



# Clean Air Status and Trends Network

## Fourth Quarter 2018 Quality Assurance Report

### Summary of Quarterly Operations (October through December) with 2018 Annual Summary

EPA Contract No. EP-W-16-015

#### Introduction

This quarterly report summarizes results from the Clean Air Status and Trends Network (CASTNET) quality assurance/quality control (QA/QC) program for data collected during fourth quarter 2018. It also provides an annual summary that includes data from the three previous quarters. The various QA/QC criteria and policies are documented in the CASTNET Quality Assurance Project Plan (QAPP; Wood, 2017). The QAPP is comprehensive and includes standards and policies for all components of project operation from site selection through final data reporting. It is reviewed annually and updated as warranted.

#### Significant Events for 2018

Amec Foster Wheeler Environment & Infrastructure Inc.'s name change to Wood Environment & Infrastructure Solutions, Inc. became official with Contract Modification P00013, which was issued by EPA on May 24, 2018.

The final version of the CASTNET QAPP Revision 9.1 was approved by EPA and uploaded to the EPA CASTNET web page during second quarter 2018. Beginning with Revision 9.1, the contact information for the site operators listed in Appendix 2 was not uploaded to the web page. Instead, a disclaimer was added to the cover page to indicate that the contents of the appendix are for authorized personnel only.

Wood developed criteria for acceptable target concentrations for ozone zero/span/precision (zsp) QC checks for data validation purposes in order to ensure demonstrable adherence to clarification published by EPA's Office of Air Quality Planning and Standards (EPA, 2018). These criteria identify zsp QC checks that pass accuracy criteria but require investigation to ensure the system is operating as intended.

During 2018, the Federal Equivalent Method (FEM) for the Thermo Scientific 49 series of ozone analyzers changed and now defines equivalence using bench temperature within a range of 5–40 degrees Celsius. Previously, shelter temperature within a range of 20–30 degrees Celsius was required.

Wood's QA Lead for the eastern region of the United States performed an internal project audit of Task Order 1003, CASTNET Base Program, during mid-March 2018. The audit verified that project activities, record keeping, and documentation protocols are followed. There was one finding. An annual project review is required for projects with a significant gross budget. The CASTNET V Base Program (Task Order 1003) meets this criterion. The 2018 project review took place in early April 2018.

The GAS153, GA site failed an ozone performance evaluation audit by the State of Georgia due to a failing ozone sample pump. The failing pump would normally have been observed during routine review procedures. In this instance, the routine reviewer was on leave, and covering assignments had been made for those review functions with this single exception. A corrective action was initiated to ensure backups are assigned for Wood reviewers and all of their designated review functions during personnel absences.

The State of North Carolina Department of Environmental Quality (NCDEQ) audited the four CASTNET ozone sites in the state during July 2018. Three of the four sites failed the performance evaluation audit at 15 parts per billion (ppb) with differences ranging from 1.6 to 2.0 ppb. The CASTNET Field Operations Manager met with the auditor and other NCDEQ personnel at the CND125, NC site in early October 2018. This site is one of the three sites that failed the audit by NCDEQ. The meeting was very positive. Several potential causes for the failures were examined, but results of the examination were inconclusive. A summary of the meeting was provided to EPA.

During fourth quarter, Wood worked with EPA to develop standardized guidance for third-party auditors and CASTNET personnel during an audit. The goal is to provide consistent instrument input for audits (e.g., CASTNET personnel noting instrument stability for QC checks) and a predictable site routine for auditors. During December, an EPA Region 3 National Performance Audit Program (NPAP) auditor, EPA Clean Air Markets Division, and Wood personnel discussed the proposed procedures. The auditor provided feedback, which was incorporated into the audit checklist.

The Wood laboratory continued evaluating nylon filter replacements for the Nylasorb filters. The best option for replacing the Nylasorb filter is a nylon filter from MTL Corp. The MTL nylon filter began being used at CASTNET sites in January 2018. However, unwashed MTL nylon filters do not meet CASTNET acceptance criteria. Wood developed a method for washing the MTL nylon filters in-house. This method consistently produces filters that pass acceptance criteria. MTL has attempted pre-washing the nylon filters, but has not consistently produced filters that pass acceptance criteria. Wood continues to work with MTL as it develops a washing system and standard operating procedures (SOP) describing activities for washing filters and monitoring the water system. An approved, finalized washing SOP that includes details on monitoring the water system is necessary to ensure a consistent filter product. Until MTL develops a consistently effective washing procedure with approved documentation, Wood will continue to wash the nylon filters in-house.

Review of the 2017 annual summary of filter pack receipt statistics indicated increasing numbers of filter packs were not being received within 14 days after removal from the tower. During 2018, review of filter pack receipt statistics continued. Investigation into possible causes of the increase in late filter packs found that the capacity of the local mail service to process and deliver network filter packs has diminished. The project manager continues to work with the local post office to ensure timely delivery. In addition, the site operators have been informed of the need to promptly return filter packs after exposure and to take proper steps to package the filter packs securely prior to shipping. A corrective action was developed. If filter packs have not been received by Monday morning, members of the CASTNET management team are informed. At that time, the post office is contacted, and if delivery

cannot be made within the required window, Wood personnel will pick up the filter packs. For 2018, filter pack return statistics remained within the 95 percent criterion.

Review of filter pack analysis control charts during creation of the First Quarter 2017 QA Report indicated possible calcium and potassium contamination. A corrective action was initiated. During May 2018, the QA Manager and Laboratory Operations Manager began investigating possible sources of contamination. Opportunities for contamination can occur during the filter pack loading/unloading and filter pack component cleaning processes. The QA Manager observed washing procedures and noted several steps were not being performed according to documented procedure. The technician handling the filter packs was re-trained, and his packing/unpacking and cleaning activities were observed to verify compliance. A set of filter packs was prepared each week for testing as process blanks to verify the effectiveness of the actions taken. The process blanks continued to show periodic contamination. It was determined that the foil used to line the bins for the washing and drying of filter pack parts was the source of the contamination. In July 2018, use of foil was discontinued. A set of filter packs for testing as process blanks was prepared each week during July and August to verify the effectiveness of the corrective actions taken. Laboratory and field blanks continued to be tested through fourth quarter. None of the filter blanks analyzed following cessation of the use of foil on July 11 exceeded the acceptance criterion for calcium or potassium.

Communication with CASTNET sites began being disrupted by VPNFilter malware beginning in late May and continuing into June 2018. The malware is aimed at home and office routers, and once the routers were infected, the malware prevented the sites from being polled. Routers at approximately half of the EPA-sponsored CASTNET sites were affected by the malware. A corrective action was opened to address the problem. Steps for recovery and prevention of further infection by the malware were developed. These steps include replacing routers with routers not susceptible to the malware and accelerating implementation of network-wide site communications upgrades (e.g., cellular modems, routers, managed networking, and new data logger software). By the end of June, Wood had replaced the malware-infected routers. No data were lost.

It was discovered during the review of the ozone systems at the North Carolina sites that some Nafion dryers were installed incorrectly. Wood began reviewing dryer configurations to determine at which sites dryers were incorrectly installed. Corrective action was initiated. Dryer installation instructions will be rewritten and clarified, and the subcontractors will be provided with refresher training to verify they understand installation procedures.

Documentation needed for the annual review by the American Association for Laboratory Accreditation (A2LA) in order to maintain International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 17025:2005 accreditation for Wood's laboratory and field operations was prepared and submitted to A2LA during second quarter 2018. The documentation was subsequently accepted by A2LA, and Wood received notice that the 17025:2005 accreditation was reaffirmed until the routine A2LA assessment in spring 2019.

The QA Manager conducted the annual management review in accordance with Wood's analytical laboratory's ISO/IEC 17025:2005 accreditation during August 2018.

The annual management review report in support of ISO/IEC 17025:2005 accreditation was completed and distributed to the Wood QA and management teams. The meeting to discuss the report was held August 6, 2018. The management team was complimentary of the program. A recommendation for improvement was to purchase an additional ion chromatography (IC) instrument for the CASTNET analytical laboratory. The IC was subsequently purchased by Wood's parent corporation in mid-October and installed on November 1, 2018. It was also recommended that the management review meeting be held earlier in the year in 2019, as has been done in previous years. Additionally, the management team requested a written report on the VPNFilter malware attack outlining the risks and corrective actions taken.

During fourth quarter, Wood completed and submitted documentation to the A2LA in support of the upcoming 2019 assessment for ISO/IEC 17025:2017 accreditation. The existing accreditation meets the requirements for 17025:2005. Revisions to ISO/IEC 17025 were promulgated in 2017.

Providing a safe working environment is one of Wood's goals. In support of this, updated information on tower installation was added to the Activity Hazard Analysis form, which will be included as a revision to the CASTNET Health and Safety Plan. Additionally, use of a hinged baseplate for installation of the tilt-down flow tower was recommended to reduce risk. A prototype of the hinged baseplate was received by Wood during December 2018. Wood will continue working with Aluma Tower to develop a usable prototype during first quarter 2019.

Wood received notification following a third party audit that one of the guy wires on the HWF187, NY tower was broken. The current site condition checklist, which is used during calibration visits, requires checking the guy wires and anchors at ground level and below grade. No record of the broken guy wire was found in site documentation. A corrective action was initiated to revise the site condition checklist to note that there are at least three guy wires on each tower and require the inspecting personnel to record the number inspected.

### **Quarterly/Annual Summary**

Table 1 lists the quarters of data that were validated to Level 3 during 2018 by site calibration group. Table 2 lists the sites in each calibration group along with the calibration schedule. Table 3 presents the measurement criteria for continuous field measurements. These criteria apply to the instrument challenges performed during site calibrations. Table 4 presents the measurement criteria for laboratory filter pack measurements. These criteria apply to the QC samples listed in the following section of this report. Table 5 presents the critical criteria for ozone monitoring. Table 6 presents the critical criteria for trace-level gas monitoring.

### **Laboratory Intercomparison Results Summary**

Wood's laboratory participated in the interlaboratory comparison program in support of the readiness verification plan to verify that the Wisconsin State Laboratory of Hygiene (WSLH) produces data of sufficient quality to detect and quantify trends in atmospheric chemistry. The WSLH is the National Atmospheric Deposition Program's Central Analytical Laboratory (WCAL). Thirty-two samples were analyzed by the Wood laboratory for the study. The Wood analytical laboratory compared well with the other laboratories.

