	Pass	
SO2 Audit level 4	0.0183	0.0175	-4.2	-0.0008	Pass	
SO2 Audit level 2	0.0028	0.0032	12.9	0.0004	Pass	
SO2 Audit level 1	0.0010	0.0005	-51.0	-0.0005	Pass	
Post Zero	-0.0001	-0.0002		-0.0001	Pass	

FINAL SUMMARY AUDIT REPORT CO BASED
EEMS Van-2

Site Name: EPA-07 Audit Date: 10/30/2018

Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Actual Difference (ppm)	Pass/Fail	Warning
Ozone						
Pre Zero						
Audit Level 6					N/A	
Audit Level 4					N/A	
Audit Level 3					N/A	
Audit Level 2					N/A	
Post Zero						
Carbon Monoxide						
Pre Zero	-0.0014	0.014		0.01538	Pass	
CO Audit level 4	2.1844	2.203	0.9	0.01859	Pass	
CO Audit level 4	1.5098	1.528	1.2	0.01825	Pass	
CO Audit level 3	0.5971	0.610	2.2	0.01289	Pass	
CO Audit level 2	0.1248	0.127	2.1	0.00262	Pass	
CO Audit level 1	0.0247	0.031	23.6	0.00582	Pass	
Post Zero	-0.0022	0.004		0.00619	Pass	
Oxides of Nitrogen						
Pre Zero	-0.00004	0.0003		0.0003	Pass	
NO Audit Point #1	0.06437	0.0654	1.6	0.0010	Pass	
NO Audit Point #2	0.04449	0.0452	1.5	0.0007	Pass	
NO Audit Point #3	0.01759	0.0181	2.9	0.0005	Pass	
NO Audit Point #4	0.00368	0.0038	3.3	0.0001	Pass	
NO Audit Point #5	0.00073	0.0010	37.0	0.0003	Pass	
Post Zero	-0.00006	0.0001		0.0002	Pass	
Pre Zero	-0.00004	0.0003		0.0003	Pass	
NOx Audit Point #1	0.06437	0.0652	1.3	0.0008	Pass	
NOx Audit Point #2	0.04449	0.0450	1.0	0.0005	Pass	
NOx Audit Point #3	0.01759	0.0179	1.8	0.0003	Pass	
NOx Audit Point #4	0.00368	0.0038	3.3	0.0001	Pass	
NOx Audit Point #5	0.00073	0.0010	37.0	0.0003	Pass	
Post Zero	-0.00006	0.0002		0.0003	Pass	
Pre Zero	0.00000	0.00010		0.00010	Pass	
NO2 Audit level 5	0.04332	0.04323	-0.2	-0.00009	Pass	
NO2 Audit level 4	0.01882	0.01870	-0.6	-0.00012	Pass	
NO2 Audit level 2	0.00445	0.00440	-1.1	-0.00005	Pass	
NO2 Audit level 1	0.00168	0.00170	1.2	0.00002	Pass	
Post Zero	0.00000	0.00000		0.00000	Pass	
Converter Efficiency NO2 level 5	99.2%				Pass	
Converter Efficiency NO2 level 4	99.7%				Pass	
Converter Efficiency NO2 level 2	102.2%				Pass	
Converter Efficiency NO2 level 1	100.0%				Pass	
Sulfur Dioxide						
Pre Zero	-0.00004	-0.00040		-0.00036	Pass	
SO2 Audit level 6	0.06588	0.06467	-1.8	-0.00121	Pass	
SO2 Audit level 5	0.04553	0.04506	-1.0	-0.00047	Pass	
SO2 Audit level 4	0.01801	0.01753	-2.7	-0.00048	Pass	
SO2 Audit level 2	0.00376	0.00316	-16.0	-0.00060	Pass	
SO2 Audit level 1	0.00074	0.00049	-33.8	-0.00025	Pass	
Post Zero	-0.00007	-0.00024		-0.00017	Pass	

FINAL SUMMARY AUDIT REPORT CO BASED
EEMS Van-3

Site Name: EPA R-7 Audit Date: 10/31/2018

Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Actual Difference (ppm)	Pass/Fail	Warning
Ozone						
Pre Zero						
Ozone audit level 6					N/A	
Ozone audit level 5					N/A	
Ozone audit level 4					N/A	
Ozone audit level 3					N/A	
Ozone audit level 2					N/A	
Post Zero						
Carbon Monoxide						
Pre Zero	0.0029	-0.001		-0.00411	Pass	
CO Audit level 4	2.6153	2.589	-1.0	-0.02634	Pass	
CO Audit level 4	1.5272	1.516	-0.7	-0.01077	Pass	
CO Audit level 3	0.5585	0.559	0.0	-0.00003	Pass	
CO Audit level 2	0.1518	0.156	2.9	0.00433	Pass	
CO Audit level 1	0.0506	0.056	10.7	0.00542	Pass	
Post Zero	-0.0022	0.004		0.00623	Pass	
Oxides of Nitrogen						
Pre Zero	0.00008	0.00000		-0.00008	Pass	
NO Audit Point #1	0.07625	0.07810	2.4	0.00185	Pass	
NO Audit Point #2	0.04453	0.04520	1.5	0.00067	Pass	
NO Audit Point #3	0.01628	0.01650	1.4	0.00022	Pass	
NO Audit Point #4	0.00442	0.00450	1.8	0.00008	Pass	
NO Audit Point #5	0.00147	0.00150	2.0	0.00003	Pass	
Post Zero	-0.00007	0.00000		0.00007	Pass	
Pre Zero	0.00009	0.00000		-0.00009	Pass	
NOx Audit Point #1	0.07758	0.07730	-0.4	-0.00028	Pass	
NOx Audit Point #2	0.04530	0.04470	-1.3	-0.00060	Pass	
NOx Audit Point #3	0.01657	0.01630	-1.6	-0.00027	Pass	
NOx Audit Point #4	0.00450	0.00430	-4.4	-0.00020	Pass	
NOx Audit Point #5	0.00150	0.00140	-6.7	-0.00010	Pass	
Post Zero	-0.00007	-0.00010		-0.00003	Pass	
Pre Zero	0.00000	0.00000		0.00000		
NO2 Audit level 5	0.04929	0.04880	-1.0	-0.00049	Pass	
NO2 Audit level 4	0.01798	0.01750	-2.7	-0.00048	Pass	
NO2 Audit level 2	0.00370	0.00350	-5.4	-0.00020	Pass	
NO2 Audit level 1	0.00136	0.00100	-26.5	-0.00036	Pass	
Post Zero	0.00000	-0.00010		-0.00010	Pass	
Converter Efficiency NO2 level 5	101.1%				Pass	
Converter Efficiency NO2 level 4	102.9%				Pass	
Converter Efficiency NO2 level 2	102.9%				Pass	
Converter Efficiency NO2 level 1	100.0%				Pass	
Sulfur Dioxide						
Pre Zero	0.00009	-0.0003		-0.0004	Pass	
SO2 Audit level 6	0.08262	0.0795	-3.8	-0.0032	Pass	
SO2 Audit level 5	0.04825	0.0457	-5.3	-0.0026	Pass	
SO2 Audit level 4	0.01765	0.0166	-6.2	-0.0011	Pass	
SO2 Audit level 2	0.00479	0.0037	-23.2	-0.0011	Pass	
SO2 Audit level 1	0.00160	0.0011	-31.3	-0.0005	Pass	
Post Zero	-0.00007	-0.0003		-0.0002	Pass	

