<u>2006 Annual Report</u>

CLEAN AIR STATUS AND TRENDS NETWORK
SITE AUDIT PROGRAM

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List of Acronyms and Abbreviations

% diff	percent difference
A/D	analog to digital converter
ARS	Air Resource Specialist, Inc.
ASTM	American Society for Testing and Materials
CASTNET	Clean Air Status and Trends Network
DAS	data acquisition system
DC	direct current
deg	degree
DVM	digital voltmeter
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	geographical positioning system
k	kilo (1000)
km	kilometer
lpm	liters per minute
MLM	Multilayer Model
m/s	meters per second
mv	milivolt
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
QAPP	Quality Assurance Project Plan
SOP	standard operating procedure
TEI	Thermo Environmental Instruments
USNO	United States Naval Observatory
V	volts
WRR	World Radiation Reference

1.0 INTRODUCTION

The Clean Air Status and Trends Network (CASTNET) is a national air monitoring program developed under mandate of the 1990 Clean Air Act Amendments. Each site in the network measures gaseous and aerosol species of atmospheric pollution using a continuous collection filter aggregated over a one week period. Hourly averages of surface ozone concentrations and selected meteorological variables are also measured.

Site measurements 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 spacial deposition patterns in atmospheric pollutants. CASTNET data are also used for long-range transport model evaluations and effects research.

CASTNET pollutant flux estimates are calculated as the aggregate product of weekly measured chemical concentrations and model-estimated deposition velocities. Currently, the National Oceanic and Atmospheric Administration's multilayer inferential model (NOAA-MLM) described by Meyers et al. [1998] is used to derive deposition velocity estimates.

As of January, 2005, the network is comprised of 87 active rural sampling sites across the Untied States and Canada, cooperatively operated by the Environmental Protection Agency (EPA), the National Park Service (NPS), and Environment Canada. MACTEC E & C is responsible for operating the EPA and Environment Canada sponsored sites, and Air Resource Specialist, Inc. (ARS) is responsible for operating the NPS 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 Quality Assurance (QA) programs are an essential part of any long-term monitoring network.

Performance audits verify that all evaluated parameters are consistent with the accuracy goals as defined in the CASTNET Quality Assurance Project Plan (QAPP). The parameter specific accuracy goals are presented in Table 2.1.

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	≤ ±5.0% above 85.0% RH; ≤ ±20.0% at or below 85.0% RH
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
Temperature	Accuracy	Comparison to 3 NIST measured baths (~ 0° C, ambient, ~ full-scale)	≤ ± 0.5° C

Table 2.1 Performance Audit Challenge and Acceptance Criteria - continued

Sensor	Parameter	Audit Challenge	Acceptance Criteria
Delta Temperature	Accuracy	Comparison to station temperature sensor	$\leq \pm 0.50°$ C
Wind Direction	Orientation Accuracy	Parallel to alignment rod/crossarm, or sighted to distant point	$\leq \pm 5°$ from degrees true
Wind Direction	Linearity	Eight cardinal points on test fixture	$\leq \pm 5°$ 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	$\leq \pm 0.5$ mps below 5.0 mps input; $\leq \pm 5.0\%$ 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	$\leq \pm 5.0\%$ of designated rate
Ozone	Slope	Linear regression of multi-point test gas concentration as measured with a certified transfer standard	$0.9000 \leq m \leq 1.1000$
	Intercept		-5.0 ppb $\leq b \leq 5.0$ ppb
	Correlation Coefficient		$0.9950 \leq r$
	Percent Difference	Comparison with Standard Concentration	$\leq \pm 10.0\%$ of test gas concentration
DAS	Accuracy	Comparison with certified standard	$\leq \pm 0.003$ VDC

Performance audits are conducted using standards that are certified as currently traceable to the National Institute of Standards and Technology (NIST), or another authoritative organization.

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 – 2006

This report covers the CASTNET sites audited in 2006. From February through November 2006, EEMS conducted field performance and systems audits at forty monitoring locations on forty-one individual monitoring stations. Twenty-nine of the sites visited are EPA sponsored and 12 are NPS sponsored. The locations and dates of the audits are presented in Table 3.1.

Table 3.1 Site Audits - 2006

Site ID	Sponsor Agency	Site Location	Visit dates
IRL141	EPA	Indian River Lagoon, FL	February 14
EVE419	NPS	Everglades Nat. Park, FL	February 16
GAS153	EPA	Georgia Station, GA	February 21
SND152	EPA	Sand Mountain, AL	February 23
SUM156	EPA	Sumatra, FL	February 28
ESP127	EPA	Edgar Evins St. Park, TN	March 2
SPD111	EPA	Speedwell, TN	March 4
PNF126	EPA	Cranberry, NC	March 5
COW137	EPA	Coweeta, NC	March 7
CAN407	NPS	Canyonlands Nat. Park, UT	April 10
MEV405	NPS	Mesa Verde Nat. Park, CO	April 11
PET427	NPS	Petrified Forest Nat. Park, AZ	April 13
CHA467	NPS	Chiricahua Nat. Monument, AZ	April 15
GRC474	NPS	Grand Canyon Nat. Park, AZ	April 17
SAL133	EPA	Salamonie Reservoir, IN	May 12
HOX148	EPA	Hoxeyville, MI	May 13
UVL124	EPA	Unionville, MI	May 17

