IMPROVE Network Technical System Audits Report

Overview of audit results from 2016-2018

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Introduction

Technical System audits (TSAs) are conducted to ensure the Interagency Monitoring of Protected Visual Environment (IMPROVE) sampling sites are being operated in accordance with the Quality Assurance Project Plan (QAPP): http://vista.cira.colostate.edu/improve/wp-content/uploads/2017/01/IMPROVE-QAPP-Signed_3_2016.pdf and all relevant standard operating procedures (SOPs): http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/.

The complete TSA consists of verifying the site's coordinates and elevation, sampler's date/time, vacuum pressure, temperature, and the flow rate of each module. The sampler stand is checked for safety, integrity and configured for proper sample collection. Pictures of the sampler modules, sampler stand/building, and surroundings are taken. When the operator is available, their sample change technique is observed to ensure that (s)he has adequate sampler and sample change knowledge. The site operators are asked about sampling safety concerns and whether the current IMPROVE Operations Contractor (UC Davis) is providing adequate support to help the operator maintain high quality sampling at the site. The sampler siting criteria is reviewed to ensure the collected samples represent local ambient background conditions as outlined in SOP 126: http://vista.cira.colostate.edu/Improve/particulate-monitoring-network .

In 2016 the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University began conducting and overseeing the TSA program for the IMPROVE network. Personnel from EPA region 2 and state representatives from CO, AZ, MO, and DE have gone through an auditor training/certification program, ensuring audit consistency throughout the network. Certified auditors conduct audits for their respective states/regions. We expect to add a representative from WY to this list in 2019. To date, CIRA and state auditors have conducted over 105 audits at 93 different IMPROVE sites and we plan to conduct audits at nearly all IMPROVE sites in the contiguous US by the end of 2020.