Wood's CASTNET laboratory regularly participates in the Environment Canada (ECAN) Proficiency Testing (PT) Program for Inorganic Environmental Substances. The results reported by the participating laboratories are evaluated for systematic bias and precision. Systematic bias is assessed using the Youden (1969) non-parametric analysis, while precision is calculated using algorithm A from the International Organization for Standardization (ISO) standard 13528 (ISO, 2005). Laboratory results are considered systematically biased when individual parameters are ranked by the Youden analysis to be consistently and significantly higher or lower than the assigned value without regard to flagged results. The CASTNET laboratory's proficiency testing plan requires action for individual test results that are greater than three standard deviations from the assigned value, bias 5 percent or higher for a single parameter, three or more biased results of any magnitude in a single study, or a consecutive study result indicating bias of any magnitude for a given parameter.

During February 2018, Wood received results for sample analyses submitted for proficiency test (PT) study 0111 for Rain and Soft Waters to the National Laboratory of Environmental Testing (NLET), a branch of the National Water Research Institute with ECAN that provides QA services. Analyses of all parameters were rated as "ideal" for PT study 0111 with the exception of sulfate (ECAN, 2018a). There was a 4 percent high bias for sulfate; however, according to the CASTNET laboratory's proficiency testing plan, a 4 percent bias is below the threshold for which corrective action is required.

During September 2018, Wood received results for sample analyses submitted to the NLET for PT study 0112 for Rain and Soft Waters. All CASTNET parameters were rated as "ideal" with the exception of one sulfate sample that received an "Action High" flag (ECAN, 2018b). The incorrect value submitted for sulfate was traced to a data entry error in the form submitted to ECAN. A corrective action was initiated, and the CASTNET QA Manager developed a spreadsheet to facilitate double entry and detect and highlight data entry errors.

The CASTNET laboratory's results for ECAN PT study codes 0111 and 0112 for the eight CASTNET parameters are listed in Table 7. The overall laboratory rating by ECAN indicates a percent score. A "Very Good" rating, the highest rating, is 0–5 percent of the sum of parameters biased and results flagged. A "Good" rating, the second highest rating, is >5–12.5 percent of the sum of the parameters biased and results flagged. For results received during 2018, the overall laboratory performance rating for Wood's analytical laboratory was "Good" for PT study 0111 and "Very Good" for PT study 0112 (ECAN, 2018a; 2018b).

### **Quality Control Analysis Count**

The QC sample statistics presented in this report are for reference standards (RF) and continuing calibration verification spikes (CCV) used to assess accuracy and for replicate sample analyses (RP) used to assess "in-run" precision. In addition, laboratory method blanks (MB) containing reagents without a filter; laboratory blanks (LB) containing reagents and a new, unexposed filter; and field blanks (FB) containing reagents and an unexposed filter that was loaded into a filter pack assembly and shipped to and from the monitoring site while remaining in sealed packaging are also included. Tables 8 through 11 present the number of analyses in each category that were performed during each quarter of 2018.

## Sample Receipt Statistics

Ninety-five percent of field samples from EPA-sponsored sites must be received by the CASTNET laboratory in Gainesville, FL no later than 14 days after removal from the sampling tower. Table 12 presents the relevant sample receipt statistics for each of the four quarters of 2018 together with an annual summary for each category.

## Data Quality Indicator Results

Figures 1 through 3 present the results of RF, CCV, and RP QC sample analyses for fourth quarter 2018. All results were within the criteria listed in Table 4 with the exception of one potassium RP result at 23 percent. The concentration of this sample was low at 3.6 times the reporting limit. Table 13 presents the percent recoveries and standard deviations for RF, CCV, and RP QC sample analyses for 2018. Quarterly averages are all within criteria.

Table 14 presents quarterly co-located filter pack precision results for data validated to Level 3 during the year. Annual average results for MCK131/231, KY and ROM406/206, CO were within the criterion for all of the 11 parameters reported.

Figure 4 presents completeness statistics for continuous measurements validated to Level 3 during the year. All parameters met the 90 percent criterion with the exception of relative humidity.

Table 15 presents summary statistics of critical criteria measurements at ozone sites collected during fourth quarter 2018. The statistics presented contain data validated at Level 2 and Level 3. All data associated with QC checks that fail to meet the criteria listed in Table 5 were or will be invalidated unless the cause of failure has no effect on ambient data collection, and passing results still meet frequency criteria. Results in shaded cells either exceed documented criteria or are otherwise notable. Table 16 presents observations associated with the shaded cell results in Table 15.

Table 17 presents summary statistics of critical criteria measurements at trace-level gas monitoring sites collected during fourth quarter 2018. The statistics presented contain data validated at Level 2 and Level 3. All data associated with QC checks that fail to meet the criteria listed in Table 6 were or will be invalidated unless the cause of failure has no effect on ambient data collection, and passing results still meet frequency criteria. Results in shaded cells either exceed documented criteria or are otherwise notable. Table 18 presents observations associated with the shaded cell results in Table 17.

## Laboratory Control Sample Analysis

The laboratory control sample (LCS) is a reagent blank spiked with the target analytes from the established analytical methods and carried through the same extraction process that field samples must undergo. The LCS is not required by the CASTNET QA/QC program. LCS analyses are performed by the laboratory to monitor for potential sample handling artifacts and provide a means to identify possible analyte loss from extraction to extraction. Figure 5 presents LCS analysis results for fourth quarter 2018. All recovery values were between 94 percent and 109 percent.

## Blank Results

Figures 6 through 8 present the results of MB, LB, and FB QC sample analyses for fourth quarter 2018. All fourth quarter results were within criteria (two times the reporting limit) listed in Table 4 with the exception of two nylon FB sulfate results at 2.5 and 9.0 times the reporting limit. The latter result was quite high, and the associated weekly sample was invalidated. Investigation did not reveal the source of contamination. Table 19 summarizes the record of filter blanks for 2018. All 2018 results were within criteria listed in Table 4 with the exception of 2 LB and 36 FB samples that occurred primarily during first and second quarters with three FB exceptions during third quarter. These were all primarily calcium and potassium results with three FB magnesium results as exceptions. As previously discussed in the Significant Events section of this report, an investigation was initiated upon observation of the first quarter results. The foil used to line the pans used to hold the filter pack housings during the washing procedure was identified as the source of contamination. No contamination was observed following elimination of the foil. All other blank QC checks in their respective batches were within criteria.

## Suspect/Invalid Filter Pack Samples

Filter pack samples that were flagged as suspect or invalid during each of the four quarters of 2018 are listed in Table 20. This table also includes associated site identification and a brief description of the reason the sample was flagged. During fourth quarter, 19 filter pack samples were invalidated.

## Field Problem Count

Table 21 presents counts of field problems affecting continuous data collection for more than one day for each quarter during 2018. The problem counts are sorted by a 30-, 60-, or 90-day time period to resolution. A category for unresolved problems is also included. Time to resolution indicates the period taken to implement corrective action.

## Field Calibration Results

A summary of field calibration failures by parameter for each quarter of 2018 is listed in Table 22. Calibrations were performed at 24 sites during fourth quarter 2018. During 2018, all sites and parameters were within the criteria listed in Table 3 with the exception of the parameters at the nine sites that are listed in Table 22.

Table 23 presents field accuracy results for 2018 based on instrument challenges performed using independent reference standards during site calibration visits. Each parameter was within its criterion with at least 90 percent frequency with the exception of relative humidity at 83.3 percent frequency. Per CASTNET project protocols, data are flagged but still considered valid if the calibration criterion is not exceeded by more than its magnitude (i.e., if within two times the criterion). All calibration failures reported in 2018 for the indicated parameters were within two times the criterion with the exception of flow rate at UVL124, MI; temperature at ALC188, TX; and relative humidity at CHE185, OK. Data associated with these failures were invalidated.

## References

- American Society for Testing and Materials (ASTM). 2008. ASTM E29-08, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications." ASTM International, West Conshohocken, PA, DOI:10.1520/E0029-08. www.astm.org.
- Environment Canada (ECAN) Water Science and Technology Directorate. 2018a. Rain and Soft Waters PT Study 0111 Report. Proficiency Testing Program, Burlington, Ontario, Canada. Prepared for Amec Foster Wheeler Environment & Infrastructure, Inc., Newberry, FL, USA.
- Environment Canada (ECAN) Water Science and Technology Directorate. 2018b. Rain and Soft Waters PT Study 0112 Report. Proficiency Testing Program, Burlington, Ontario, Canada. Prepared for Wood Environment & Infrastructure Solutions, Inc., Newberry, FL, USA.
- International Organization for Standardization (ISO). 2005. *Statistical Methods for the Use in Proficiency Testing by Interlaboratory Comparisons, Annex C, Robust Analysis, Section C.1: Algorithm A*. Standard 13528. ISO 13528:2005(E).
- U.S. Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards (OAQPS). 2018. *Steps to Qualify or Validate Data after an Exceedance of Critical Criteria Checks*. Ambient Monitoring Technology Information Center (AMTIC) Policy Memoranda and Technical Guidance, <https://www.epa.gov/amtic/policy-memoranda-and-technical-guidance>. Accessed January 2019.
- U.S. Environmental Protection Agency (EPA). 2017. Title 40 *Code of Federal Regulations* Part 58, "Appendix A to Part 58 – Quality Assurance Requirements for Monitors used in Evaluations of National Ambient Air Quality Standards."
- Wood Environment & Infrastructure Solutions, Inc. (Wood) formerly known as Amec Foster Wheeler Environment & Infrastructure, Inc. 2017. *Clean Air Status and Trends Network (CASTNET) Quality Assurance Project Plan (QAPP) Revision 9.1*. Prepared for U.S. Environmental Protection Agency (EPA), Office of Air and Radiation, Clean Air Markets Division, Washington, DC. Contract No. EP-W-16-015. Gainesville, FL. <https://java.epa.gov/castnet/documents.do>.
- Youden, W.J. (Ku, H.H., ed). 1969. *Precision Measurement and Calibration*. NBS Special Publication 300-Volume 1. U.S. Government Printing Office, Washington, DC.