Ozone Certification Records

TEI # 49CPS-70008-364 **EEMS# 01110** **Van 2**

EPA file	date	start time	slope	intercept	correlatioin	location
c1030001	30-Oct-18	12:36	0.99854	-0.01471	1	R-7
c1030002	30-Oct-18	13:47	0.99987	0.07221	1	R-7
c1030003	30-Oct-18	14:54	1.00049	0.02946	1	R-7
c1030004	30-Oct-18	16:01	1.00194	-0.06198	1	R-7
c1030005	30-Oct-18	17:08	1.00053	0.03421	1	R-7
c1030006	30-Oct-18	18:14	1.00346	-0.08366	1	R-7
c1030007	30-Oct-18	19:21	1.00366	0.03229	1	R-7
c1030008	30-Oct-18	20:27	1.00361	0.04543	1	R-7
c1030009	30-Oct-18	21:34	1.00196	0.07279	1	R-7
c1030010	30-Oct-18	22:40	1.00424	-0.08910	1	R-7
		AVG =	**1.001513**	**0.006656**	**1**	

Ozone Transfer Standard Verification Summary Report

U. S. Environmental Protection Agency
Region 4 Science and Ecosystem Support Division
Enforcement and Investigations Branch
Superfund and Air Section
980 College Station Rd.
Athens, GA 30605

EEMS# 01113

	EPA Standard	GUEST Instrument
Agency:	EPA Region 4	EEMS
Contact:	Keith Harris	Eric Hebert
Make:	NIST	Thermo
Model:	SRP	49CPS
S/N:	10	517112167

SESD Project #: 18-0504
Test #: #1 "as found"

Guest Test Status: PASS
Guest Known Offset: 0

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0047	0.0888	0.999995	452	0
Upper Tolerance:	1.0300	3.0000			
LowerTolerance:	0.9700	-3.0000			

Cycle Start Date / Time	File Name	Slope	Intercept	R^2	Upper Range (ppb O_3)	Lower Range (ppb O_3)
6/11/18 5:44 PM	Cal18061100.xls	1.0048	-0.1497	0.9999968	447	-0.10
6/11/18 7:21 PM	Cal18061101.xls	1.0043	0.1144	0.9999992	451	-0.07
6/11/18 8:58 PM	Cal18061102.xls	1.0028	0.0908	0.9999930	452	0.18
6/11/18 10:34 PM	Cal18061103.xls	1.0054	0.1292	0.9999961	452	-0.21
6/12/18 12:11 AM	Cal18061200.xls	1.0059	-0.0218	0.9999917	453	-0.21
6/12/18 1:48 AM	Cal18061201.xls	1.0046	0.2092	0.9999906	453	-0.05
6/12/18 3:25 AM	Cal18061202.xls	1.0051	0.2493	0.9999961	454	-0.02

Comments:

Instrument tested as found.
Ozone calibration factors at time of test: O3 BKG: -0.2 ppb O3 COEF: 1.015

Verification Expires on: June 12, 2019

Keith Harris Date 06/12/18

Ozone Transfer Standard Verification Summary Report

U. S. Environmental Protection Agency
Region 4 Science and Ecosystem Support Division
Enforcement and Investigations Branch
Superfund and Air Section
980 College Station Rd.
Athens, GA 30605

	EPA Standard	GUEST Instrument
Agency:	EPA Region 4	EEMS
Contact:	Mike Crowe	Eric Hebert
Make:	NIST	Thermo
Model:	SRP	49CPS
S/N:	10	517112167
Guest Test Status:		**PASS**
Guest Known Offset:		0

SESD Project #: 18-0684
Test #: #1 "as found" and "as left"

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0040	-0.2990	0.9999948	466	0
Upper Tolerance:	1.0300	3.0000			
LowerTolerance:	0.9700	-3.0000			

Cycle Start Date / Time	File Name	Slope	Intercept	R^2	Upper Range (ppb O_3)	Lower Range (ppb O_3)
9/6/18 4:30 PM	Cal18090600.xls	1.0011	-0.3694	0.9999963	462	0.01
9/6/18 6:08 PM	Cal18090601.xls	1.0023	-0.2375	0.9999955	467	-0.03
9/6/18 7:46 PM	Cal18090602.xls	1.0041	-0.2949	0.9999984	466	-0.12
9/6/18 9:23 PM	Cal18090603.xls	1.0049	-0.3866	0.9999898	466	0.14
9/6/18 11:01 PM	Cal18090604.xls	1.0036	0.0000	0.9999939	468	-0.17
9/7/18 12:39 AM	Cal18090700.xls	1.0068	-0.4757	0.9999934	466	0.17
9/7/18 2:17 AM	Cal18090701.xls	1.0057	-0.3287	0.9999966	466	0.13

Comments:

Instrument tested as found.
Ozone calibration factors at time of test: O3 BKG: -0.2 ppb O3 COEF: 1.015

Verification Expires on: **September 7, 2019**

Mike Crowe Date 9/7/18

Ozone Transfer Standard Verification Summary Report

U. S. Environmental Protection Agency
Region 4 Science and Ecosystem Support Division
Enforcement and Investigations Branch
Superfund and Air Section
980 College Station Rd.
Athens, GA 30605

	EPA Standard	GUEST Instrument
Agency:	EPA Region 4	EEMS
Contact:	Mike Crowe	Eric Hebert
Make:	NIST	Thermo
Model:	SRP	49i
S/N:	10	1180030022

SESD Project #: 18-0685 **Guest Test Status:** **PASS**
Test #: #1 **Guest Known Offset:** 0

"as left"

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0029	0.1098	0.999998	466	0.02
Upper Tolerance:	1.0300	3.0000			
LowerTolerance:	0.9700	-3.0000			

Cycle Start Date / Time	File Name	Slope	Intercept	R^2	Upper Range (ppb O_3)	Lower Range (ppb O_3)
9/6/18 4:30 PM	Cal18090600.xls	1.0029	-0.0058	0.9999992	462	0.01
9/6/18 6:08 PM	Cal18090601.xls	1.0015	0.1241	0.9999981	467	-0.03
9/6/18 7:46 PM	Cal18090602.xls	1.0032	0.0080	0.9999991	466	-0.12
9/6/18 9:23 PM	Cal18090603.xls	1.0032	0.0787	0.9999960	466	0.14
9/6/18 11:01 PM	Cal18090604.xls	1.0016	0.3333	0.9999989	468	-0.17
9/7/18 12:39 AM	Cal18090700.xls	1.0045	0.0649	0.9999976	466	0.17
9/7/18 2:17 AM	Cal18090701.xls	1.0036	0.1654	0.9999983	466	0.13

Comments: New Level 2 standard. Prior to test one instrument was adjusted to more closely match the SRP.

Ozone calibration factors at time of test: O3 BKG: -0.4 ppb O3 COEF: 0.990

Instrument within tolerance.

Verification Expires on: **September 7, 2019**

Mike Crowe Mike Crowe Date 9/7/18

Ozone Transfer Standard Verification Summary Report

U. S. Environmental Protection Agency
Region 4 Science and Ecosystem Support Division
Enforcement and Investigations Branch
Superfund and Air Section
980 College Station Rd.
Athens, GA 30605

EEMS #01114 (van 3)

	EPA Standard	GUEST Instrument
Agency:	EPA Region 4	EEMS
Contact:	Mike Crowe	Eric Hebert
Make:	NIST	Thermo
Model:	SRP	49i
S/N:	10	1180030022
Guest Test Status:		**PASS**
Guest Known Offset:		0

SESD Project #:

Test #: #1 "as found" and "as left"

Level 2 Averages:	Slope	Intercept	R^2	High O_3	Lower O_3
	0.9984	0.2709	0.9999986	363	0
Upper Tolerance:	1.0300	3.0000			
LowerTolerance:	0.9700	-3.0000			

Cycle Start Date / Time	File Name	Slope	Intercept	R^2	Upper Range (ppb O_3)	Lower Range (ppb O_3)
6/11/19 5:01 PM	Cal19061101.xls	0.9984	0.2057	0.9999981	360	0.24
6/11/19 6:37 PM	Cal19061102.xls	0.9975	0.3485	0.9999992	363	-0.02
6/11/19 8:13 PM	Cal19061103.xls	0.9992	0.1985	0.9999984	363	0.12
6/11/19 9:50 PM	Cal19061104.xls	0.9980	0.3826	0.9999987	364	-0.14
6/11/19 11:26 PM	Cal19061105.xls	0.9991	0.0000	0.9999981	364	-0.13
6/12/19 1:02 AM	Cal19061200.xls	0.9983	0.3572	0.9999990	365	0.12
6/12/19 2:39 AM	Cal19061201.xls	0.9986	0.4040	0.9999988	365	-0.05

Comments:

Instrument tested as found.
Ozone calibration factors at time of test: O3 BKG: -0.4 ppb O3 COEF: 0.990

Instrument within tolerance

Verification Expires on: **June 12, 2020**
September 12, 2019 (For NPAP use)

Mike Crowe Date 6/12/19

Ozone Transfer Standard Verification Summary Report

U. S. Environmental Protection Agency
Region 4 Science and Ecosystem Support Division
Enforcement and Investigations Branch
Superfund and Air Section
980 College Station Rd.
Athens, GA 30605

EEMS # 01115

	EPA Standard	GUEST Instrument
Agency:	EPA Region 4	EEMS
Contact:	Keith Harris	Eric Hebert
Make:	NIST	TEI
Model:	SRP	49 iQps
S/N:	10	1180930075

SESD Project #: 19-0229
Test #: # 1 "as left"

Guest Test Status: PASS
Guest Known Offset: 0

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0080	-0.4021	0.9999972	465	0
Upper Tolerance:	1.0300	3.0000			
LowerTolerance:	0.9700	-3.0000			

Cycle Start Date / Time	File Name	Slope	Intercept	R^2	Upper Range (ppb O_3)	Lower Range (ppb O_3)
3/25/19 4:13 PM	Cal19032501.xls	1.0014	-0.5404	0.9999967	463	-0.14
3/25/19 5:54 PM	Cal19032502.xls	1.0020	-0.5316	0.9999971	465	-0.06
3/25/19 7:31 PM	Cal19032503.xls	1.0132	-0.4537	0.9999977	467	-0.17
3/25/19 9:09 PM	Cal19032504.xls	1.0121	-0.3056	0.9999979	466	-0.20
3/25/19 10:45 PM	Cal19032505.xls	1.0140	0.0000	0.9999975	464	0.12
3/26/19 12:22 AM	Cal19032600.xls	1.0057	-0.4967	0.9999960	465	0.05
3/26/19 1:59 AM	Cal19032601.xls	1.0073	-0.4869	0.9999976	465	0.14

Comments: New Level 2 standard. Prior to test one instrument was adjusted to more closely match the SRP.