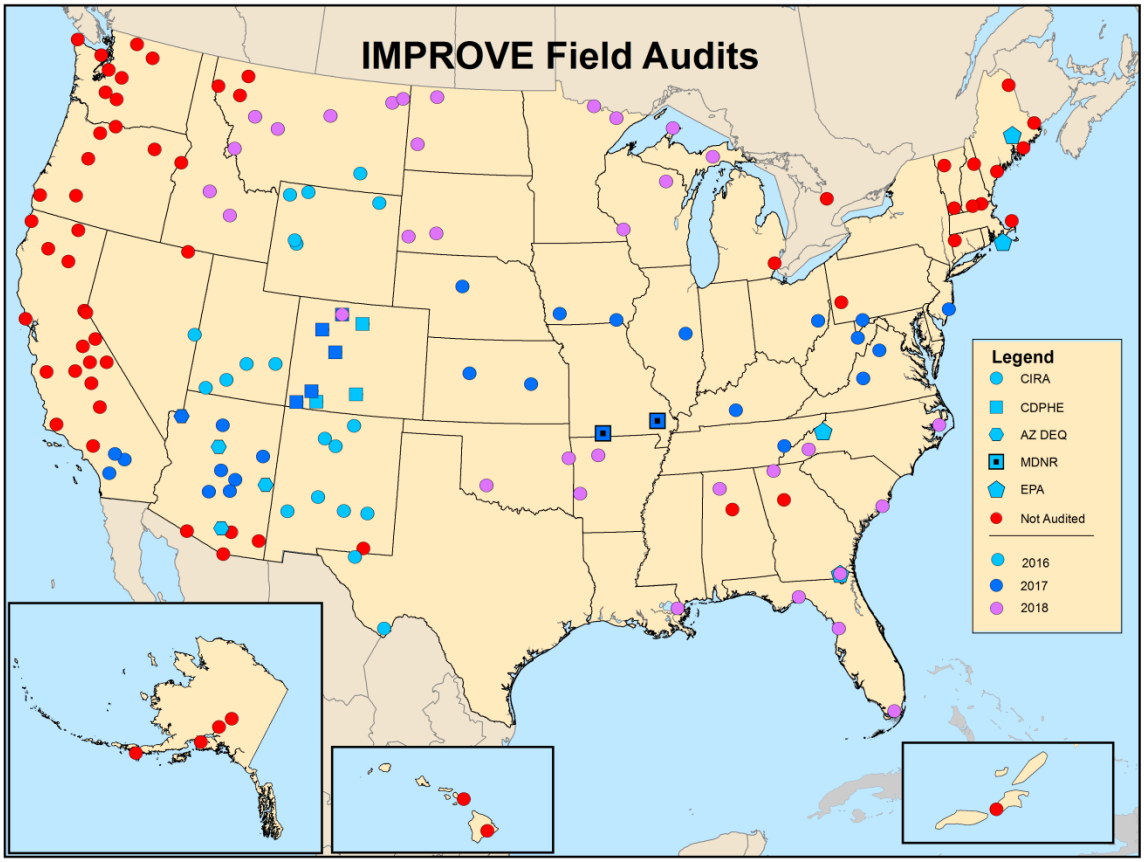


Figure 1. Map of IMPROVE sampling sites. Shown are sites that have been audited from 2016-2018, the auditing agency, and sites yet to be audited.

Results

This report presents the results of all audits performed since CIRA took over auditing responsibilities, encompassing audits from 2016-2018. Data collected include sampler flow rate, sampler vacuum pressure, sampler temperature, sampler time, and sampler siting criteria.

Sampler Flow Rate

The IMPROVE sampler consists of four separate channels which are commonly referred to as modules A, B, C, and D. Modules A, B, and C operate at a nominal flow rate of 22.8 liters/minute (lpm) and utilize a cyclone to achieve a 2.5 micron size cut. Module D operates at a nominal flow rate of 16.9 lpm and utilizes an impactor at the inlet to achieve a 10 micron size cut. Pressure transducers are used to measure the pressure drop across the cyclone for modules A, B, and C and across a critical orifice/needle valve for module D. During the bi-annual sampler maintenance procedures conducted by the IMPROVE Operations contractor (UC Davis), UC

Davis personnel generate calibration curves, which linearly relate measured pressure drops to sampler flow rates for each module. A secondary flow rate is calculated for modules A, B, and C by measuring the pressure drop across the flow controlling needle valve. The flow rate measured by the pressure drop across the cyclone is referred to as "CYC" while the flow rate calculated from the pressure drop across the orifice is referred to as "ORI".

During an audit the IMPROVE sampler flow rate is compared to a NIST traceable reference standard. Most auditors use trical or tetraCal flow meters. For audits conducted by CIRA the flow rates were measured using a tetraCal flow meter which had been calibrated and certified by Mesa Labs. All audit devices undergo certification annually. Modules A, B, and C fail the flow rate test if the audit device flow rate differs from the nominal flow rate by more than 10%.

$$Failure\ when: \left(\frac{|22.8 - Measured\ Flow\ Rate|}{22.8} \times 100\%\right) > 10\%$$

Module D fails the flow rate test if the audit device flow rate differs from its nominal flow rate by more than 10%.

$$Failure\ when: \left(\frac{|16.9 - Measured\ Flow\ Rate|}{16.9} \times 100\%\right) > 10\%$$

Module flow rates can also fail the audit test if calculated sampler flow rate differs from the audit device flow rate by more than 10%.

$$Failure\ when: \left(\frac{|Sampler\ Flow\ Rate - \ Measured\ Flow\ Rate|}{Measured\ Flow\ Rate} \times 100\%\right) > 10\%$$

Results of audit flow rate checks are shown in Tables 1-4 and Figures 2-5. These figures show the nominal flow rate (solid red lines), the allowed deviation from nominal flow rate (dashed red lines), and a 1:1 line between the audit device and the IMPROVE sampler flow rates for all audits from 2016-2018.

Table 1. Summary Statistics for Module A for 2016-2018 audits.

Statitic	Audit flow	ORI flow	CYC flow	ORI % diff	CYC % diff
Min	21.30	21.09	21.79	0.0000	0.04433
1st Qu	22.14	22.65	22.71	0.7686	1.07184
Median	22.56	22.92	22.95	1.8658	2.08786
Mean	22.54	22.91	22.98	2.3024	2.58233
3rd Qu	22.90	23.14	23.21	3.0721	4.07385
Max	24.16	27.38	24.29	20.6699	7.90760

Figure 2. Module A Flow Rate Comparison for 2016-2018 audits.