**Table 1** Data Validated to Level 3 through Fourth Quarter 2018

Calibration Group*	Months Available	Number of Months	Complete Quarters	Number of Quarters
SE-4/MW-6 <sup>†</sup>	July 2016 – June 2018	12	Quarter 3 2016 – Quarter 2 2018	4
E-1/SE-5	August 2016 – July 2018	12	Quarter 4 2016 – Quarter 2 2018	3
MW-7/W-9	September 2016 – August 2018	12	Quarter 4 2016 – Quarter 2 2018	3
E-2/MW-8	October 2016 – September 2018	12	Quarter 4 2016 – Quarter 3 2018	4
E-3/W-10 <sup>‡</sup>	May 2016 – April 2018	12	Quarter 3 2016 – Quarter 1 2018	3

**Notes:** \*The sites contained in each calibration group are listed in Table 2.

<sup>†</sup>Contains MCK131/231 co-located pair

<sup>‡</sup>Contains ROM206 of the ROM406/ROM206 co-located pair

**Table 2** Field Calibration Schedule for 2018

Calibration Group	Months Calibrated	Sites Calibrated			
Eastern Sites (23 Total)					
E-1 (8 Sites)	February/August	BEL116, MD BWR139, MD	WSP144, NJ CTH110, NY	ARE 128, PA PSU106, PA	PED108, VA VPI120, VA
E-2 (10 Sites)	April/October	ABT147, CT ASH135, ME	HOW191, ME WST109, NH	CAT175, NY HWF187, NY <sup>2</sup>	NIC001, NY EGB181, ON WFM105, NY UND002, VT
E-3 (5 Sites)	May/November	KEF112, PA MKG113, PA	LRL117, PA PAR107, WV	CDR119, WV	
Southeastern Sites (11 Total)					
SE-4 (6 Sites)	January/July	SND152, AL GAS153, GA	BFT142, NC CND125, NC	COW137, NC SPD111, TN	
SE-5 (5 Sites)	February/August	CAD150, AR IRL141, FL	SUM156, FL CVL151, MS	DUK008, NC <sup>1</sup>	
Midwestern Sites (19 Total)					
MW-6 (6 Sites)	January/July	CDZ171, KY CKT136, KY	MCK131, KY MCK231, KY	PNF126, NC <sup>2</sup> ESP127, TN	
MW-7 (9 Sites)	March/September	ALH157, IL BVL130, IL <sup>3</sup>	STK138, IL VIN140, IN	RED004, MN DCP114, OH	OXF122, OH PRK134, WI QAK172, OH
MW-8 (4 Sites)	April/October	SAL133, IN HOX148, MI	ANA115, MI UVL124, MI		
Western Sites (11 Total)					
W-9 (5 Sites)	March/September	KNZ184, KS KIC003, KS	CHE185, OK SAN189, NE	ALC188, TX	
W-10 (6 Sites)	May/November	GTH161, CO ROM206, CO <sup>1</sup>	NPT006, ID CNT169, WY	PND165, WY <sup>1</sup> PAL190, TX	

**Notes:** <sup>1</sup>Trace-level gas calibrations are performed quarterly in February, May, August, and November.

<sup>2</sup>Trace-level gas calibrations are performed quarterly in January, April, July, and October.

<sup>3</sup>Trace-level gas calibrations are performed quarterly in March, June, September, and December.

**Table 3** Data Quality Indicators for CASTNET Continuous Measurements

Measurement		Criteria <sup>1</sup>	
Parameter <sup>2</sup>	Method	Precision	Accuracy
Filter pack flow	Mass flow controller	± 10%	± 5%
Ozone <sup>3</sup>	UV absorbance	All points within ± 2% of full scale of best fit straight line Linearity error < 5%	
Wind speed	Anemometer	± 0.5 m/s	The greater of ± 0.5 m/s for winds < 5 m/s or ± 5% for winds ≥ 5 m/s
Wind direction	Wind vane	± 5°	± 5°
Sigma theta	Wind vane	Undefined	Undefined
Ambient temperature	Platinum RTD	± 1.0°C	± 0.5°C
Delta temperature	Platinum RTD	± 0.5°C	± 0.5°C
Relative humidity	Thin film capacitor	± 10% (of full scale)	± 10%
Precipitation	Tipping bucket rain gauge	± 10% (of reading)	± 0.05 inch <sup>4</sup>
Solar radiation	Pyranometer	± 10% (of reading taken at local noon)	± 10%
Surface wetness	Conductivity bridge	Undefined	Undefined

**Notes:** °C = degrees Celsius  
m/s = meters per second  
RTD = resistance-temperature device  
UV = ultraviolet

<sup>1</sup>Precision criteria apply to co-located instruments, and accuracy criteria apply to calibration of instruments. Co-located precision criteria do not apply to CASTNET sites that are configured and operated in accordance with Part 58 of Title 40 of the *Code of Federal Regulations* (EPA, 2017)

<sup>2</sup>Meteorological parameters are only measured at five of the EPA-sponsored CASTNET sites: IRL141, FL; BVL130, IL; BEL116, MD; CHE185, OK; and PND165, WY.

<sup>3</sup>Ozone is not measured at nine EPA-sponsored CASTNET sites: KIC003, KS; KNZ184, KS; RED004, MN; DUK008, NC; EGB181, ON; CAT175, NY; NIC001, NY; WFM105, NY; and UND002, VT.

<sup>4</sup>For target value of 0.50 inch

**Table 4** Data Quality Indicators for CASTNET Laboratory Measurements

Analyte	Method	Precision <sup>1</sup> (MARPD)	Accuracy <sup>2</sup> (%)	Nominal Reporting Limits	
				mg/L	µg/Filter
Ammonium (NH <sub>4</sub> <sup>+</sup> )	AC	20	90–110	0.020*	0.5
Sodium (Na <sup>+</sup> )	ICP-OES	20	95–105	0.005	0.125
Potassium (K <sup>+</sup> )	ICP-OES	20	95–105	0.006	0.15
Magnesium (Mg <sup>2+</sup> )	ICP-OES	20	95–105	0.003	0.075
Calcium (Ca <sup>2+</sup> )	ICP-OES	20	95–105	0.006	0.15
Chloride (Cl <sup>-</sup> )	IC	20	95–105	0.020	0.5
Nitrate (NO <sub>3</sub> <sup>-</sup> )	IC	20	95–105	0.008*	0.2
Sulfate (SO <sub>4</sub> <sup>2-</sup> )	IC	20	95–105	0.040	1.0

**Notes:** <sup>1</sup>This column lists precision goals for both network precision calculated from co-located filter samples and laboratory precision based on replicate samples.

<sup>2</sup>This column lists laboratory accuracy goals based on reference standards and continuing calibration verification spikes. The criterion is 90–110 percent for ICP-OES reference standards.

AC = automated colorimetry  
 IC = ion chromatography  
 ICP-OES = inductively coupled plasma-optical emission spectrometry  
 MARPD = mean absolute relative percent difference  
 mg/L = milligrams per liter  
 µg/Filter = micrograms per filter  
 \* = as nitrogen

Values are rounded according to American Society for Testing and Materials (ASTM) E29-08, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications" (ASTM, 2008).

For more information on analytical methods and associated precision and accuracy criteria, see the CASTNET QAPP, (Wood, 2017).

**Table 5** Ozone Critical Criteria\*

Type of Check	Analyzer Response
Zero	Less than ± 3.1 parts per billion (ppb)
Span	Less than ± 7.1 percent between supplied and observed concentrations
Single Point QC	Less than ± 7.1 percent between supplied and observed concentrations

**Notes:** \*Applies to CASTNET sites that are configured and operated in accordance with Part 58 of Title 40 of the *Code of Federal Regulations* (EPA, 2017). The minimum frequency for these checks is once every two weeks.

Values are rounded according to ASTM E29-08, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications" (ASTM, 2008).

**Table 6** Trace-level Gas Monitoring Critical Criteria\*

Parameter	Analyzer Response	
	Zero Check	Span Check / Single Point QC Check
SO <sub>2</sub>	Less than ± 1.51 ppb	Less than ± 10.1 percent between supplied and observed concentrations
NO <sub>y</sub>	Less than ± 1.51 ppb	
CO	Less than ± 30.1 ppb	

**Notes:** \*Applies to CASTNET sites that are configured and operated in accordance with Part 58 of Title 40 of the *Code of Federal Regulations* (EPA, 2017). The minimum frequency for these checks is once every two weeks.

Values are rounded according to ASTM E29-08, "Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications" (ASTM, 2008).

SO<sub>2</sub> = sulfur dioxide

NO<sub>y</sub> = total reactive oxides of nitrogen

CO = carbon monoxide

ppb = parts per billion

**Table 7** CASTNET Laboratory Results for ECAN PT Studies

Test Parameter	Analytical Method	Reference Method	Laboratory Performance Rating*	
			Good: Study 0111 Winter 2018	Very Good: Study 0112 Summer 2018
Ammonia	AC	EPA Method 350.1	Ideal	Ideal
Chloride	IC	EPA Method 300.0	Ideal	Ideal
Nitrate + Nitrite	IC	EPA Method 300.0	Ideal	Ideal
Sulfate	IC	EPA Method 300.0	High bias: 3.6%   -0.0041	1 of 10 samples flagged
Calcium	ICP-OES	EPA Method 6010	Ideal	Ideal
Magnesium	ICP-OES	EPA Method 6010	Ideal	Ideal
Potassium	ICP-OES	EPA Method 6010	Ideal	Ideal
Sodium	ICP-OES	EPA Method 6010	Ideal	Ideal

**Notes:** \*Expressed as bias percent slope (percent deviation of test results from assigned values) | y-intercept.

Ideal slope = 1 | y-intercept = 0. Any result not 1 | 0 is reported as biased by ECAN.