Table 3.1 Site Audits - 2006 - continued

Site ID	Sponsor Agency	Site Location	Visit dates
ANA115	EPA	Ann Arbor, MI	May 18
LYK123	EPA	Lykens, OH	May 19
DEN417	NPS	Denali Nat. Park, AK	June 20
NCS415	NPS	North Cascades Nat. Park, WA	June 26
MOR409	NPS	Mount Rainier Nat. Park, WA	June 28
GRB411	NPS	Great Basin Nat. Park, NV	July 4
CON186	EPA	Converse Station, CA	July 6
JOT403	NPS	Joshua Tree Nat. Monument, CA	July 9
ABT147	EPA	Abington, CT	August 24
ASH135	EPA	Ashland, ME	August 26
ACA416	NPS	Acadia Nat. Park, ME	August 28
HOW132	EPA	Howland, ME	August 30
CAT175	EPA	Claryville, NY	September 20
HWF187	EPA	Huntington Wildlife Forest, NY	September 21
WST109	EPA	Woodstock, NH	September 23
LYE145	EPA	Lye Brook, VT	September 25
CTH110	EPA	Connecticut Hill, NY	October 1
EGB181/281	EPA	Egbert, ON	October 3
MKG113	EPA	M. K. Goddard St. Park, PA	October 5
KEF112	EPA	Kane Experimental Forest, PA	October 7
PSU106	EPA	Penn State University, PA	November 14
ARE128	EPA	Arendtsville, PA	November 16
BEL116	EPA	Beltsville, MD	November 20

4.0 PERFORMANCE AUDIT RESULTS

Table 4.1 summarizes the number of test failures by variable tested. Seven of the 41 sites visited were equipped with multiple (backup) data loggers. Functional tests of the backup loggers are included in Table 4.1. All other variable test results are those recorded from the site's primary logger. Some conditions that were encountered, and impact data accuracy but are not part of the performance tests are also included in the summary. Those conditions include temperature sensor blower function, wind speed cup or propeller integrity, flow system leak tests, and sensor siting criteria.

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 are 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. Other than one potential problem with the signal cable for the solar radiation standard used at one site (CTH110), no 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 Appendix 1. The variable specific data forms included in Appendix 1 for each site 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.

Table 4.1 Performance Audit Results by Variable Tested

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Ozone	38	4	10.5
Flow Rate	41	9	21.95
Wind Direction Orientation Average Error	40	8	20.0
Orientation Maximum Error	40	16	40.0
Wind Direction Linearity Average Error	39	1	2.6
Linearity Maximum Error	39	6	15.4
Wind Direction Starting Torque	39	3	7.9
Wind Speed Low Range Average Error	40	2	5.0
Low Range Maximum Error	40	3	7.5
Wind Speed High Range Average Error	40	3	7.5
High Range Maximum Error	40	7	17.5
Wind Speed Starting Torque	40	8	20.0
Temperature	40	1	2.5
2 Meter Temperature	5	0	0.0
Delta Temperature	35	3	8.6

Table 4.1 Performance Audit Results by Variable Tested - continued

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Relative Humidity Low Range	40	2	5.0
Relative Humidity High Range	40	15	37.5
Solar Radiation	38	10	26.3
Precipitation	40	3	7.5
Surface Wetness	40	1	2.5
DAS Analog to Digital	48	2	4.2
DAS Battery Backup	48	7	14.6

4.1 Ozone

Thirty-eight ozone analyzers were audited during 2006. Each was challenged with ozone-free air and four up-scale concentrations. Two challenges were in the range of 30 – 80 ppb, and one in each of the ranges of 150 – 200 ppb, and 360 – 450 ppb. The ozone test gas concentrations were determined with a NIST-traceable standard that was certified by USEPA, Region IV on three separate occasions in 2006. Of the 38 analyzers tested, four (just over 10%) were outside the acceptance criteria of ≤ ±10.0% of the test gas concentration, three were outside the slope acceptance criteria, and 2 were outside the intercept acceptance criteria established in the CASTNET QAPP. The results are presented in Table 4.2.

Two sites (CAT175 and LYE145) are operating ozone analyzers manufactured by ***2 B Technologies***. The analyzers were selected for these sites due to their low power requirements since the sites utilize solar and wind-generated power. The model 202, ***2 B Technologies*** analyzers are not subjected to routine QA checks as are the other CASTNET ozone analyzers. Both of these analyzers were operating with an average error for the four test gas concentrations of approximately 30%. The maximum error observed at CAT175 was over 55%, and greater than -64% at site LYE145.

Only two of the thirty-six ***ThermoEnvironmental*** analyzers audited were out of the acceptance criteria. The failure of one of those analyzers (at site BEL116) was caused by a low analog output signal, and not an instrument failure.

4.2 Flow Rate

The dry deposition filter pack sampling system flow rates at all forty-one sites were audited. A NIST-traceable dry-piston primary flow rate device was used for the tests. Eight, or nearly 20% of the systems checked were outside the acceptance criterion of ± 5.0%. The results are summarized in Table 4.2.

An additional system was is included in the results summarized in Table 4.1 due to a failed leak-test. When the day/night system at EGB281 was leak-tested during the audit, it was discovered that the three-way solenoid was leaking between the independent sample lines that are connected to each filter pack. This could possibly allow air to be pulled through the filters during the wrong day/night cycle (i.e. the day filter could be collecting at night and the night filter could be collecting during the day).

Table 4.2 Performance Audit Results for Ozone and Flow Rate

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
IRL141	1.8	2.3	1.01126	0.80541	0.99999	1.518	1.50	-1.16
EVE419	N/A	N/A	N/A	N/A	N/A	2.957	2.98	0.88
GAS153	3.7	5.0	1.02249	1.23357	1.00000	1.520	1.52	0.00
SND152	2.9	5.0	1.01859	0.56032	1.00000	1.516	1.50	-1.05
SUM156	0.3	1.3	0.99803	0.68549	1.00000	1.517	1.50	-1.14
ESP127	0.7	-1.3	1.01347	-1.52151	0.99999	1.480	1.50	1.35