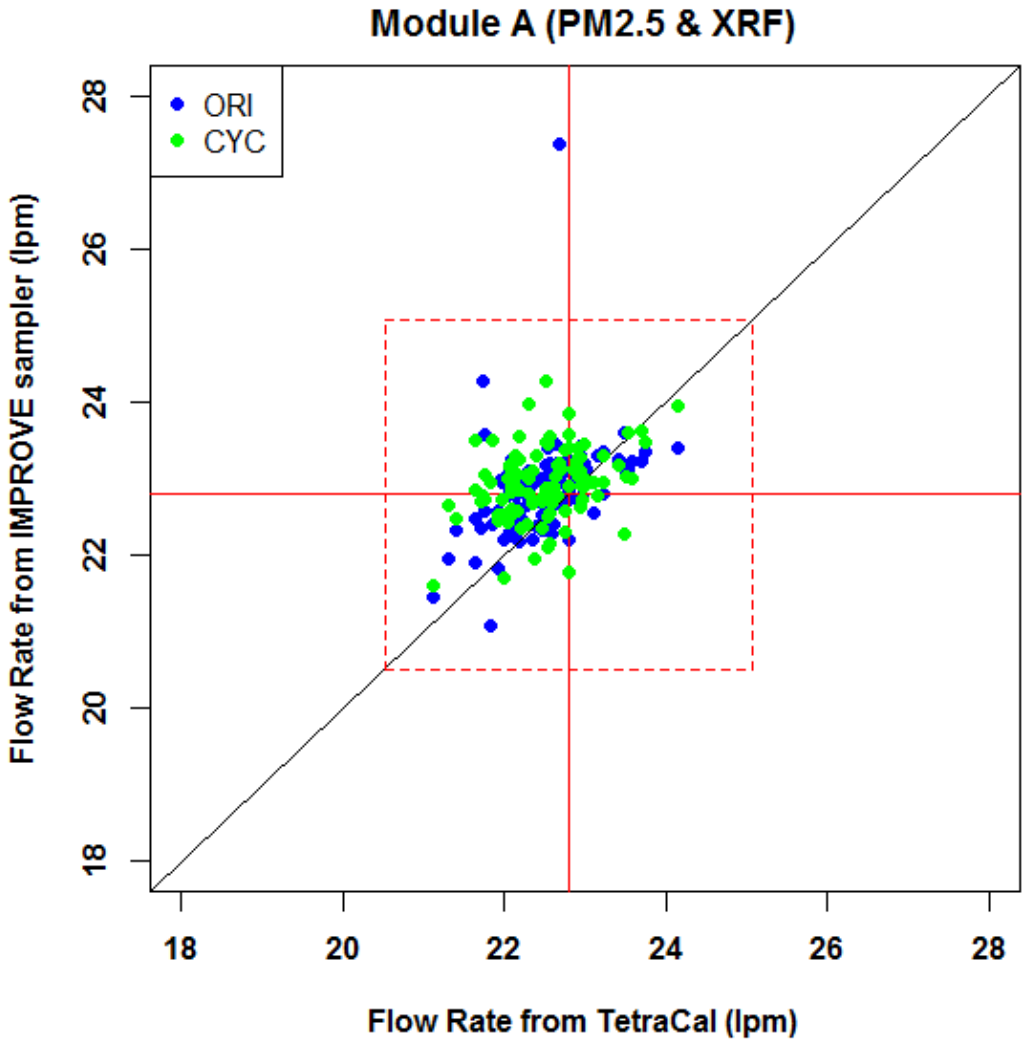


Table 2. Summary Statistics for Module B for 2016-2018 audits.

Statistic	Audit flow	ORI flow	CYC flow	ORI % diff	CYC % diff
Min.	20.56	21.84	21.31	0.04303	0.04331
1st Qu.	22.02	22.52	22.55	1.43937	1.55422
Median	22.44	22.78	22.89	2.31111	2.83912
Mean	22.49	22.80	22.95	2.75602	3.25169
3rd Qu.	22.93	23.05	23.30	3.61337	4.37812
Max.	25.06	24.37	24.69	8.89521	12.37664

Figure 3. Module B Flow Rate Comparison for 2016-2018 audits.