AC = automated colorimetry

ICP-OES = inductively coupled plasma-optical emission spectrometry

IC = ion chromatography

Source: ECAN (2018a; 2018b)

**Table 8** QC Analysis Count for First Quarter 2018

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO <sub>4</sub> <sup>2-</sup>	54	208	87	18	24	93
	NO <sub>3</sub> <sup>-</sup>	54	208	87	18	24	93
	NH <sub>4</sub> <sup>+</sup>	36	184	86	18	24	93
	Cl <sup>-</sup>	54	208	87	18	24	93
	Ca <sup>2+</sup>	37	190	86	18	24	93
	Mg <sup>2+</sup>	37	190	86	18	24	93
	Na <sup>+</sup>	37	190	86	18	24	93
	K <sup>+</sup>	37	190	86	18	24	93
Nylon	SO <sub>4</sub> <sup>2-</sup>	52	221	85	17	26	120
	NO <sub>3</sub> <sup>-</sup>	52	221	85	17	26	120
Cellulose	SO <sub>4</sub> <sup>2-</sup>	54	194	87	18	26	93

**Table 9** QC Analysis Count for Second Quarter 2018

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO <sub>4</sub> <sup>2-</sup>	55	206	84	18	26	96
	NO <sub>3</sub> <sup>-</sup>	55	206	84	18	26	96
	NH <sub>4</sub> <sup>+</sup>	34	180	84	17	26	96
	Cl <sup>-</sup>	55	206	84	18	26	96
	Ca <sup>2+</sup>	34	184	84	17	26	96
	Mg <sup>2+</sup>	34	184	84	17	26	96
	Na <sup>+</sup>	34	184	84	17	26	96
		K <sup>+</sup>	34	184	84	17	26
Nylon	SO <sub>4</sub> <sup>2-</sup>	54	210	82	18	26	95
	NO <sub>3</sub> <sup>-</sup>	54	210	82	18	26	95
Cellulose	SO <sub>4</sub> <sup>2-</sup>	50	178	81	17	26	95

**Table 10** QC Analysis Count for Third Quarter 2018

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO <sub>4</sub> <sup>2-</sup>	52	198	85	17	24	95
	NO <sub>3</sub> <sup>-</sup>	52	198	85	17	24	95
	NH <sub>4</sub> <sup>+</sup>	34	179	85	17	24	95
	Cl <sup>-</sup>	52	198	85	17	24	95
	Ca <sup>2+</sup>	34	182	87	17	24	95
	Mg <sup>2+</sup>	34	182	87	17	24	95
	Na <sup>+</sup>	34	182	87	17	24	95
	K <sup>+</sup>	34	182	87	17	24	95
Nylon	SO <sub>4</sub> <sup>2-</sup>	50	201	75	17	24	95
	NO <sub>3</sub> <sup>-</sup>	50	201	75	17	24	95
Cellulose	SO <sub>4</sub> <sup>2-</sup>	51	175	79	17	24	94

**Table 11** QC Analysis Count for Fourth Quarter 2018

Filter Type	Parameter	RF Sample Count	CCV Sample Count	RP Sample Count	MB Sample Count	LB Sample Count	FB Sample Count
Teflon	SO <sub>4</sub> <sup>2-</sup>	51	191	80	17	24	91
	NO <sub>3</sub> <sup>-</sup>	51	191	80	17	24	91
	NH <sub>4</sub> <sup>+</sup>	34	174	80	17	24	91
	Cl <sup>-</sup>	51	191	80	17	24	91
	Ca <sup>2+</sup>	34	176	81	17	24	91
	Mg <sup>2+</sup>	34	176	81	17	24	91
	Na <sup>+</sup>	34	176	81	17	24	91
	K <sup>+</sup>	34	176	81	17	24	91
Nylon	SO <sub>4</sub> <sup>2-</sup>	53	196	80	19	24	91
	NO <sub>3</sub> <sup>-</sup>	53	196	80	19	24	91
Cellulose	SO <sub>4</sub> <sup>2-</sup>	52	177	78	19	24	91

**Table 12** Filter Pack Receipt Summary for 2018

Description	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Summary
Count of samples received more than 14 days after removal from tower:	38	15	18	66	137
Count of all samples received:	796	854	814	739	3203
Fraction of samples received within 14 days:	0.952	0.982	0.978	0.911	0.957
Average interval in days:	6.7	4.933	4.966	7.674	6.068*
First receipt date:	01/02/2018	04/02/2018	07/02/2018	10/01/2018	01/02/2018
Last receipt date:	03/28/2018	06/29/2018	09/28/2018	12/28/2018	12/28/2018

**Note:** Sample shipments for the Egbert, Ontario site (EGB181) are in groups of four. Samples associated with EGB181 are excluded from this statistic.

\*annual average

**Table 13** Filter Pack QC Summary for 2018

Filter Type	Parameter	Reference Sample <sup>1</sup> Recovery (%R)			Continuing Calibration Verification Samples (%R)			In-Run Replicate <sup>2</sup> (RPD)		
		Mean	Std. Dev.	Count <sup>3</sup>	Mean	Std. Dev.	Count <sup>3</sup>	Mean	Std. Dev.	Count <sup>3</sup>
		Teflon	SO <sub>4</sub> <sup>2-</sup>	99.21	1.03	51	100.48	0.83	191	1.21
	NO <sub>3</sub> <sup>-</sup>	99.52	0.98	51	98.50	0.95	191	1.68	1.59	80
	NH <sub>4</sub> <sup>+</sup>	103.17	1.43	34	101.28	1.52	174	0.64	0.76	80
	Ca <sup>2+</sup>	101.65	3.33	34	100.54	1.41	176	2.10	1.96	81
	Mg <sup>2+</sup>	99.44	1.82	34	99.94	0.78	176	1.67	1.89	81
	Na <sup>+</sup>	97.37	1.58	34	99.84	1.10	176	1.29	1.76	81
	K <sup>+</sup>	99.18	1.92	34	99.85	1.00	176	1.93	3.10	81
	Cl <sup>-</sup>	98.58	1.47	51	103.06	0.68	191	1.56	1.06	80
Nylon	SO <sub>4</sub> <sup>2-</sup>	104.12	0.88	53	101.37	1.50	196	4.97	4.02	80
	NO <sub>3</sub> <sup>-</sup>	99.87	1.75	53	99.21	1.50	196	3.03	2.65	80
Cellulose	SO <sub>4</sub> <sup>2-</sup>	100.32	1.47	52	100.68	0.74	177	1.41	1.20	78

**Notes:** % R = percent recovery  
RPD = relative percent difference

<sup>1</sup>Results of reference sample analyses provide accuracy estimates

<sup>2</sup>Results of replicate analyses provide precision estimates

<sup>3</sup>Number of QC Samples

**Table 14** Precision Results for Third Quarter 2017 through Second Quarter 2018

Quarter	SO <sub>4</sub> <sup>2-</sup>	NO <sub>3</sub> <sup>-</sup>	NH <sub>4</sub> <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	Cl <sup>-</sup>	HNO <sub>3</sub>	SO <sub>2</sub>	Total NO <sub>3</sub> <sup>-</sup>
MCK131/231, KY											
2017 Q3	6.26	9.52	5.96	8.69	6.4	7.63	6.27	0.4	9.76	4.66	8.65
2017 Q4	14.07	11.84	11.48	15.07	14.1	15.58	21.28	6.65	16.66	10.26	13.66
2018 Q1	2.76	5.18	2.38	9.30	6.82	4.34	15.74	10.56	6.26	4.66	4.11
2018 Q2	3.22	6.74	3.47	7.26	9.01	3.11	3.68	0.34	3.06	4.38	2.49
Average	6.58	8.32	5.82	10.08	9.08	7.67	11.74	4.49	8.94	5.99	7.23
ROM406/206, CO											
2017 Q3	4.96	13.49	8.95	7.71	8.44	10.06	6.84	7.66	6.76	7.67	7.3
2017 Q4	7.13	16.8	6.02	8.85	10.51	7.39	14.82	15.88	7.88	12.95	8.11
2018 Q1	5.39	13.48	11.39	9.17	5.77	11.34	16.36	9.94	12.74	6.38	11.05
2018 Q2	5.36	9.46	6.23	10.94	8.31	7.19	12.87	6.9	17.14	12.93	11.58
Average	5.71	13.31	8.15	9.17	8.26	9.00	12.72	10.10	11.13	9.98	9.51

**Notes:** One of 88 site-quarter-parameters were outside criterion

**Table 15** Ozone QC Summary for Fourth Quarter 2018 (1 of 2)

Site ID	% Span Pass <sup>1</sup>	Span  %D  <sup>2</sup>	% Single Point QC Pass <sup>1</sup>	Single Point QC  %D  <sup>2</sup>	% Zero Pass <sup>1</sup>	Zero Average (ppb) <sup>2</sup>
ABT147, CT	100.00	1.36	100.00	1.34	100.00	0.21
ALC188, TX	100.00	0.88	100.00	1.02	100.00	0.61
ALH157, IL	100.00	0.85	100.00	0.89	100.00	0.21
ANA115, MI	100.00	1.19	100.00	1.92	100.00	0.10
ARE128, PA	100.00	3.25	98.92	3.12	100.00	0.23
ASH135, ME	100.00	1.90	100.00	2.12	100.00	0.24
BEL116, ME	100.00	1.23	100.00	1.18	100.00	0.31
BFT142, NC*	N/A	N/A	N/A	N/A	N/A	N/A
BVL130, IL	100.00	2.47	100.00	2.25	100.00	0.19
BWR139, MD	98.65	2.66	100.00	1.76	100.00	0.52
CAD150, AR	100.00	0.98	100.00	1.12	100.00	0.39
CDR119, WV	100.00	1.92	100.00	1.16	100.00	0.18
CDZ171, KY	100.00	1.92	100.00	1.16	100.00	0.18
CKT136, KY	100.00	0.58	100.00	0.69	100.00	0.14
CND125, NC	100.00	1.06	100.00	1.27	100.00	0.25
CNT169, WY	100.00	0.60	100.00	0.78	100.00	0.20
COW137, NC	100.00	1.14	97.06	1.58	97.06	0.70
CTH110, NY	100.00	2.63	100.00	2.45	100.00	0.46
CVL151, MS	84.04	3.75	100.00	2.17	100.00	0.18