Table 4.2 Performance Audit Results for Ozone and Flow Rate - continued

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
SPD111	1.3	2.6	1.01411	-0.04875	0.99999	1.427	1.50	**5.12**
PNF126	0.9	1.3	1.01019	-0.03669	1.00000	1.427	1.50	**5.09**
COW137	2.2	2.6	1.01499	0.81984	1.00000	1.481	1.50	1.30
CAN407	1.5	-2.5	0.99563	-0.96706	0.99999	3.087	3.04	-1.52
MEV405	1.3	2.4	1.00158	1.36998	1.00000	3.164	3.00	**-5.18**
PET427	2.1	2.6	1.02866	-1.19058	0.99999	3.129	3.00	-4.12
CHA467	1.1	2.7	1.00709	0.41870	0.99999	3.109	2.99	-3.82
GRC474	1.8	2.7	1.00752	0.95917	1.00000	3.056	3.01	-1.66
SAL133	1.1	2.3	1.01278	-0.06043	0.99998	1.475	1.51	2.35
HOX148	1.3	2.1	1.02316	-0.91121	1.00000	1.458	1.50	2.88
UVL124	2.4	2.7	1.02284	0.33866	0.99999	1.474	1.50	1.77
ANA115	1.5	-2.2	1.02339	-1.27177	0.99999	1.441	1.50	4.07
LYK123	1.1	2.9	1.03232	-1.86030	0.99999	1.463	1.51	3.19
DEN417	4.7	-6.4	0.93265	1.31356	0.99999	3.027	3.00	-0.88
NCS415	1.5	2.3	1.01564	-0.43336	0.99999	2.935	**2.94***	0.18
MOR409	0.3	0.7	1.00769	-0.33171	1.00000	2.985	3.01	0.73
GRB411	1.4	2.2	1.02225	-0.18616	0.99999	3.187	2.99	**-6.18**
CON186	2.4	2.9	1.02790	-0.47964	0.99998	2.963	3.01	1.59
JOT403	2.8	3.2	1.03191	-0.24666	1.00000	3.049	3.00	-1.61
ABT147	1.8	3.8	1.04167	-2.30878	0.99998	1.490	1.49	-0.07
ASH135	2.8	3.8	1.02704	0.03557	0.99999	1.452	1.49	2.62
ACA416	3.6	5.3	1.03184	0.41194	0.99999	1.487	**1.40***	**-5.85**
HOW132	1.0	-2.6	1.01373	-1.42429	0.99999	1.467	1.49	1.57
CAT175	**31.2**	55.9	**0.51482**	**36.39312**	0.99994	1.453	1.50	3.23

Table 4.2 Performance Audit Results for Ozone and Flow Rate - continued

Site	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
HWF187	1.9	-3.1	0.96366	2.12769	0.99998	1.429	1.50	4.99
WST109	5.2	-7.2	0.92301	2.07114	1.00000	1.408	1.50	**6.53**
LYE145	**28.7**	-64.1	0.98045	**-15.27815**	0.99773	1.412	1.50	**6.06**
CTH110	0.1	0.5	1.00478	-0.28726	1.00000	1.441	1.50	4.08
EGB181	N/A	N/A	N/A	N/A	N/A	1.494	1.50	0.40
EGB281	N/A	N/A	N/A	N/A	N/A	1.450	1.50	**3.45****
MKG113	1.0	2.8	0.99265	0.85505	1.00000	1.466	1.50	2.30
KEF112	2.1	5.6	0.99677	-0.94130	0.99999	1.542	1.50	-2.72
PSU106	1.5	-4.5	1.00748	-1.87783	1.00000	1.472	1.50	1.93
ARE128	**10.1**	-11.3	**0.88282**	1.79164	0.99999	1.488	1.51	1.48
BEL116	**26.9**	-31.3	**0.76496**	-1.80092	0.99977	1.394	1.49	**6.86**

* **Note:** The filter pack sampling system is not operating at the target flow rate.
** **Note:** Leak detected in the Day/Night valve.

4.3 Wind Speed

The wind speed sensors at all forty sites equipped for meteorological measurements were audited. When the acceptance criteria are applied to the average error of the wind speed sensors tests, only one sensor (site ABT147) is outside acceptance criteria. However, the CASTNET QAPP states that the acceptance criteria are applied to any test value. If the acceptance criteria are applied to the maximum error observed for each sensor, the number of failures increases to five. The results of the wind speed performance audits are presented in Table 4.3.

4.3.1 Wind Speed Starting Threshold

The condition of the wind speed bearings was 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 one half the DQO. Therefore, 0.5 g-cm was used for the acceptance limit for audit purposes. This value is within the manufacture's specifications for a properly maintained system.

Eight of the sites had wind speed sensors with bearing starting torque measured to be 0.5 g-cm or higher. One of those sensors (at site CTH110) was found to be assembled with the chopper wheel misaligned and contacting the sensor diodes. In light wind this sensor was observed to stop at that point in the rotation. The starting threshold for this sensor was the torque required to move the chopper wheel past that point in the rotation.

4.4 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. A separate orientation test was used to determine if the sensor was installed and operating properly aligned to measure wind direction accurately in degrees true. An audit standard compass was used to perform the orientation tests.

All forty wind direction sensors were tested for orientation accuracy. The condition of one sensor (at site CAN407) was deteriorated to the point where excessive handling may have worsened the operation. The screws that secure the sensor components were loose allowing the upper and lower sections to move independently and excessively. Due to its condition, a linearity test was not performed on that sensor.

Using the average error of the orientation tests for each of the 40 sensors tested, 8 were outside the acceptance criterion of ± 5 degrees. Of the 39 sensors tested for linearity, the results were considerably better with only one test average outside the acceptance limit. However, the CASTNET QAPP states that the acceptance criteria are applied to any test value. When the acceptance criteria are expanded to include the maximum errors observed for each sensor, the number of failures increases to16 for orientation and 6 for linearity. The results of the wind direction performance audits are presented in Table 4.3.

4.4.1 Wind Direction Starting Threshold

The condition of the wind direction bearings was 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 at 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.

Three of the 39 wind direction sensors that were tested for starting threshold torque were found to be above the audit criteria. The test results are provided in Table 4.3. One of the three sensors (at site CHA467) was found to be assembled with the wind direction vane thumb-wheel misaligned and contacting the potentiometer assembly. This condition caused the vane to stop at that position in the rotation. The starting threshold was the torque required to move the vane past that position.