Ozone calibration factors at time of test: O3 BKG: 0.31 ppb O3 COEF: 1.013

Verification Expires on: **March 26, 2020**

Keith Harris Date 03/26/19

Date

2/8/2018 - - **Calculation of correction factor for RH standard with most recent certification of EEMS Hygropalm**

TMI Cert date = 1/24/2018

	TMI STD	EEMS Hygropalm		
Cert #	A2722301	01225		
			diff	corrected
	15.0	15.3	-0.3	14.9
	25.0	25.2	-0.2	25.1
	35.0	35.3	-0.3	35.5
	33.0	32.6	0.4	32.7
	50.0	49.4	0.6	50.0
	75.0	73.6	1.4	74.9

RH 01225

2018 correction: slope= 0.9705

intercept= 0.8783

corr = 0.9999229

Eric Hebert 2/8/2018

At EEMS	**Date 2/8/2018**	translator =	01220		Kestrel		
Hygropalm 01225			EEMS Van 2		EEMS AER		EEMS
		ID =	01220		2093323		
raw	corrected		raw	corrected	raw	corrected	raw	corrected
66.6	67.72		66.1	67.39	66.3	66.54		#DIV/0!
71.2	72.46		71.8	73.36	72.2	72.89		#DIV/0!
95.7	97.70		95.0	97.67	94.4	96.77		#DIV/0!
45.6	46.08		44.9	45.17	50.2	49.21		#DIV/0!
4.0	3.22		5.2	3.57	6.1	1.76		#DIV/0!
	-0.90			-1.88		-4.80		#DIV/0!
	-0.90			-1.88		-4.80		#DIV/0!
	-0.90			-1.88		-4.80		#DIV/0!
		Thermocouple offset =	N/A		N/A		N/A	
POST CALIBRATION CHECK								
	-0.90			-1.88		-4.80		#DIV/0!
	slope =		**0.954301**		**0.9293934**		**#DIV/0!**	
	intercept =		**1.789636**		**4.4601953**		**#DIV/0!**	
	correlation =		**0.9998**		**0.9986**		**#DIV/0!**	

Certificate Number
A2722301
Issue Date: 01/24/18

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01225

Description: THERMO HYGROMETER
Manufacturer: ROTRONIC
Model Number: HYGROPALM
Serial Number: 40861 002/124431
Technician: STEVE TORRES
On-Site Calibration: ☐
Comments:

Calibration Date: 01/24/2018
Calibration Due: 01/24/2019
Procedure: TMI-M-HYGROTHERMOGRAPHS
Rev: 2/22/2011
Temperature: 71 F
Humidity: 38 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the SI units through the National Institute of Standards and Technology (NIST) or other National Metrological Institute (NMI). The method of calibration is direct comparison to a known standard, derived from natural physical constants, ratio measurements or compared to consensus standards.

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration is within the current Scope of Accreditation and complies with the requirements of ISO/IEC 17025:2005 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
0710649	THUNDER SCIENTIFIC	2500ST	8/26/2017	3/25/2018

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Certificate Number
A2722301
Issue Date: 01/24/18

Certificate of Calibration

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
Temperature Accuracy	15.0	14.6	15.4	15.3	15.3	C	
Temperature Accuracy	25.0	24.6	25.4	25.2	25.2	C	
Temperature Accuracy	35.0	34.6	35.4	35.3	35.3	C	
Humidity Accuracy	33.0	31.4	34.6	32.6	32.6	%	
Humidity Accuracy	50.0	48.4	51.6	49.4	49.4	%	
Humidity Accuracy	75.0	73.4	76.6	73.6	73.6	%	

EEMS # 01225

Slope = 0.9705

Int = 0.8783

r^2 = 0.99992

2/2/2018

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Date

2/13/2018 **- - Calibration and verification of three RTD meters with most recent certification of EEMS RTD**

TMI Cert data -- 1/24/2018

	TMI STD	EEMS RTD 01229	diff	corrected
Cert #	A2380069			
	-25.00	-25.04	0.040	-25.024
	0.00	0.01	-0.010	0.030
	100.00	99.96	0.040	99.994
	150.00	149.96	0.040	150.000

RTD 01229

2018 correction: slope= 0.9998626

intercept= -0.019771

corr= 1.0000000

Eric Hebert 2/13/2018

At EEMS raw	**Date 2/13/2018** RTD 01229 corrected	EEMS raw	corrected	**RTD 01226** EEMS van 2 raw	corrected	**RTD 01228 / 3** EEMS van 1 raw	corrected
0.06	0.08		#DIV/0!	0.04	0.08	-0.01	0.08
12.45	12.47		#DIV/0!	12.43	12.49	12.45	12.43
21.37	21.39		#DIV/0!	21.36	21.52	21.48	21.29
29.83	29.85		#DIV/0!	29.82	29.86	29.99	29.86
40.14	40.17		#DIV/0!	40.13	40.16	40.38	40.17
48.38	48.41		#DIV/0!	48.37	48.40	48.67	48.40
24.97	24.99		#DIV/0!	24.96	25.00	25.10	25.00
slope =		**#DIV/0!**		**1.00010**		**1.007566**	
intercept =		**#DIV/0!**		**-0.03870**		**-0.0921**	
correlation =		**#DIV/0!**		**1.0000**		**1.0000**	

Certificate Number
A2721736
Issue Date: 01/24/18

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01229

Description:	DIGITAL STIK THERMOMETER	Calibration Date:	01/24/2018
Manufacturer:	FLUKE	Calibration Due:	01/24/2019
Model Number:	1551A EX	Procedure:	FLUKE 1551A EX,52A EX Rev: 11/1/2010
Serial Number:	3275143	Temperature:	71 F
Technician:	STEVE TORRES	Humidity:	38 % RH
		As Found Condition:	**IN TOLERANCE**
		Calibration Results:	**IN TOLERANCE**

On-Site Calibration: ☐
Comments: TUR is 2 to 1

Limiting Attribute:

This instrument has been calibrated using standards traceable to the SI units through the National Institute of Standards and Technology (NIST) or other National Metrological Institute (NMI). The method of calibration is direct comparison to a known standard, derived from natural physical constants, ratio measurements or compared to consensus standards.