**Table 15** Ozone QC Summary for Fourth Quarter 2018 (2 of 2)

Site ID	% Span Pass <sup>1</sup>	Span  %D  <sup>2</sup>	% Single Point QC Pass <sup>1</sup>	Single Point QC  %D  <sup>2</sup>	% Zero Pass <sup>1</sup>	Zero Average (ppb) <sup>2</sup>
DCP114, OH	100.00	1.76	100.00	1.89	100.00	0.18
ESP127, TN	100.00	2.35	100.00	2.72	100.00	0.21
GAS153, GA	100.00	0.55	100.00	1.53	100.00	1.20
GTH161, CO	100.00	2.73	100.00	2.78	100.00	0.14
HOX148, MI	100.00	2.91	100.00	1.96	100.00	0.53
HWF187, NY	100.00	0.74	100.00	0.86	100.00	0.13
IRL141, FL	100.00	0.71	100.00	0.67	100.00	0.65
KEF112, PA	100.00	1.47	100.00	1.48	100.00	0.23
LRL117, PA	91.92	4.87	91.92	5.40	100.00	0.20
MCK131, KY	98.92	1.64	100.00	1.78	100.00	0.35
MCK231, KY	100.00	1.17	98.94	1.55	98.94	0.31
MKG113, PA	100.00	1.41	100.00	1.30	100.00	0.27
NPT006, ID	100.00	2.17	100.00	0.73	100.00	0.32
OXF122, OH	100.00	1.41	98.97	1.34	100.00	0.49
PAL190, TX	100.00	0.87	100.00	0.77	100.00	0.35
PAR107, WV	100.00	0.80	100.00	0.89	100.00	0.19
PED108, VA	100.00	0.44	100.00	0.73	100.00	0.25
PND165, WY	100.00	0.87	100.00	1.86	100.00	0.60
PNF126, NC	100.00	0.30	100.00	1.14	100.00	0.68
PRK134, WI	100.00	0.61	100.00	0.82	100.00	0.18
PSU106, PA	100.00	0.75	100.00	0.75	100.00	0.15
QAK172, OH	100.00	2.25	98.85	2.33	100.00	0.43
ROM206, CO	100.00	1.03	100.00	1.15	100.00	0.16
SAL133, IN	100.00	4.51	100.00	4.43	100.00	0.17
SAN189, NE	100.00	0.90	100.00	1.09	100.00	0.21
SND152, AL	100.00	1.30	100.00	1.79	100.00	0.51
SPD111, TN	98.90	1.30	96.70	1.39	98.90	0.98
STK138, IL	98.98	1.17	100.00	1.02	100.00	0.18
SUM156, FL**	100.00	0.73	100.00	0.47	100.00	0.83
UVL124, MI	100.00	1.02	100.00	1.19	100.00	0.15
VIN140, IN	100.00	1.22	100.00	1.04	100.00	0.47
VPI120, VA	98.80	3.40	100.00	2.15	100.00	0.49
WSP144, NJ	100.00	1.77	100.00	1.96	100.00	0.23
WST109, NH	100.00	0.90	100.00	0.80	100.00	0.16

**Notes:** <sup>1</sup>Percentage of comparisons that pass the criteria listed in Table 5. Values falling below 90 percent are addressed in Table 16.

<sup>2</sup>Absolute value of the average percent differences between the on-site transfer standard and the site monitor. Values exceeding the criteria listed in Table 5 are addressed in Table 16.

\*Site was down during fourth quarter due to hurricane damage from Hurricane Florence

\*\*Statistics are based on 14 days of available data. Site was down for the rest of the period due to damage from Hurricane Michael.

%D = percent difference

**Table 16** Ozone QC Observations for Fourth Quarter 2018

Site ID	QC Criterion	Comments
CVL151, MS	% Span Pass	The site analyzer malfunctioned in late November and was replaced December 5.

**Table 17** Trace-level Gas QC Summary for Fourth Quarter 2018

Parameter	% Span Pass <sup>1</sup>	Span  %D  <sup>2</sup>	% Single Point QC Pass <sup>1</sup>	Single Point QC  %D  <sup>2</sup>	% Zero Pass <sup>1</sup>	Zero Average (ppb) <sup>2</sup>
BVL130, IL						
SO <sub>2</sub>	100.00	0.92	100.00	2.38	100.00	0.41
NO <sub>y</sub>	100.00	1.97	100.00	2.02	100.00	0.38
CO	100.00	0.94	72.22	8.78	77.14	20.50
DUK008, NC						
NO <sub>y</sub>	100.00	1.46	100.00	3.47	100.00	0.39
HWF187, NY						
NO <sub>y</sub>	100.00	0.79	100.00	1.40	100.00	0.15
PND165, WY						
NO <sub>y</sub>	97.87	2.77	95.74	7.27	100.00	0.13
PNF126, NC						
NO <sub>y</sub>	100.00	1.27	100.00	2.77	100.00	0.43
ROM206, CO						
NO <sub>y</sub>	100.00	1.55	100.00	0.93	100.00	0.17

**Notes:** <sup>1</sup>Percentage of comparisons that pass the criteria listed in Table 6. Values falling below 90 percent are addressed in Table 18.

<sup>2</sup>Absolute value of the average percent differences between the supplied and observed concentrations. Values exceeding the criteria listed in Table 6 are addressed in Table 18.

%D = percent difference

ppb = parts per billion

**Table 18** Trace-level Gas QC Observations for Fourth Quarter 2018

Site ID	Parameter	QC Criterion	Comments
BVL130, IL	CO	% Single Point QC Pass % Zero Pass	There were auto reference issues during November and December.

**Table 19** Summary of Filter Blanks for 2018 (1 of 2)

Parameter Name	Detection Limit Total $\mu\text{g}$	Total Number	Number > Detection Limit	Average Total $\mu\text{g}$	Average Absolute Deviation	Maximum Total $\mu\text{g}$
<b>FIELD BLANKS</b>						
Teflon-NH <sub>4</sub> <sup>+</sup> -N	0.500	375	0	0.500	0.000	0.500
Teflon- NO <sub>3</sub> <sup>-</sup> -N	0.200	375	7	0.201	0.002	0.330
Teflon- SO <sub>4</sub> <sup>2-</sup>	1.000	375	0	1.000	0.000	1.000
Cl <sup>-</sup>	0.500	375	0	0.500	0.000	0.500
Ca <sup>2+</sup>	0.150	375	61	0.168	0.032	0.535
Mg <sup>2+</sup>	0.075	375	26	0.077	0.004	0.183
Na <sup>+</sup>	0.125	375	11	0.127	0.004	0.458
K <sup>+</sup>	0.150	375	55	0.195	0.079	2.608
Nylon- NO <sub>3</sub> <sup>-</sup> -N	0.200	402	2	0.200	0.000	0.283
Nylon - SO <sub>4</sub> <sup>2-</sup>	1.000	402	3	1.024	0.047	8.900
Cellulose - SO <sub>4</sub> <sup>2-</sup>	2.000	375	9	2.017	0.033	3.645
<b>LABORATORY BLANKS</b>						
Teflon-NH <sub>4</sub> <sup>+</sup> -N	0.500	102	0	0.500	0.000	0.500
Teflon- NO <sub>3</sub> <sup>-</sup> -N	0.200	102	0	0.200	0.000	0.200
Teflon- SO <sub>4</sub> <sup>2-</sup>	1.000	102	0	1.000	0.000	1.000
Cl <sup>-</sup>	0.500	102	0	0.500	0.000	0.500
Ca <sup>2+</sup>	0.150	102	7	0.160	0.020	0.650
Mg <sup>2+</sup>	0.075	102	2	0.077	0.004	0.228
Na <sup>+</sup>	0.125	102	0	0.125	0.000	0.125
K <sup>+</sup>	0.150	102	2	0.152	0.004	0.363
Nylon- NO <sub>3</sub> <sup>-</sup> -N	0.200	104	0	0.200	0.000	0.200
Nylon -SO <sub>4</sub> <sup>2-</sup>	1.000	104	0	1.000	0.000	1.000
Cellulose -SO <sub>4</sub> <sup>2-</sup>	2.000	104	0	2.000	0.000	2.000
<b>METHOD BLANKS</b>						
Teflon-NH <sub>4</sub> <sup>+</sup> -N	0.500	69	0	0.500	0.000	0.500
Teflon- NO <sub>3</sub> <sup>-</sup> -N	0.200	70	1	0.200	0.001	0.225
Teflon- SO <sub>4</sub> <sup>2-</sup>	1.000	70	0	1.000	0.000	1.000
Cl <sup>-</sup>	0.500	70	0	0.500	0.000	0.500
Ca <sup>2+</sup>	0.150	69	0	0.150	0.000	0.150
Mg <sup>2+</sup>	0.075	69	0	0.075	0.000	0.075
Na <sup>+</sup>	0.125	69	0	0.125	0.000	0.125
K <sup>+</sup>	0.150	69	0	0.150	0.000	0.150
Nylon- NO <sub>3</sub> <sup>-</sup> -N	0.200	72	0	0.200	0.000	0.200
Nylon -SO <sub>4</sub> <sup>2-</sup>	1.000	72	0	1.000	0.000	1.000
Cellulose -SO <sub>4</sub> <sup>2-</sup>	2.000	73	0	2.000	0.000	2.000

**Table 19** Summary of Filter Blanks for 2018 (2 of 2)

Parameter Name	Detection Limit Total µg	Total Number	Number > Detection Limit	Average Total µg	Average Absolute Deviation	Maximum Total µg
ACCEPTANCE TEST VALUES <sup>1</sup>						
Teflon-NH <sub>4</sub> <sup>+</sup> -N	0.500	264	0	0.500	0.000	0.500
Teflon- NO <sub>3</sub> <sup>-</sup> -N	0.200	264	0	0.200	0.000	0.200
Teflon- SO <sub>4</sub> <sup>2-</sup>	1.000	264	0	1.000	0.000	1.000
Cl <sup>-</sup>	0.500	264	0	0.500	0.000	0.500
Ca <sup>2+</sup>	0.150	264	5	0.151	0.001	0.255
Mg <sup>2+</sup>	0.075	264	1	0.075	0.000	0.100
Na <sup>+</sup>	0.125	264	1	0.125	0.000	0.190
K <sup>+</sup>	0.150	264	1	0.150	0.000	0.165
Nylon- NO <sub>3</sub> <sup>-</sup> -N	0.200	320	0	0.200	0.000	0.200
Nylon -SO <sub>4</sub> <sup>2-</sup>	1.000	320	0	1.000	0.000	1.000
Cellulose -SO <sub>4</sub> <sup>2-</sup>	2.000	288	0	2.000	0.000	2.000