Table 4.3 Performance Audit Results for Wind Sensors

Site	Wind Direction					Wind Speed				
	Orientation Error		Linearity Error		Starting Torque (g-cm)	Low Range Error		High Range Error		Starting Torque (g-cm)
	Ave (deg)	Max (deg)	Ave (deg)	Max (deg)		Ave (m/s)	Max (m/s)	Ave (% diff)	Max (% diff)	
IRL141	**5.3**	**8***	1.8	3	12	0.05	0.10	0.6	1.6	0.3
EVE419	3	3	1	2	10	0.07	0.17	0.4	0.8	0.4
GAS153	0.5	1	1.5	4	12	0.07	0.18	2.7	3.5	0.3
SND152	**11**	**17***	**9**	**36***	8	0.12	0.18	1.3	2.6	0.4
SUM156	0.5	1	1	3	15	0.06	0.10	4.1	**5.3***	0.2
ESP127	1.8	4	1	2	8	0.05	0.10	0.3	0.6	0.2
SPD111	4	**7***	2	**6***	8	0.04	0.10	0.4	1.0	0.2
PNF126	4.8	**7***	1	2	8	0.16	0.28	2.6	3.7	0.3
COW137	1.2	3	1	1	8	0.30	0.37	2.0	4.9	0.4
CAN407	**9**	**11***	NP	NP	NP	0.03	0.06	2.7	**8.3***	0.3
MEV405	1.5	3	1	2	8	0.01	0.02	2.3	**7.2***	**1.2**
PET427	**16.5**	**20***	2	5	14	0.10	0.20	2.8	2.9	0.4
CHA467	**6.3**	**8***	2	**7***	**32**	0.09	0.16	0.5	0.8	0.4
GRC474	**8.3**	**13***	2	**8***	20	0.13	0.26	1.4	1.6	**0.5**
SAL133	3.8	**7***	1	5	10	0.03	0.10	0.9	1.6	0.2
HOX148	1.2	5	2	5	10	0.13	0.22	1.1	2.0	0.3
UVL124	4.5	5	1	3	10	0.13	0.22	1.0	2.0	0.2
ANA115	2.6	4	1	2	8	0.00	0.00	0.2	0.5	0.2
LYK123	1.5	2	1	3	**45**	0.03	0.08	3.4	4.4	0.4
DEN417	4.3	**8***	3.5	**13***	8	0.00	0.01	0.2	0.3	0.3
NCS415	1.5	4	2	**6***	12	0.03	0.06	1.6	1.7	0.4
MOR409	3.4	**6***	1	5	6	0.05	0.08	1.3	1.6	0.2

Table 4.3 Performance Audit Results for Wind Sensors - continued

Site	Wind Direction					Wind Speed				
	Orientation Error		Linearity Error		Starting Torque (g-cm)	Low Range Error		High Range Error		Starting Torque (g-cm)
	Ave (deg)	Max (deg)	Ave (deg)	Max (deg)		Ave (m/s)	Max (m/s)	Ave (% diff)	Max (% diff)	
GRB411	2.5	3	1	5	6	0.02	0.03	0.9	2.9	0.2
CON186	2	4	1	3	12	0.13	0.23	1.6	2.6	0.3
JOT403	0.3	1	1	2	8	**0.04***	0.05	**1.3***	3.0	0.2
ABT147	**5.4**	**9***	1	2	12	**0.27***	0.40	**6.1**	**7.2***	**0.9**
ASH135	2.5	4	1	3	15	0.08	0.20	0.4	1.0	0.3
ACA416	3.3	**6***	2	5	8	0.41	**0.95***	3.4	**10.5***	0.3
HOW132	5	**8***	1	3	15	0.17	0.40	1.8	3.1	0.4
CAT175	**40.8**	**45***	1	2	12	0.07	0.10	4.2	4.6	0.3
HWF187	1.3	3	1	3	10	0.07	0.11	1.0	1.6	**0.5**
WST109	2.3	4	2	3	15	0.09	0.14	1.6	2.7	0.3
LYE145	4.5	5	0.5	2	15	0.12	0.20	4.4	4.9	**0.8**
CTH110	1.6	4	1	2	8	0.08	0.10	0.2	0.4	**0.6**
EGB181	2.8	4	0.5	1	**42**	0.08	0.10	1.6	2.1	0.4
MKG113	2.2	**6***	2	5	8	0.22	0.30	1.4	3.3	0.3
KEF112	1.8	3	1	2	15	0.11	0.22	1.0	2.0	**0.5**
PSU106	1	3	1	2	6	0.04	0.10	2.1	2.4	0.2
ARE128	1.4	2	1	4	8	0.06	0.18	0.3	0.4	0.2
BEL116	3	4	1	3	15	0.08	0.18	1.4	1.9	**0.5**

* **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. Maximum error values outside criteria and systems that fail for other reasons are denoted.

4.5 Temperature, Two Meter Temperature, and Delta Temperature

The temperature measurement systems at all forty sites equipped to measure meteorological variables consist of a temperature sensor mounted at 9 meters on the meteorological tower. Thirty-five of those sites employed a second sensor to measure delta temperature, or temperature difference, from the 9-meter sensor and delta temperature sensor mounted at approximately 2 meters from the ground. R. M. Young systems calculate delta temperature as the upper sensor minus the lower sensor, and Climatronics systems calculate delta temperature as the lower sensor minus the upper sensor.

Five of the forty sites utilized a sensor to measure temperature at approximately two meters (2-meter temperature). It is assumed that delta temperature at these five sites is calculated as part of the data management process and the result of that calculation is not recorded on-site.

Thirty-eight of the forty sites use shields to house the sensors that are designed to be mechanically aspirated with forced air blowers. The sensors were removed from the sensor shields, and placed in a uniform temperature bath with a precision NIST-traceable RTD, during the audit.