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration is within the current Scope of Accreditation and complies with the requirements of ISO/IEC 17025:2005 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
899976	FLUKE	5618B-12	12/6/2016	2/21/2018
A11967	HART SCIENTIFIC	9140	3/30/2017	5/8/2018
A88072	FLUKE/HART	1502A	12/14/2017	3/20/2018
B7B759	HART SCIENTIFIC	9103	11/28/2017	11/28/2018

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Certificate Number
A2721736
Issue Date: 01/24/18

Certificate of Calibration

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
Temperature Accuracy	-25.00	-25.05	-24.95	-25.04	-25.04	°C	
Temperature Accuracy	0.00	-0.05	0.05	0.01	0.01	°C	
Temperature Accuracy	100.00	99.95	100.05	99.96	99.96	°C	
Temperature Accuracy	150.00	149.95	150.05	149.96	149.96	°C	

FEMS # 01229

Slope = 0.9998626

Inter = -0.019771

r^2 = 1.00000

ED 2/2/2018

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

EPLAB

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

EEMS#
01245
01246

Instrument: Precision Spectral Pyranometer, Model PSP, Serial Number 34341F3

Procedure: This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.

Transfer Standard: Eppley Precision Spectral Pyranometer, Model PSP, Serial Number 21231F3

Results:

Sensitivity: **$S = 9.41\ \mu V / Wm^{-2}$**
Uncertainty: $U_{95} = \pm 0.91\%$ (95% confidence level, k=2)
Resistance: 699 Ω at 23°C

Date of Test: February 14, 2018

Traceability: This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Twelfth International Pyrheliometric Comparisons (IPC XII) at Davos, Switzerland in September-October 2015. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".

Due Date: Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.

Customer: EEMS
Gainesville, FL

Signatures: Dulra L. Gentry
In Charge of Test:

Thomas J. Kirk
Reviewed by:

Eppley SO: 65150

Date of Certificate: February 14, 2018

Remarks: Outer hemisphere replaced. Unit paired with 455 Amplifier #10765.
Amplifier set to Gain = 75.91 so that 1 V output = 1400 Wm^{-2}.

End of Report

PACKING LIST

The Eppley Laboratory, Inc.
12 Sheffield Ave.

Phone # 401-847-1020 Fed. ID No. 05-0136490

S.O. No. 65150

2/13/2018

Name / Address

EEMS
Att: Eric Hebert
1128 NW 39th Drive
Gainesville, FL 32605

Ship To

EEMS
Att: Eric Hebert
1128 NW 39th Drive
Gainesville, FL 32605

EEMS # 01245/01246

P.O...

Ship Date 2/23/2018

Ship Via FedEx COLLECT

Recalibration Model 8-48 # 23824

Recalibration of Model PSP # 34341F3 NO CASES
REPLACE OUTER HEMISPHERE

Reset Amplifier # 10765 w/ CABLE

SET GAIN SO 1V = 1400 W_M^{-2}

$1400 \times S = V_{FULL}$

$S =$ 9.41

$V_{FULL}(\mu V) =$ 13174

$V_{FULL}(V) =$ 0.013174

$GAIN = \frac{1V}{V_{FULL}(V)} =$ 75.91

Made in USA

Terms Credit Card

FOB Newport, RI USA

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

EEMS # 01247

Instrument: Black & White Pyranometer, Model 8-48, Serial Number 23824

Procedure: This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.

Transfer Standard: Eppley Black & White Pyranometer, Model 8-48, Serial Number 14061

Results:

Sensitivity: **$S = 8.82\ \mu V / Wm^{-2}$**

Uncertainty: $U_{95} = \pm 0.91\%$ (95% confidence level, k=2)

Resistance: 347 Ω at 23°C

Date of Test: February 13, 2018

Traceability: This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Twelfth International Pyrheliometric Comparisons (IPC XII) at Davos, Switzerland in September-October 2015. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".

Due Date: Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.

Customer: EEMS
Gainesville, FL

Signatures: Debra L. Hunter — In Charge of Test: Thomas D. Kirk — Reviewed by:

Eppley SO: 65150

Date of Certificate: February 14, 2018

Remarks:

End of Report

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

CERTIFICATE OF CALIBRATION AND TESTING

Model: 18802/18811
Serial Number: CA04013

Description: Anemometer Drive - 2 motors, 20 to 15,000 RPM
(18802 comprised of 18820A Control Unit and 18830A Motor Assembly)
(18811 comprised of 18820A Control Unit and 18831A 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.

EEMS
01253
01254
01255

Nominal Motor RPM RPM	27106D Output Frequency Hz (1)	Calculated RPM (2)	Indicated RPM (3)
18802	☑ Clockwise and Counterclockwise rotation verified.		
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
18811	☑ Clockwise and Counterclockwise rotation verified.		
30.0	5	30.0	30.0
150.0	25	150.0	150.0
300.0	50	300.0	300.0
450.0	75	450.0	450.0
600.0	100	600.0	600.0
750.0	125	750.0	750.0
990.0	165	990.0	990.0

(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: 53020093

Date: 11 JULY 2018
Calibration Interval: One year

Tested By : DG

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

CERTIFICATE OF CALIBRATION AND TESTING

Model: 18802/18811
Serial Number: CA04353

Description: Anemometer Drive - 2 motors, 20 to 15,000 RPM
(18802 comprised of 18820A Control Unit and 18830A Motor Assembly)
(18811 comprised of 18820A Control Unit and 18831A 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)
18802	☑ Clockwise and Counterclockwise rotation verified.		
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
18811	☑ Clockwise and Counterclockwise rotation verified.		
30.0	5	30.0	30.0
150.0	25	150.0	150.0
300.0	50	300.0	300.0
450.0	75	450.0	450.0
600.0	100	600.0	600.0
750.0	125	750.0	750.0
990.0	165	990.0	990.0

(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: 53020093

Date: 19 April 2018
Calibration Interval: One year

Tested By : DG

Warren-Knight Instrument Company
2045 Bennett Road
Philadelphia, PA 19116
Phone: 215-464-9300; Fax: 215-464-9303
Web: http://www.warrenind.com