**Note:** <sup>1</sup>Only filter batches passing QC requirements are used for sampling and analysis.

**Table 20** Filter Packs Flagged as Suspect or Invalid (1 of 2)

Site ID	Sample No.	Reason
First Quarter 2018		
JOT403, CA	1805003-12	Insufficient flow data
NIC001, NY	1801001-35 1802001-35 1803001-35 1804001-35	There was an undetected leak in the flow system. The site operator was retrained in leak check procedures.
NPT006, ID	1803004-04	Power failure
PNF126, NC	1802001-41 1803001-41	The data logger malfunctioned and was replaced.
Second Quarter 2018		
BAS601, WY	1817005-01	Suspect values
BUF603, WY	1815005-02	Power outage
CKT136, KY	1817001-13 1818001-13	Suspect values
CTH110, NY	1815001-17	Suspect potassium value
EGB181, ON	1814001-21	Filter pack was not secure
GRS420, TN	1817003-11	Failed leak check
NIC001, NY	1814001-35	Power outage
UND002, VT	1818001-51	Power outage
WFM105, NY	1818001-55	Power outage

**Table 20** Filter Packs Flagged as Suspect or Invalid (2 of 2)

Third Quarter 2018		
CHA467, AZ	1829003-04	Polling issue
CNT169, WY	1827001-15	Polling issue
HOX148, MI	1835001-26	Polling issue
JOT403, CA	1831003-12	Polling issue
KIC003, KS	1830004-03	Power failure
UND002, VT	1827001-51 1828001-51 1831001-51 1833001-51	Intermittent power failures
YEL408, WY	1833003-24	Polling issue
Fourth Quarter 2018		
BAS601, WY	1844005-01	Polling issue
CNT169, WY	1842001-15 1847001-15 1848001-15	Polling issue
CVL151, MS	1847001-18	Polling issue
EGB181, ON	1841001-21	Suspect values
JOT403, CA	1841003-12 1844003-12	Power outage Polling issue
NEC602, WY	1848005-04	Polling issue
PED108, VA	1841001-39	Power outage
SAN189, NE	1843004-06	Polling issue
SHE604, WY	1844005-05	Polling issue
SHN418, VA	1846003-20	Power outage
SUM156, FL*	1841001-50	Hurricane damage
THR422, ND	1841003-21	Polling issue
UND002, VT	1840001-51 1844001-51 1845001-51 1848001-51	Intermittent power failures

**Note:** \*Hurricane Michael damaged both the site and surrounding county infrastructure.

**Table 21** Field Problems Affecting Data Collection

Days to Resolution	Problem Count
First Quarter 2018	
30	424
60	20
90	2
Unresolved by End of Quarter	16
Second Quarter 2018	
30	515
60	34
90	3
Unresolved by End of Quarter	11
Third Quarter 2018	
30	653
60	17
90	2
Unresolved by End of Quarter	15
Fourth Quarter 2018	
30	411
60	12
90	2
Unresolved by Date of Publication	20

**Table 22** Field Calibration Failures by Parameter for 2018

Site ID	Parameter(s)
First Quarter 2018	
CHE185, OK	Relative Humidity
PNF126, NC	Flow Rate
VIN140, IN	Temperature (0°C and ambient)
Second Quarter 2018	
HOX148, MI	Temperature (ambient)
BVL130, IL	Solar Radiation
Third Quarter 2018	
SND152, AL	Temperature (ambient)
ALC188, TX	Temperature (0°C and ambient)
Fourth Quarter 2018	
EGB181, ON	Temperature (0°C and ambient)
UVL124, MI	Flow Rate

**Note:** °C = degrees Celsius

\*Per CASTNET project protocols, data for all parameters except flow are flagged as “suspect” (S) but still considered valid if the calibration criterion is not exceeded by more than its magnitude (i.e., if within two times the criterion). If flow calibrations fall within two times the criterion, these data are adjusted per approved protocol described in the CASTNET QAPP, (Wood, 2017). Please refer to Table 15 for documentation of the QC failures affecting the validity of ozone data.

**Table 23** Accuracy Results for 2018 Field Measurements

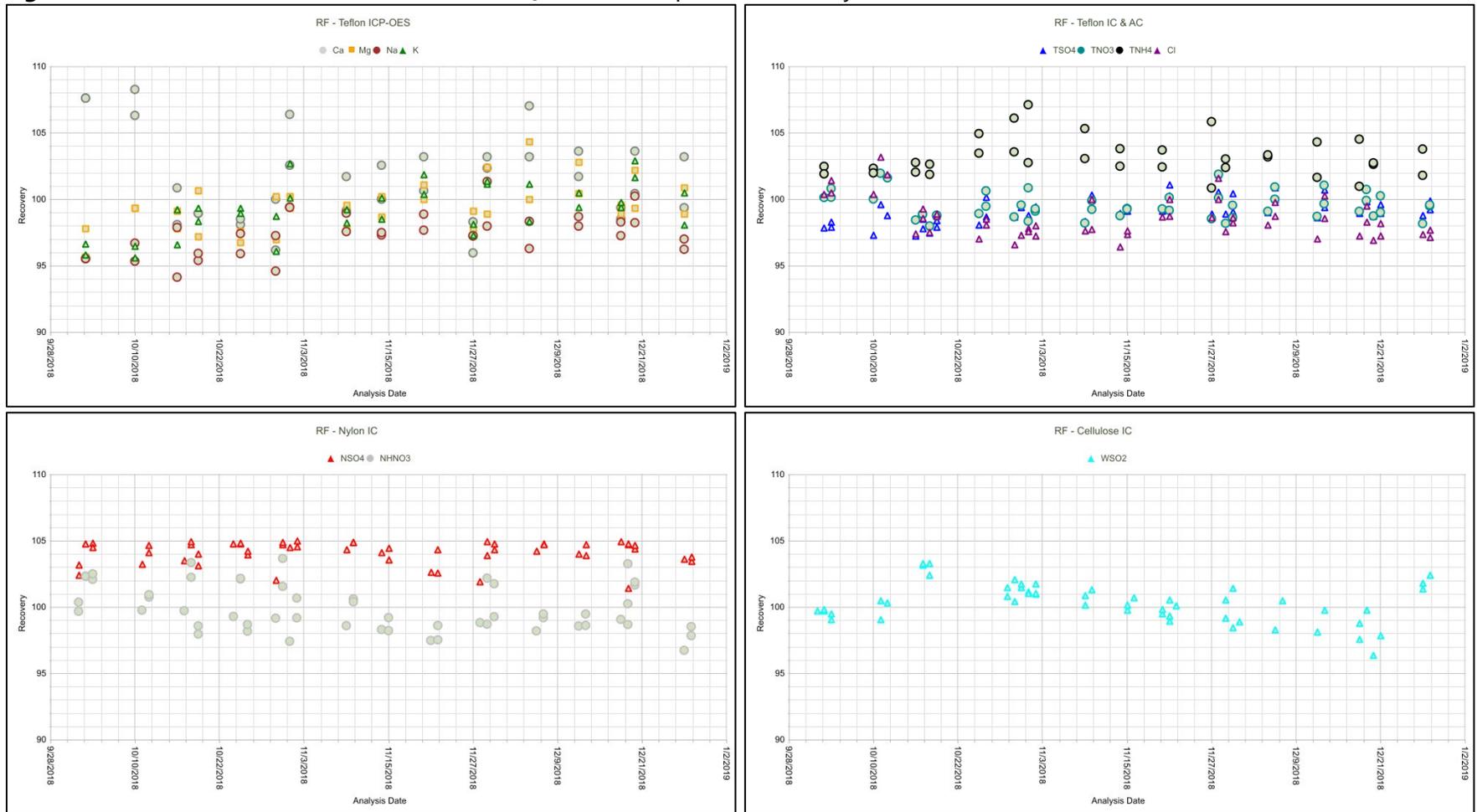
Parameter	Percent Within Criterion
Flow Rate*	98.3
Wind Speed < 5 m/s	100.0
Wind Speed ≥ 5 m/s	100.0
Wind Direction North	100.0
Wind Direction South	100.0
Temperature (0°C)*	97.5
Temperature (ambient)*	95.9
Delta Temperature (0°C)	100.0
Delta Temperature (ambient)	100.0
Relative Humidity*	83.3
Precipitation	100.0
Solar Radiation*	87.5
Wetness (w/in 0.5 volts)	100.0