All of the NPS sponsored sites with Climatronics systems were configured to report the delta temperature as the upper sensor minus the lower, by reversing the zero and full-scale settings for the delta temperature channel in the DAS configuration. This is not a problem provided the data validation procedures account for the system configuration. This is a difference from the EPA sponsored site configuration.

Results of the tests indicate that all but one temperature sensor were within the acceptance criterion. All of the 2-meter temperature sensors and delta temperature sensors were found to be within the acceptance criterion. The average errors for all sensors are presented in Table 4.4.

4.5.1 Temperature Shield Blower Motors

Three of the delta temperature shield blower motors were found not functioning. The sites with this condition were EVE419, UVL124, and ACA416. Although the sensors are accurate at these sites, delta temperature data are not accurate given that the shield blowers are not functioning as designed. These results are included in Table 4.1.

4.6 Relative Humidity

The relative humidity systems at the sites were tested with a combination of primary standard salt solutions, and a certified transfer standard relative humidity probe. The results of the average and maximum errors for low range tests (RH ≤ 85.0 %) and results of the average error for high range tests (RH > 85.0 %) are presented in Table 4.4.

The relative humidity measurement being made at each of the forty sites equipped for meteorological measurements is provided by a sensor supplied by any one of three different manufactures. At EPA sponsored sites with R. M. Young equipment, humidity sensors are operating in naturally aspirated shields. At EPA sponsored sites with Climatronics equipment, humidity sensors are operating in shields designed to be mechanically aspirated with forced-air blowers. All of the NPS sponsored sites operate humidity sensors in shields that are designed to be mechanically aspirated with forced-air blowers.

During 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 shield configurations.

A large number (15 out of 40) of sensors were outside the acceptance criterion when tested at 85% or higher relative humidity. One relative humidity aspirated shield blower motor was found not functioning at site JOT403. That sensor was outside the criterion when tested in the high RH range, and it was considered as a failed system for the summary of low range tests included in Table 4.1.

Table 4.4 Performance Audit Results for Temperature and Humidity

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Delta Temperature Ave. Error (deg C)	Relative Humidity		
				Low Range		High Range
				Ave. Error (%)	Max. Error (%)	Ave. Error (%)
IRL141	0.19		0.07	5.3	-7.9	1.0
EVE419	0.35		**0.09****	2.7	-7.2	1.9
GAS153	0.10		0.05	8.2	-11.3	**5.8**
SND152	0.18		0.03	2.4	3.8	2.7
SUM156	0.22		0.02	3.7	-4.7	4.5
ESP127	0.16		0.07	5.3	7.2	2.0
SPD111	0.02		0.04	2.7	-5.5	4.6
PNF126	0.46		0.14	2.1	-5.4	2.7
COW137	0.18		0.07	11.9	20.0	1.8
CAN407	0.12		0.06	2.0	4.0	0.3
MEV405	0.08		0.01	5.1	-16.1	3.7
PET427	0.15		0.08	6.8	-13.2	**8.3**
CHA467	0.33		0.04	2.3	4.2	2.2
GRC474	0.09		0.50	1.3	-2.2	4.5
SAL133	0.07		0.03	4.1	4.7	**5.8**
HOX148	0.12		0.04	11.7	17.2	3.0
UVL124	0.11		**0.05****	4.8	-8.2	2.8
ANA115	0.11		0.07	12.3	14.9	**6.8**
LYK123	0.09		0.01	6.0	8.6	3.6
DEN417	0.09		0.18	6.0	-7.8	**7.5**
NCS415	0.09		0.01	5.7	9.6	**7.1**
MOR409	0.08		0.11	4.9	-12.2	0.5

Table 4.4 Performance Audit Results for Temperature and Humidity - continued

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Delta Temperature Ave. Error (deg C)	Relative Humidity		
				Low Range		High Range
				Ave. Error (%)	Max. Error (%)	Ave. Error (%)
GRB411	0.15		0.08	5.3	6.4	3.3
CON186	0.16	0.08		1.7	-3.6	**5.3**
JOT403	0.04		0.07	**2.6***	-4.2	**10.6**
ABT147	0.13		0.12	**23.5**	**26.0***	**7.5**
ASH135	0.10		0.05	**20.7**	**25.8***	**8.8**
ACA416	0.16		**0.11****	6.0	6.2	1.8
HOW132	0.42		0.07	9.9	11.7	4.6
CAT175	**1.31**	0.18		4.3	4.8	0.9
HWF187	0.10	0.07		8.0	10.9	**6.5**
WST109	0.39		0.04	17.5	**27.1***	**7.6**
LYE145	0.16	0.11		5.4	7.4	1.8
CTH110	0.10		0.03	11.5	13.4	3.5
EGB181	0.29		0.21	3.6	4.6	0.5
MKG113	0.10		0.06	7.4	16.1	**8.8**
KEF112	0.08		0.01	7.2	13.3	2.4
PSU106	0.09		0.04	4.4	9.6	0.4
ARE128	0.11		0.05	11.2	**21.2***	**8.8**
BEL116	0.15	0.18		4.1	6.5	**7.1**

* **Note:** The humidity system acceptance criteria were applied to the average of the results. The data validation section of the CASTNET QAPP does not indicate if it applies to the average error or all error values. Maximum error failures are denoted.

** **Note:** Shield blower failures.

4.7 Solar Radiation

The ambient conditions encountered during the audit visits were suitable, with high enough light levels for accurate comparisons. A NIST-traceable Eppley PSP and translator were used as the audit standard.

One solar radiation system (at site CON186) was not operating during the site audit visit due to damage from an electrical storm. The other 39 sites were tested but one result, from site CTH110, was not reported due to a potential problem with the audit standard signal cable. Seven of the 38 sites had results that were outside the acceptance criterion. Five sites are operating sensors that are poorly sited and shaded by trees or other obstructions. Three of these five sites had test results that were within acceptance criterion. However, the siting conditions were considered to be affecting data quality and therefore the sites are included in the summary results in Table 4.1. Photographs of all the sensors that are poorly sited (ESP127, DEN417, WST109, MKG113, and KEF112) are included in the systems reports in Appendix 1. The results of the individual tests for each site are included in Table 4.5.