EEMS # 01265

Van 2

Calibration Data Record			Temperature: 68° Humidity: 34%
Customer Name	EE&MS	Item Name	USAKATA
Manufacturer		Model	5-25
Serial Number	190037	Calibration Date	3-5-18
Calibration Frequency		Job Card Number	S-24487
Customer Reference Number		Date of Certification	3-5-18

Measurement Standards

Theodolite Wild T-3 S/N 18801 Calibration 01/19/18 Due 01/19/19 NIST Number 738/229329-83 738/223398

Optical Wedge K&E 71-7020 S/N 5167 Calibration; 02/12/14 Due 2/12/19, NIST Number 731/244084-89 731/221617

Initial Report

Vanes		Direction (Degree)	Tolerance (Minute)	Compass Needle Error (Minute)
Pivot in line with Circle/Sights	☐ Pass ☐ Fail	0	+/-30	
Needle		45	+/-30	
Pivot Sharpness	☐ Pass ☐ Fail	90	+/-30	
Straightness (+/-15 Minutes)	☐ Pass ☐ Fail	135	+/-30	
Balance	☐ Pass ☐ Fail	180	+/-30	
Lifter Function	☐ Pass ☐ Fail	225	+/-30	
Azimuth Ring		270	+/-30	
Control Knob Function	☐ Pass ☐ Fail	315	+/-30	
Pinion Gear	☐ Pass ☐ Fail			
Graduation Clarity	☐ Pass ☐ Fail			
Graduation less than 1 minute in any position	☐ Pass ☐ Fail			
Level Bubble				
Bubble in Level	☐ Pass ☐ Fail			
Physical Condition	☐ Pass ☐ Fail			

Pass/Repair/Replace

Pass	N/A	Replace	Repair	
☐	☐	☐	☐	Needle ☐ Sharpen ☐ Magnetize
☐	☐	☐	☐	Cap with Jewel
☐	☐	☐	☐	Pivot ☐ Sharpen
☐	☐	☐	☐	Level ☐ Remount
☐	☐	☐	☐	North Sight
☐	☐	☐	☐	North Sight Block
☐	☐	☐	☐	South Sight
☐	☐	☐	☐	South Sight Block
☐	☐	☐	☐	Vane Spring
☐	☐	☐	☐	Drive
☐	☐	☐	☐	Control Knob Assembly
☐	☐	☐	☐	Cover Glass
☐	☐	☐	☐	Cover Glass Gasket
☐	☐	☐	☐	Clamp Screw
☐	☐	☐	☐	Pinion Gear
☐	☐	☐	☐	Compass Ring

Final Report

Vanes		Direction (Degree)	Tolerance (Minute)	Compass Needle Error (Minute)
Pivot in line with Circle/Sights	☑ Pass ☐ Fail	0	+/-30	<30
Needle		45	+/-30	<30
Pivot Sharpness	☑ Pass ☐ Fail	90	+/-30	<30
Straightness (+/-15 Minutes)	☑ Pass ☐ Fail	135	+/-30	<30
Balance	☑ Pass ☐ Fail	180	+/-30	<30
Lifter Function	☑ Pass ☐ Fail	225	+/-30	<30
Azimuth Ring		270	+/-30	<30
Control Knob Function	☑ Pass ☐ Fail	315	+/-30	<30
Pinion Gear	☑ Pass ☐ Fail			
Graduation Clarity	☑ Pass ☐ Fail			
Graduation less than 1 minute in any position	☑ Pass ☐ Fail			
Level Bubble				
Bubble in Level	☑ Pass ☐ Fail			
Physical Condition	☑ Pass ☐ Fail			

Certification

Joseph Paologgi	John Noga, Quality Assurance
Repair Technician	John Noga

Warren-Knight Instrument Company
2045 Bennett Road
Philadelphia, PA 19116
Phone: 215-464-9300; Fax: 215-464-9303
Web: http://www.warrenind.com

Ucm 1

EEMS
#01272

CERTIFICATION OF CALIBRATION AND CONFORMANCE

We hereby certify that the equipment below has been manufactured and/or inspected by standards traceable to NIST. Calibration of the specified instrument has been performed in compliance with ANSI Z540-1 requirements. It is warranted that the equipment has been calibrated to be in full conformance with the drawings and specifications of the instrument. Calibration tests were performed on the material specified below and were in accordance with all applicable quality assurance requirements with data on file at our facility.

Ineffective if graduation ring is not set to 0 degrees.

Customer Name:	Environmental Engineering & Measurement Services, Inc.
Purchase Order #:	
Instrument:	Ushikata Tracon S-25 Compass
Serial Number:	199578
Quantity:	1
Calibration Due:	05/2018

John Noga, Quality Control

May 10, 2018

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 02/06/15 Due 02/06/16 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-7020 S/N 5167 Calibration 02/12/14 Due 02/12/19 731/244084-89 731/2216117

EEMS
~~# 01272~~

SEG

Page 1 of 1

Warren-Knight Instrument Company
2045 Bennett Road
Philadelphia, PA 19116
Phone: 215-464-9300; Fax: 215-464-9303
Web: http://www.warrenind.com

~~Van 1~~

Calibration Data Record			Temperature: 68° Humidity: 34%
Customer Name	EE & MS	Item Name	ISHIKATA
Manufacturer		Model	S-25
Serial Number	191832	Calibration Date	3-5-18
Calibration Frequency		Job Card Number	S-24488
Customer Reference Number		Date of Certification	3-5-18

Measurement Standards

Theodolite Wild T-3 S/N 18801 Calibration 01/19/18 Due 01/19/19 NIST Number 738/229329-83 738/223398

Optical Wedge K&E 71-7020 S/N 5167 Calibration; 02/12/14 Due 2/12/19, NIST Number 731/244084-89 731/221617