**Notes:** °C = degrees Celsius

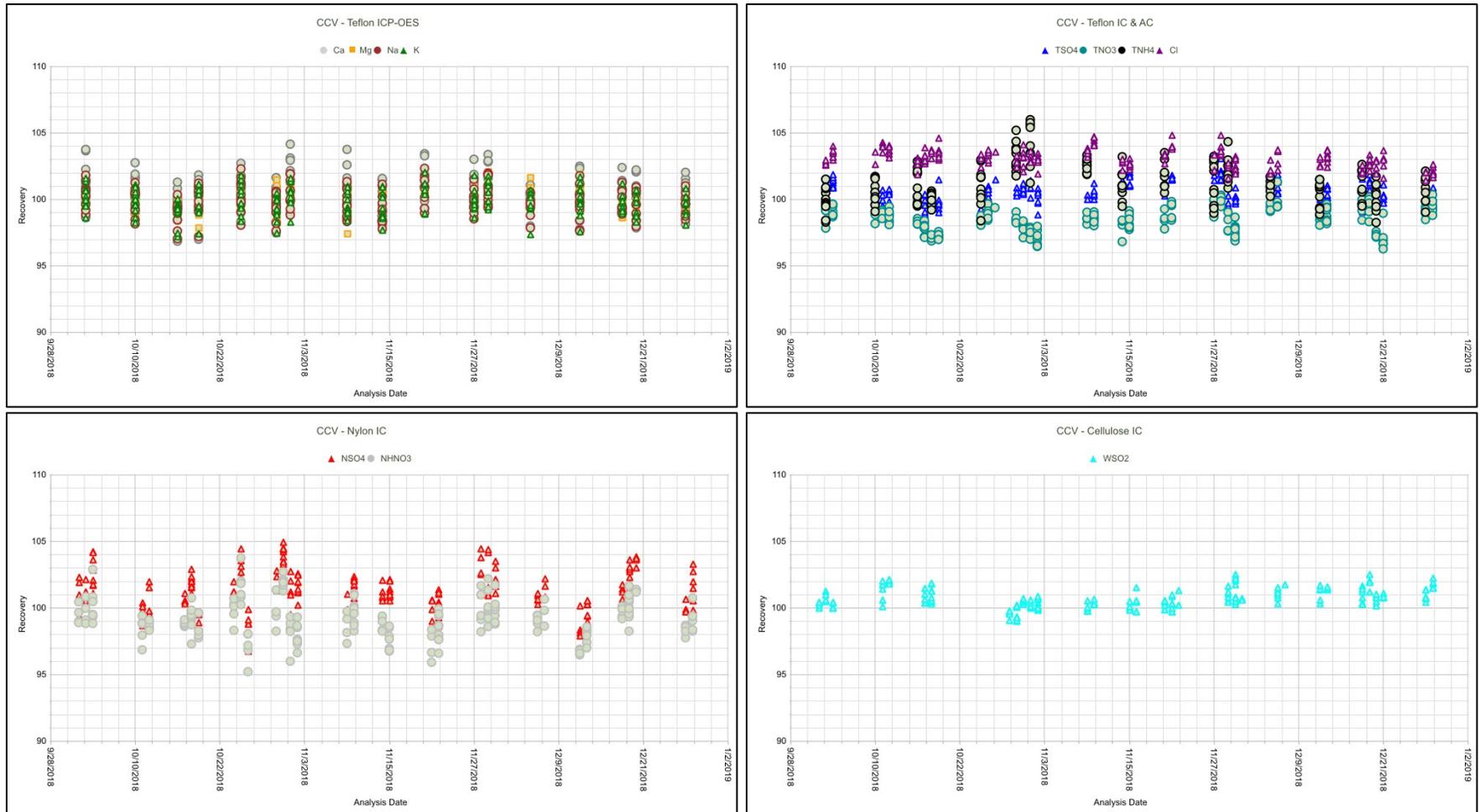
m/s = meters per second

\*Per CASTNET project protocols, data are flagged as “suspect” (S) but still considered valid if the calibration criterion is not exceeded by more than its magnitude (i.e., if within two times the criterion). All calibration failures reported in 2018 for the indicated parameters were within two times the criterion with the exception of flow rate at UVL124, MI; temperature (0°C and ambient) at ALC188, TX; and relative humidity at CHE185, OK. Associated data were invalidated.

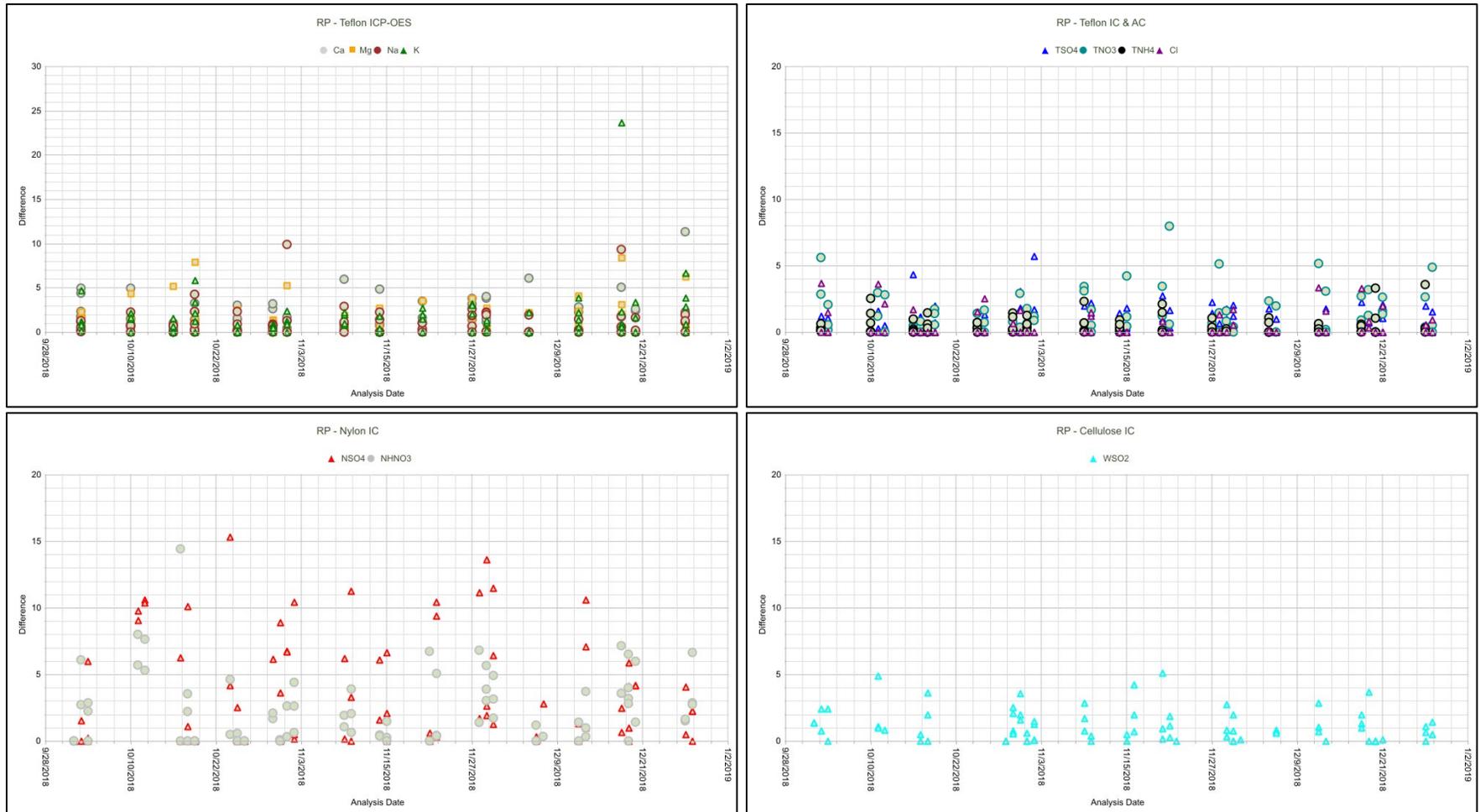
**Figure 1** Reference Standard Results for Fourth Quarter 2018 (percent recovery)



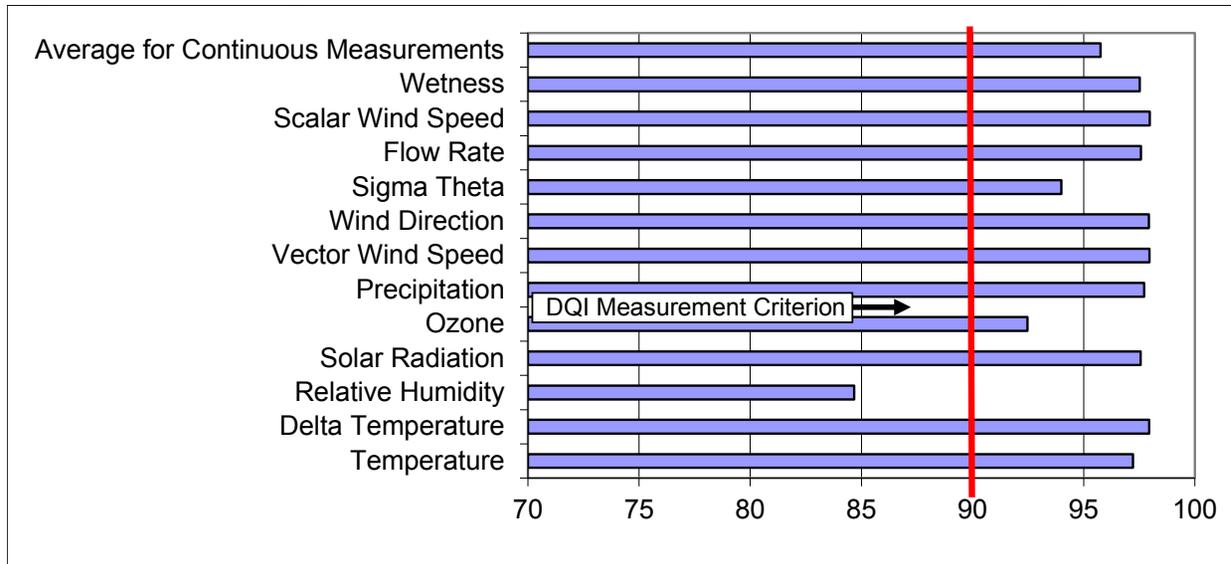
**Figure 2** Continuing Calibration Spike Results for Fourth Quarter 2018 (percent recovery)