4.8 Precipitation

All forty meteorological sites audited used a tipping bucket rain gauge for the 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 (mm at NPS sites and inches at EPA sites) of water entered were compared to the amount recorded by the DAS. All but one system (at site ACA416) were within the acceptable criterion. The results are summarized in Tables 4.5.

Four of the sites (IRL141, EVE419, CHA467, and BEL116) have tipping bucket rain gauges with heaters that are malfunctioning. Two of those were not considered to negatively affect data quality since only frozen precipitation would be affected and only BEL116 and CHA467 are likely to encounter frozen precipitation. Both of those sites are included in the summary results found in Table 4.1 although it should be noted that precipitation data quality at BEL116 and CHA467 are rarely affected due to sensor heater malfunction.

4.9 Surface Wetness

The acceptance criteria established for the surface wetness sensors used at the CASTNET sites requires the sensor has a positive response from a condition of dry, to a condition of wet. All of the sensors tested exhibited a positive response to a wet condition. However, the sensor response at site PNF126 was intermittent possibly due to the condition of the sensor's power and signal cable. The condition of this sensor was considered to negatively affect data quality and that result is included in Table 4.1.

In the CASTNET QAPP, ***Appendix 1: CASTNET Field Standard Operating Procedures***, a regular maintenance and calibration procedure is described for the surface wetness sensor. The procedure is a sensitivity adjustment intended to provide consistent response from the surface wetness sensors at all of the CASTNET sites. The procedure requires that a decade resistance device be installed in a test-jack fixture within the surface wetness sensor circuit to by-pass the sensor grid. Then, to adjust the sensor response to the specifications provided, independent of the response to a wet condition. This test was performed during the audits to determine if the sensor responded within the specified range of 235 to 245 k ohms.

Since there are no DQO identified for the sensitivity tests, they are not considered in the evaluation of data quality. The results are presented in Table 4.5 as the resistance required for the sensor response to change from dry to wet (on), and from wet to dry (off). As stated in the paragraph above, all of the sensors responded when the grid surface was wet, and most were near the specified sensitivity.

Table 4.5 Performance Audit Results for Solar Radiation, Precipitation, and Surface Wetness

Site	Solar Radiation Error				Precipitation Ave. Error (% diff)	Surface Wetness	
	Daytime Ave. (% diff)	Max. Value (w/m2)	Max. Observed (w/m2)	Max. Value (% diff)		Sensitivity On (k ohm)	Sensitivity Off (k ohm)
IRL141	0.1	826	816	-1.2	4.0	200	210
EVE419	7.5	702	648	-7.7	4.7	230	240
GAS153	1.7	701	715	2.0	1.0	220	230
SND152	3.4	486	495	1.9	4.0	180	190
SUM156	**55.2**	807	378	-53.2	0.7	190	200
ESP127	8.9	761	687	-9.7	2.3	180	200
SPD111	**14.5**	800	684	-14.5	6.0	190	200
PNF126	1.1	794	772	-2.8	2.7	190	200
COW137	2.7	835	852	2.0	4.3	160	170
CAN407	3.8	980	938	-4.3	5.0	170	180
MEV405	2.2	1003	1026	2.3	3.0	220	230
PET427	4.1	1013	963	-4.9	7.0	180	190
CHA467	2.4	1006	1007	0.1	5.5	**NP***	**NP***
GRC474	5.9	1007	942	-6.5	4.0	**NP***	**NP***
SAL133	**10.1**	286	311	8.7	0.0	230	240
HOX148	1.6	249	251	0.8	1.0	250	260
UVL124	0.3	943	929	-1.5	3.0	860	870
ANA115	1.7	493	472	-4.3	2.7	230	240
LYK123	3.7	876	878	0.2	5.0	250	260
DEN417	**11.9**	794	704	-11.3	3.0	**NP***	**NP***
NCS415	1.7	867	846	-2.4	3.0	230	240
MOR409	0.9	656	676	3.0	1.0	160	170

Table 4.5 Performance Audit Results for Solar Radiation, Precipitation, and Surface Wetness - continued

Site	Solar Radiation Error				Precipitation Ave. Error (% diff)	Surface Wetness	
	Daytime Ave. (% diff)	Max. Value (w/m2)	Max. Observed (w/m2)	Max. Value (% diff)		Sensitivity On (k ohm)	Sensitivity Off (k ohm)
GRB411	9.1	977	1139	16.6	2.5	270	280
CON186	**NP***	**NP***	**NP***	**NP***	2.0	160	170
JOT403	6.7	949	873	-8.0	2.7	140	150
ABT147	3.4	820	829	1.1	9.0	200	210
ASH135	2.6	827	781	-5.6	1.0	120	130
ACA416	1.5	120	127	5.8	**11.0**	350	360
HOW132	8.1	740	711	-3.9	2.5	130	140
CAT175	**16.1**	341	385	12.9	4.0	200	210
HWF187	4.8	384	390	1.6	4.0	760	770
WST109	2.2	478	475	-0.6	4.0	440	450
LYE145	**12.7**	719	795	10.6	1.0	220	230
CTH110	**Not Reported**	**Not Reported**	**Not Reported**	**Not Reported**	1.0	220	230
EGB181	3.3	633	651	2.8	0.0	170	180
MKG113	**16.6**	727	534	-26.5	6.0	200	210
KEF112	9.0	719	701	-2.5	6.0	230	240
PSU106	4.1	316	330	4.4	0.5	250	260
ARE128	1.5	532	524	-1.5	1.0	1200	1250
BEL116	2.9	506	513	1.4	6.7	300	310

* **Note:** NP = not performed due to system failure or test-jack not present.