Initial Report

Vanes		Direction (Degree)	Tolerance (Minute)	Compass Needle Error (Minute)
Pivot in line with Circle/Sights	☐ Pass ☐ Fail	0	+/-30	
Needle		45	+/-30	
Pivot Sharpness	☐ Pass ☐ Fail	90	+/-30	
Straightness (+/-15 Minutes)	☐ Pass ☐ Fail	135	+/-30	
Balance	☐ Pass ☐ Fail	180	+/-30	
Lifter Function	☐ Pass ☐ Fail	225	+/-30	
Azimuth Ring		270	+/-30	
Control Knob Function	☐ Pass ☐ Fail	315	+/-30	
Pinion Gear	☐ Pass ☐ Fail			
Graduation Clarity	☐ Pass ☐ Fail			
Graduation less than 1 minute in any position	☐ Pass ☐ Fail			
Level Bubble				
Bubble in Level	☐ Pass ☐ Fail			
Physical Condition	☐ Pass ☐ Fail			

Pass/Repair/Replace

Pass	N/A	Replace	Repair	
☐	☐	☐	☐	Needle ☐ Sharpen ☐ Magnetize
☐	☐	☐	☐	Cap with Jewel
☐	☐	☐	☐	Pivot ☐ Sharpen
☐	☐	☐	☐	Level ☐ Remount
☐	☐	☐	☐	North Sight
☐	☐	☐	☐	North Sight Block
☐	☐	☐	☐	South Sight
☐	☐	☐	☐	South Sight Block
☐	☐	☐	☐	Vane Spring
☐	☐	☐	☐	Drive
☐	☐	☐	☐	Control Knob Assembly
☐	☐	☐	☐	Cover Glass
☐	☐	☐	☐	Cover Glass Gasket
☐	☐	☐	☐	Clamp Screw
☐	☐	☐	☐	Pinion Gear
☐	☐	☐	☐	Compass Ring

Final Report

Vanes		Direction (Degree)	Tolerance (Minute)	Compass Needle Error (Minute)
Pivot in line with Circle/Sights	☑ Pass ☐ Fail	0	+/-30	<30
Needle		45	+/-30	<30
Pivot Sharpness	☑ Pass ☐ Fail	90	+/-30	<30
Straightness (+/-15 Minutes)	☑ Pass ☐ Fail	135	+/-30	<30
Balance	☑ Pass ☐ Fail	180	+/-30	<30
Lifter Function	☑ Pass ☐ Fail	225	+/-30	<30
Azimuth Ring		270	+/-30	<30
Control Knob Function	☑ Pass ☐ Fail	315	+/-30	<30
Pinion Gear	☑ Pass ☐ Fail			
Graduation Clarity	☑ Pass ☐ Fail			
Graduation less than 1 minute in any position	☑ Pass ☐ Fail			
Level Bubble				
Bubble in Level	☑ Pass ☐ Fail			
Physical Condition	☑ Pass ☐ Fail			

Certification

Joseph Paolozzi Repair Technician	John Noga, Quality Assurance John Noga

Doc templates 2/wk-40-1360 survey compass calibration record

Certificate Number
A2721737
Issue Date: 01/24/18

Certificate of Calibration

EEMS#

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: 01310

Description: DIGITAL MULTIMETER
Manufacturer: FLUKE
Model Number: 187
Serial Number: 86590148
Technician: JACOB BUDOVSKY
On-Site Calibration: ☐
Comments:

Calibration Date: 01/24/2018
Calibration Due: 01/24/2019
Procedure: ~~METCAL~~ FLUKE 187 Rev: 6/15/2015
Temperature: 73 F
Humidity: 44 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the SI units through the National Institute of Standards and Technology (NIST) or other National Metrological Institute (NMI). The method of calibration is direct comparison to a known standard, derived from natural physical constants, ratio measurements or compared to consensus standards.

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration is within the current Scope of Accreditation and complies with the requirements of ISO/IEC 17025:2005 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
3834901	FLUKE	5522A/SC1100	4/12/2017	4/12/2018

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Certificate Number
A2721741
Issue Date: 01/24/18

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01311

Description: DIGITAL MULTIMETER
Manufacturer: FLUKE
Model Number: 287
Serial Number: 95740135
Technician: JACOB BUDOVSKY
On-Site Calibration: ☐
Comments:

Calibration Date: 01/24/2018
Calibration Due: 01/24/2019
Procedure: METCAL FLUKE 287
Rev: 6/15/2015
Temperature: 73 F
Humidity: 44 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the SI units through the National Institute of Standards and Technology (NIST) or other National Metrological Institute (NMI). The method of calibration is direct comparison to a known standard, derived from natural physical constants, ratio measurements or compared to consensus standards.

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration is within the current Scope of Accreditation and complies with the requirements of ISO/IEC 17025:2005 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

This certificate shall not be reproduced, except in full, without the written permission of Technical Maintenance, Inc.

Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
3834901	FLUKE	5522A/SC1100	4/12/2017	4/12/2018

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Certificate Number
A2721757
Issue Date: 01/24/18

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01312

Description: DIGITAL MULTIMETER
Manufacturer: FLUKE
Model Number: 287
Serial Number: 95740243
Technician: JACOB BUDOVSKY
On-Site Calibration: ☐
Comments:

Calibration Date: 01/24/2018
Calibration Due: 01/24/2019
Procedure: METCAL FLUKE 287
Rev: 6/15/2015
Temperature: 73 F
Humidity: 44 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the SI units through the National Institute of Standards and Technology (NIST) or other National Metrological Institute (NMI). The method of calibration is direct comparison to a known standard, derived from natural physical constants, ratio measurements or compared to consensus standards.

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration is within the current Scope of Accreditation and complies with the requirements of ISO/IEC 17025:2005 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

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Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
3834901	FLUKE	5522A/SC1100	4/12/2017	4/12/2018

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

MesaLabs

NVLAP

NVLAP Lab Code 200661-0

Calibration Certificate

CertificateNo. 220139

Product 200-530+ High Defender 530+ High Flow

Serial No. 159956

Cal. Date 21-Feb-2018

Sales Date 28-Feb-2018 *Calibration interval commences on sale date.*

Sold To:

Environmental Engineering & Measurement Services
8010 SW 17th Place
Gainesville, FL 32607
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.