**Figure 3** Replicate Sample Analysis Results for Fourth Quarter 2018 (percent difference)

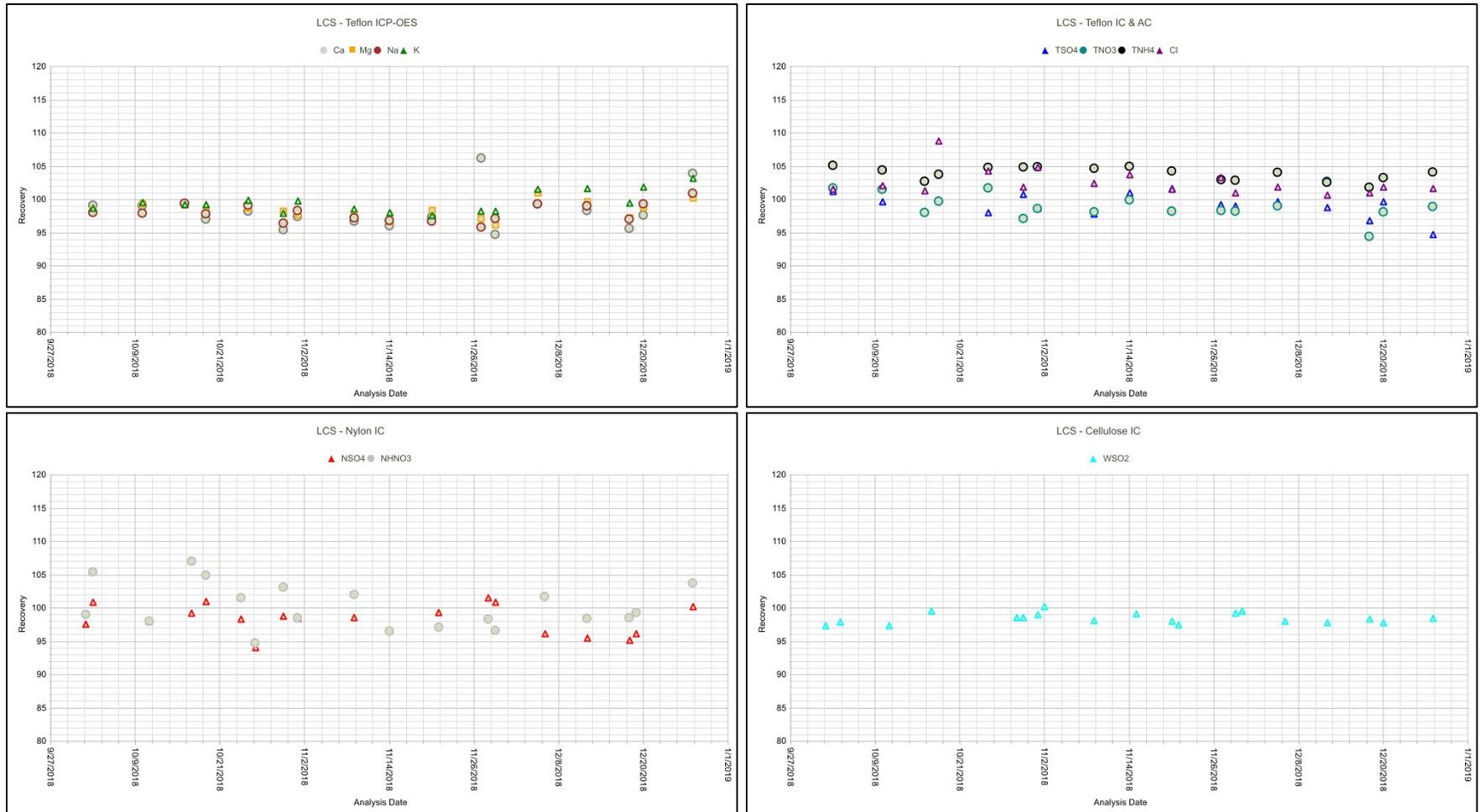


**Figure 4** Percent Completeness of Measurements for Second Quarter 2017 through Third Quarter 2018\*

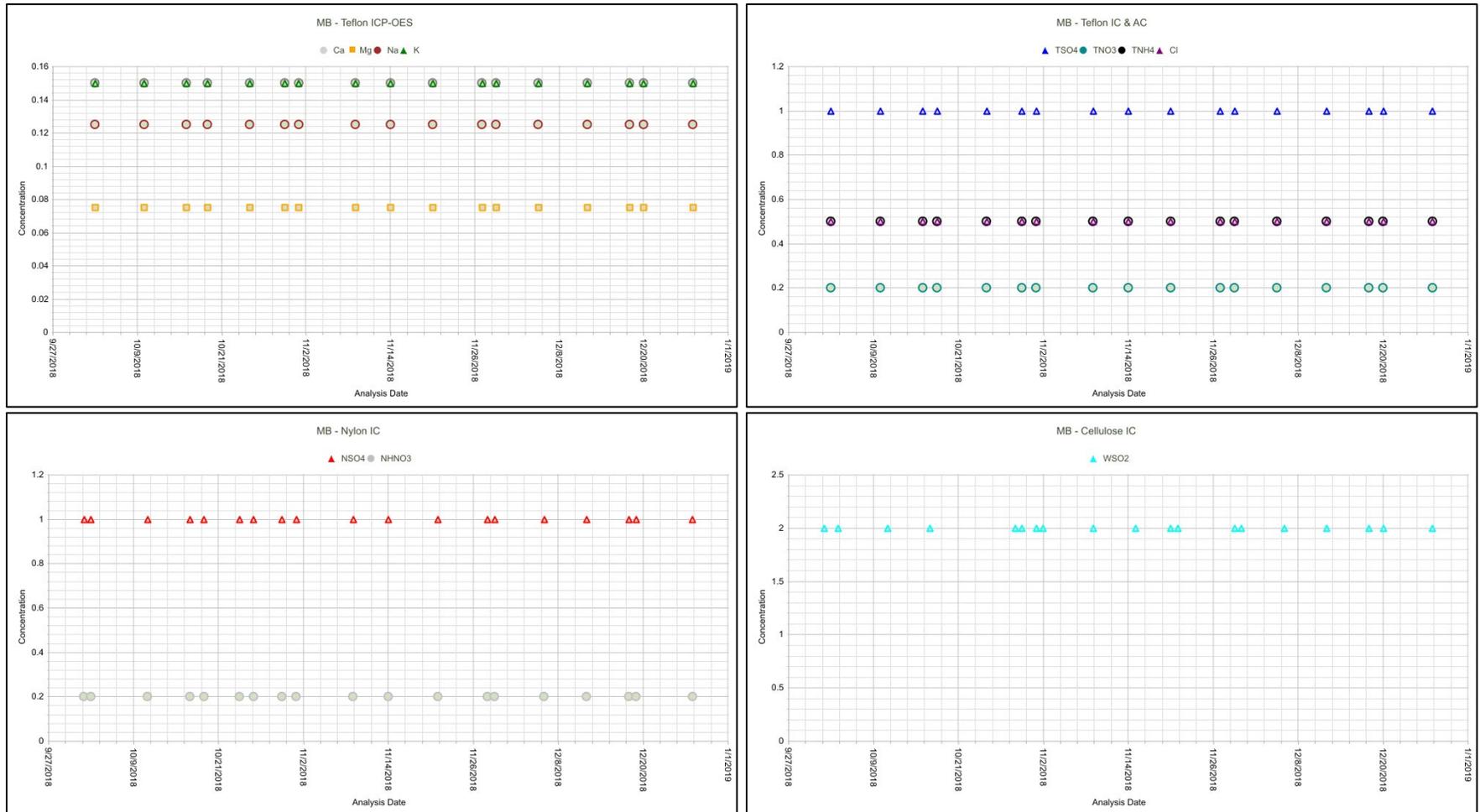


Note: \*Presents Level 3 data available during the fourth quarter of 2018

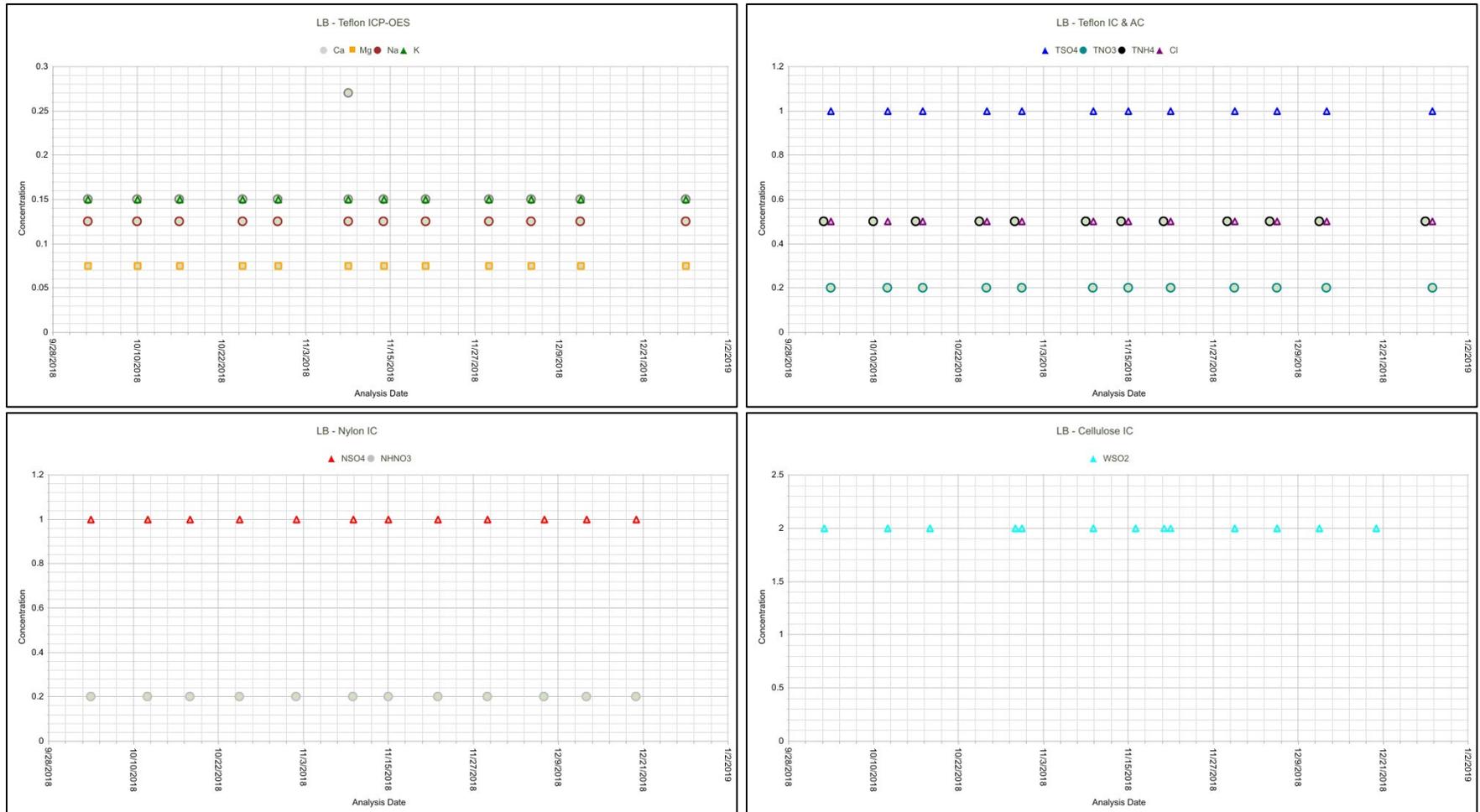
**Figure 5** Laboratory Control Sample Results for Fourth Quarter 2018 (percent recovery)



**Figure 6** Method Blank Analysis Results for Fourth Quarter 2018 (total micrograms)



**Figure 7** Laboratory Blank Analysis Results for Fourth Quarter 2018 (total micrograms)



**Figure 8** Field Blank Analysis Results for Fourth Quarter 2018 (total micrograms)