4.10 Data Acquisition Systems (DAS)

All of the NPS sponsored sites visited utilize an ESC logger as the primary and only DAS. The majority of the EPA sponsored sites visited use Odessa dataloggers as the primary DAS. One site, BEL116 uses a logger manufactured by H2NS. Seven of the EPA sponsored sites also use an Odessa logger as a backup DAS. The results presented in Table 4.6 only include the tests performed on the primary logger at each site. The DAS functionality tests in Table 4.1 include all of the dataloggers, primary and backup.

4.10.1 Analog Tests

The accuracy of each primary logger was tested on two different channels with a NIST-traceable Fluke digital voltmeter. One logger (at site HOW132) was outside the acceptance criterion of ± 0.003 volts.

The logger at SUM156 was observed to have an analog to digital voltage converter problem. When communicating with datalogger through the RS232 port, the voltage signals on all the input channels was observed to decrease by approximately 40%. This problem affects data quality for all measurements but only during the relatively short period of time that DAS communication is occurring. The audit tests for each measured variable at site SUM156 were performed without using the RS232 communication port on the logger which is the normal operating mode. It is unclear what impact this problem has on the final hourly averages recorded for each variable.

4.10.2 Functionality Tests

Other performance tests used to evaluate the DAS included the verification of the date and time, and operation of the battery backup system used to save the DAS date, time, and configuration during a power outage. The results of these tests are included in Table 4.6. The battery backup tests are included in Table 4.1 for all dataloggers. Three of the seven failed tests were primary loggers. Two primary loggers (CAT175 and LYE145) do not have battery backup capability.

Table 4.6 Performance Audit Results for Data Acquisition Systems

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)	Battery Test (pass/fail)
	Low Channel		High Channel				
	Average	Maximum	Average	Maximum			
IRL141	0.0002	0.0003	0.0002	0.0003	Y	0.50	Pass
EVE419	0.0002	0.0003	0.0001	0.0003	Y	1.00	Pass
GAS153	0.0001	0.0003	0.0001	0.0003	Y	2.50	Pass
SND152	0.0007	0.0013	0.0006	0.0013	Y	1.42	Pass
SUM156	**0.0005***	0.0013	**0.0003***	0.0013	Y	2.10	Pass
ESP127	0.0003	0.0010	0.0003	0.0010	Y	0.67	Pass
SPD111	0.0002	0.0008	0.0002	0.0008	Y	0.25	Pass
PNF126	0.0002	0.0007	0.0002	0.0007	Y	2.67	Pass
COW137	0.0002	0.0003	0.0002	0.0003	Y	1.58	Pass
CAN407	0.0001	0.0003	0.0001	0.0002	Y	0.33	Pass
MEV405	0.0001	0.0001	0.0001	0.0002	Y	1.00	Pass
PET427	0.0005	0.0005	0.0000	0.0002	Y	0.50	Pass
CHA467	0.0001	0.0002	0.0001	0.0002	Y	0.05	Pass
GRC474	0.0002	0.0004	0.0001	0.0002	Y	1.25	Pass
SAL133	0.0001	0.0003	0.0001	0.0003	Y	0.50	Pass
HOX148	0.0002	0.0004	0.0002	0.0004	Y	0.83	Pass
UVL124	0.0002	0.0008	0.0004	0.0008	Y	1.33	Pass
ANA115	0.0006	0.0012	0.0006	0.0012	Y	0.75	Pass
LYK123	0.0009	0.0016	0.0009	0.0016	Y	0.50	Pass

Table 4.6 Performance Audit Results for Data Acquisition Systems - continued

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)	Battery Test (pass/fail)
	Low Channel		High Channel				
	Average	Maximum	Average	Maximum			
DEN417	0.0001	0.0003	0.0001	0.0002	Y	0.33	Pass
NCS415	0.0001	0.0002	0.0001	0.0002	Y	1.50	Pass
MOR409	0.0002	0.0004	0.0000	0.0002	Y	0.33	Pass
GRB411	0.0002	0.0008	0.0004	0.0011	Y	1.33	Pass
CON186	0.0001	0.0002	0.0001	0.0002	Y	0.25	Pass
JOT403	0.0001	0.0002	0.0002	0.0003	Y	0.50	Pass
ABT147	0.0008	0.0010	0.0008	0.0010	Y	0.08	Pass
ASH135	0.0013	0.0018	0.0013	0.0018	Y	0.67	Pass
ACA416	0.0001	0.0003	0.0001	0.0002	Y	0.33	Pass
HOW132	**0.0068**	0.0070	**0.0061**	0.0070	Y	0.50	Pass
CAT175	0.0004	0.0008	0.0004	0.0008	**N**	**1448.25**	**Pass****
HWF187	0.0000	0.0002	0.0000	0.0001	Y	0.03	Pass
WST109	0.0008	0.0026	0.0007	0.0026	Y	0.33	**Fail**
LYE145	0.0007	0.0014	0.0006	0.0014	Y	**39.00**	**Pass****
CTH110	0.0015	0.0027	0.0011	0.0026	Y	0.50	Pass
EGB181	0.0007	0.0020	0.0007	0.0020	Y	1.67	**Fail**
MKG113	0.0019	0.0030	0.0019	0.0030	Y	2.00	**Fail**
KEF112	0.0003	0.0008	0.0003	0.0008	**N**	525599.33	Pass
PSU106	0.0005	0.0008	0.0004	0.0008	Y	0.03	Pass
ARE128	0.0003	0.0010	0.0003	0.0010	Y	1.08	Pass
BEL116	0.0002	0.0014	0.0002	0.0014	Y	0.00	Pass

* **Note:** Failed during RS232 communication.
** **Note:** No battery backup capability.

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. Maps of each site with 1 kilometer, 5 kilometer, and 40 kilometer radius circles are provided in the systems reports in Appendix 1.