Calibration Data

Certificate No 220139
Technician Zenaida Ortiz

Lab. Pressure 767 mmHg
Lab. Temperature 22.6 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
25678.82 sccm	25678.88 sccm	0.0%	1.00%	In Tolerance
5090.1 sccm	5112.62 sccm	-0.44%	1.00%	In Tolerance
1557.48 sccm	1564.08 sccm	-0.42%	1.00%	In Tolerance
22 °C	22 °C	-	± 0.8°C	In Tolerance
766 mmHg	766 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML_800_44	101897	31-Jul-2017	31-Jul-2018
Percision Thermometer	305460	28-Sep-2017	28-Sep-2018
Precision Barometer	2981392	20-Jul-2017	20-Jul-2018

$m = 1.0005537$

$b = -0.015698166$

$r^2 = 0.999999$

Vaw 3
FEMS
01414

MesaLabs

EEMS# 01416

NVLAP®

NVLAP Lab Code 200661-0

Calibration Certificate

Certificate No. 241285

Product 200-220H Definer 220 High Flow

Serial No. 122974

Cal. Date 13-Jul-2018

Sold To: Environmental Engineering & Measurement Services
8010 SW 17th Place
Gainesville, FL 32607
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 22.7 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
25271 sccm	25133 sccm	0.55%	1.00%	In Tolerance
5038.9 sccm	5001.35 sccm	0.75%	1.00%	In Tolerance
1507.4 sccm	1500.8 sccm	0.44%	1.00%	In tolerance
22.8 °C	22.6 °C	-	± 0.8°C	In Tolerance
751 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	01-May-2018	01-May-2019
Percision Thermometer	305460	29-Sep-2017	29-Sep-2018
Precision Barometer	2981392	21-Jul-2017	21-Jul-2018

Page 1 of 2

MesaLabs

EEMS # 01416

NVLAP Lab Code 200661-0

As Shipped Calibration Data

Certificate No 241285
Technician Lilianna Malinowska

Lab. Pressure 758 mmHg
Lab. Temperature 22.7 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
25167 sccm	25120.5 sccm	0.19%	1.00%	In Tolerance
5009.7 sccm	5000.5 sccm	0.18%	1.00%	In Tolerance
1505.6 sccm	1500.2 sccm	0.36%	1.00%	In Tolerance
22.7 °C	22.7 °C	-	± 0.8°C	In Tolerance
758 mmHg	758 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	01-May-2018	01-May-2019
Percision Thermometer	305460	29-Sep-2017	29-Sep-2018
Precision Barometer	2981392	21-Jul-2017	21-Jul-2018

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:

$m = 1.001779$

$b = 1.614506$

$r^2 = 1.00000$

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

Mesa Laboratories Inc. 10 Park Place Butler, NJ 07405 USA
(973) 492-8400 FAX (973) 492-8270 www.mesalabs.com Symbol "MLAB" on the NAS

Certification of Bios 01417 with NIST traceable Bios 01416
3/1/2018

Eric Hebert

01417:
m = 0.9970
b = -0.1997

EEMS 01416 vs EEMS 01417				
MFC Setting (L/min)	**01417 Reading (sl/min)**	**01416 Flow (sl/min @ 760 mm Hg/25C)**	**Curve Predicted**	**% error in curve prediction**
10	9.9989	**10.1121**	**9.769**	**-3.39%**
9	9.3241	**8.8570**	**9.096**	**2.70%**
8	8.1766	**7.9793**	**7.952**	**-0.34%**
7	7.3439	**6.9874**	**7.122**	**1.93%**
6	6.4992	**6.1151**	**6.280**	**2.70%**
5	5.3960	**5.2074**	**5.180**	**-0.52%**
4	4.4549	**4.2544**	**4.242**	**-0.30%**
3	3.4101	**3.3295**	**3.200**	**-3.88%**

Zero MFC Slope	**0.9970**	**Slope Accuracy**	**0.9937**
Zero MFC Intercept	**-0.1997**	**Intercept Accuracy**	**0.0416**

Certification of Bios 01421 with NIST traceable Bios 01416
3/1/2018

Eric Hebert

Bios 01421:
m = 0.9845
b = 0.1030

EEMS 01416 vs EEMS 01421				
MFC Setting (L/min)	01421 Reading (sl/min)	01416 Flow (sl/min @ 760 mm Hg/25C)	Curve Predicted	% error in curve prediction
9	9.1940	9.0922	9.155	0.69%
8	8.1676	8.2304	8.144	-1.05%
7	7.1663	7.1902	7.158	-0.44%
6	6.2513	6.2382	6.257	0.31%
5	5.2931	5.3034	5.314	0.20%
4	4.3257	4.3216	4.362	0.93%
3	3.3248	3.3366	3.376	1.19%
2	2.2647	2.3865	2.333	-2.26%

Zero MFC Slope	0.9845	Slope Accuracy	0.9995
Zero MFC Intercept	0.1030	Intercept Accuracy	0.0028

EPA United States Environmental Protection Agency

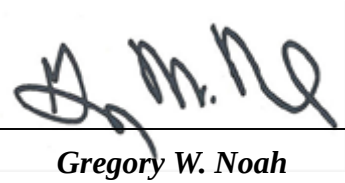
Field Scientist Certification

Martin Valvur

Has satisfactorily completed

The US Environmental Protection Agency's
"National Performance Audit Program (NPAP)
Field Scientist Re-certification Course"

Office of Air Quality Planning and Standards
Research Triangle Park, NC
Course Dates: April 13-14, 2017



Gregory W. Noah
NPAP National Coordinator
USEPA, OAQPS, AAMG

EPA United States Environmental Protection Agency

Field Scientist Certification

Eric Hebert

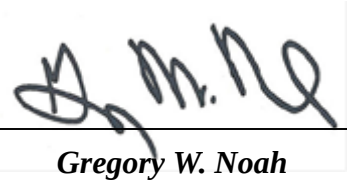
Has satisfactorily completed

The US Environmental Protection Agency's

"National Performance Audit Program (NPAP)

Field Scientist Re-certification Course"

Office of Air Quality Planning and Standards
Research Triangle Park, NC
Course Dates: April 13-14, 2017



Gregory W. Noah
NPAP National Coordinator
USEPA, OAQPS, AAMG