There are some inconsistencies within the QAPP between the site coordinates listed in the main section and those listed in Appendix 2. There is at least one significant inconsistency (for site CON186) where the difference in site location is approximately 10 kilometers, with the main section of the QAPP being incorrect. Two other sites (IRL141 and SUM156) are listed with the same latitude in the main section of the QAPP which is also incorrect. The QAPP inconsistencies and the difference between the listed coordinates and those obtained with the audit Global Positioning System (GPS) are apparent in the 1 kilometer maps (and the 5 kilometer map for site CON186) included in Appendix 1 of this report.

As described in the solar radiation performance evaluation section, five sites (ESP127, DEN417, WST109, MKG113, and KEF112) have problems regarding shading of the solar radiation sensors during certain times of the day. Photographs of the sensors and obstructions are included in the systems reports in Appendix 1. At some sites (IRL141, SPD111, CAN407, PET427, and JOT403) the lower temperature shield is mounted at a height other than two meters as described in the QAPP.

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.

5.2 Sample Inlets

At the site CON186, a tree is within five meters of the ozone and filter sample inlet. With consideration given to the siting criteria compromises described in the previous section, the rest of the analyzer sample trains are sited properly and in accordance with the CASTNET QAPP. The filter packs and ozone inlets are designed to sample from 10 meters. Teflon tubing of adequate diameter is used for the ozone inlets. Most of the filter pack sample lines are also Teflon. Inline filters are present in the sample trains. With the exception of site DEN417 the ozone zero, span, and precision calibration test gases are introduced at the ozone sample inlet, through all filters and the entire sample train.

5.3 Data Acquisition Systems

The performance test results of the DAS at the sites have been discussed in the previous sections. The inaccuracies within the DAS and their impact on data quality have been accounted for by recording each test measurement from the DAS. Problems with particular systems (at site SUM156) have been described in the performance results section. Other issues that are related to the DAS operation and field systems are presented here.

The H2NS DAS at BEL116 did not record the data status flag with the wind channels in the intermediate and final data average. Channels were marked as down during the audit but the flags did not appear on the recorded data. This problem was observed with the H2NS logger during the audit at site CND125 in 2005 as well.

The Odessa dataloggers were observed to have different versions of firmware installed at different sites. This issue causes some logger functions to work at some sites and not at others.

The firmware inconsistency may be the reason that logger dates were not correct at sites KEF112 and CAT175. However, these sites were inconsistent with respect to the DAS date error, CAT175 was one day (plus 8.25 minutes) off and KEF112 was one year off.

5.4 Infrastructure

Some problems with the infrastructure at the sites were observed. These include the degradation of exposed signal and power cables as depicted in the photograph of site PNF126 included in the systems report in Appendix 1. Other sites have similar cable conditions, particularly where protective conduit is not used. Some conduits are not sealed which allow insects and rodents to gain access and damage cables and connections. Many of the shelters are showing signs of deterioration from moisture and water damage due to leaks. Others (particularly SAL133) are infested with rodents. Some (particularly CON186 and ARE128) are cluttered and dirty.

5.5 Field Site Maintenance

Nearly all of the aspirated shields used at the EPA sponsored sites were functioning and well maintained. A few of the shields at NPS sites were not properly maintained. Those include sites EVE419, MOR409, JOT403, and ACA416. The aspirated shields for the temperature sensors at site MOR409 were found to be particularly dirty. Photographs of the shields at MOR409 are included in the systems report in Appendix 1.

A procedural difference between EPA sponsored, and NPS sponsored sites was observed. There are very few notes and calibration results documented on-site at the NPS sites. It was not clear if systems were found within established operational limits or if instrument maintenance was performed during previous visits by ARS. Various instrument settings were not displayed to verify that instruments were operating as left during the previous calibration.

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. An electronic logbook is also included in the interface software. This system permits easy access to site documentation data, however as noted previously there was no data regarding instrument calibration records, and little descriptive site data that could be used for validation purposes.

5.6 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 MACTEC 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. At site SUM156 it was not clear if solar radiation sensors and translators were installed as matched sets.

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. Some of the more experienced operators have suggested that CASTNET could be improved if the operators felt more included in the program results and reporting functions, similar to the NADP operators. It was suggested that a CASTNET operator newsletter and annual meeting would be helpful.

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

5.6.1 Site Operator Training Program

A new program was begun by MACTEC to address the site operator training concerns. It is the CASTNET Operator Refresher Training Course and had been provided to at least two of the site operators that were audited this year. Those operators are at sites MKG113 and ARE128. The instructors for the course were Mr. Tom Lavery and Mr. Kemp Howell of MACTEC. During the systems audits for sites MKG113 and ARE128, the site operators were interviewed regarding the training provided just a few months before the audit visits. Both operators said that meteorological properties were discussed as they related to review of data for reasonable values.

5.7 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 incorrect completion of the "reasonable conditions" checks and improper reporting of "initial flow", "final flow", and "leak check" values. A few operators do not use the "chain-of-custody" label.

Not all sites had complete calibration records for installed and operating equipment. This mostly occurred due to the site operator installing the equipment, but failing to retain and file the calibration information. As previously described the NPS sponsored sites had little or no calibration records or they were not available for review.

5.8 Site Sensor and FSAD Identification

Another documentation issue involves the identification of sensors 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 are missing serial numbers and/or client ID numbers (EPA barcodes). Others have numbers that are illegible. Better identification of the sensors should be performed to allow the proper tracking and recording of maintenance procedures for the sensors.

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). Most areas of CASTNET site operations are acceptable. 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. The previous 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 Follow-up visits

It is recommended that some of the conditions encountered during the audits should be addressed when the sites are visited during the next scheduled site maintenance and calibration visit. In order to determine if that occurred some type of follow-up procedure should be established. This procedure may not need to be another audit, and should not be performed two years after the audit when the condition was first discovered.

For example, the voltage output of the ozone analyzer at site BEL116 was observed to be 27% low during the audit. A review of the calibration documentation and/or a call to the site operator would determine if the condition was corrected during the subsequent calibration visit. Similar procedures could be used for other conditions observed during the audits, such as site operator training, sensor repositioning, and sensor adjustments.

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