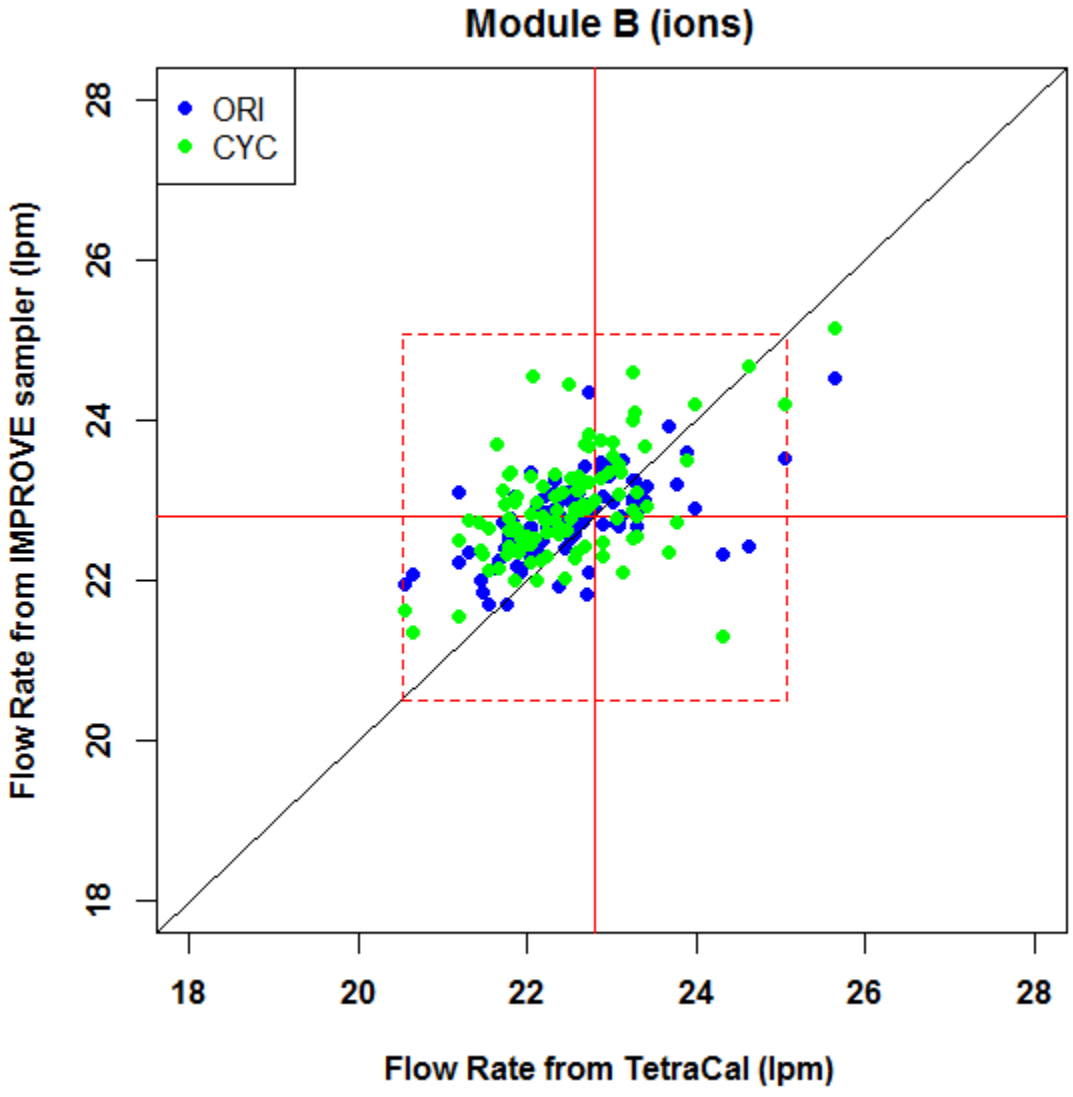


Table 3. Summary Statistics for Module C for 2016-2018 audits.

Statistic	Audit flow	ORI flow	CYC flow	ORI % diff	CYC % diff
Min.	20.65	22.05	21.54	0.000	0.1267
1st Qu	22.06	22.57	22.70	1.071	1.1051
Median	22.66	22.87	23.03	1.722	2.7181
Mean	22.60	22.90	23.11	2.283	3.0549
3rd Qu	23.11	23.08	23.40	2.893	4.5236
Max.	24.64	25.20	26.25	11.332	13.7264

Figure 4. Module C Flow Rate Comparison for 2016-2018 audits.

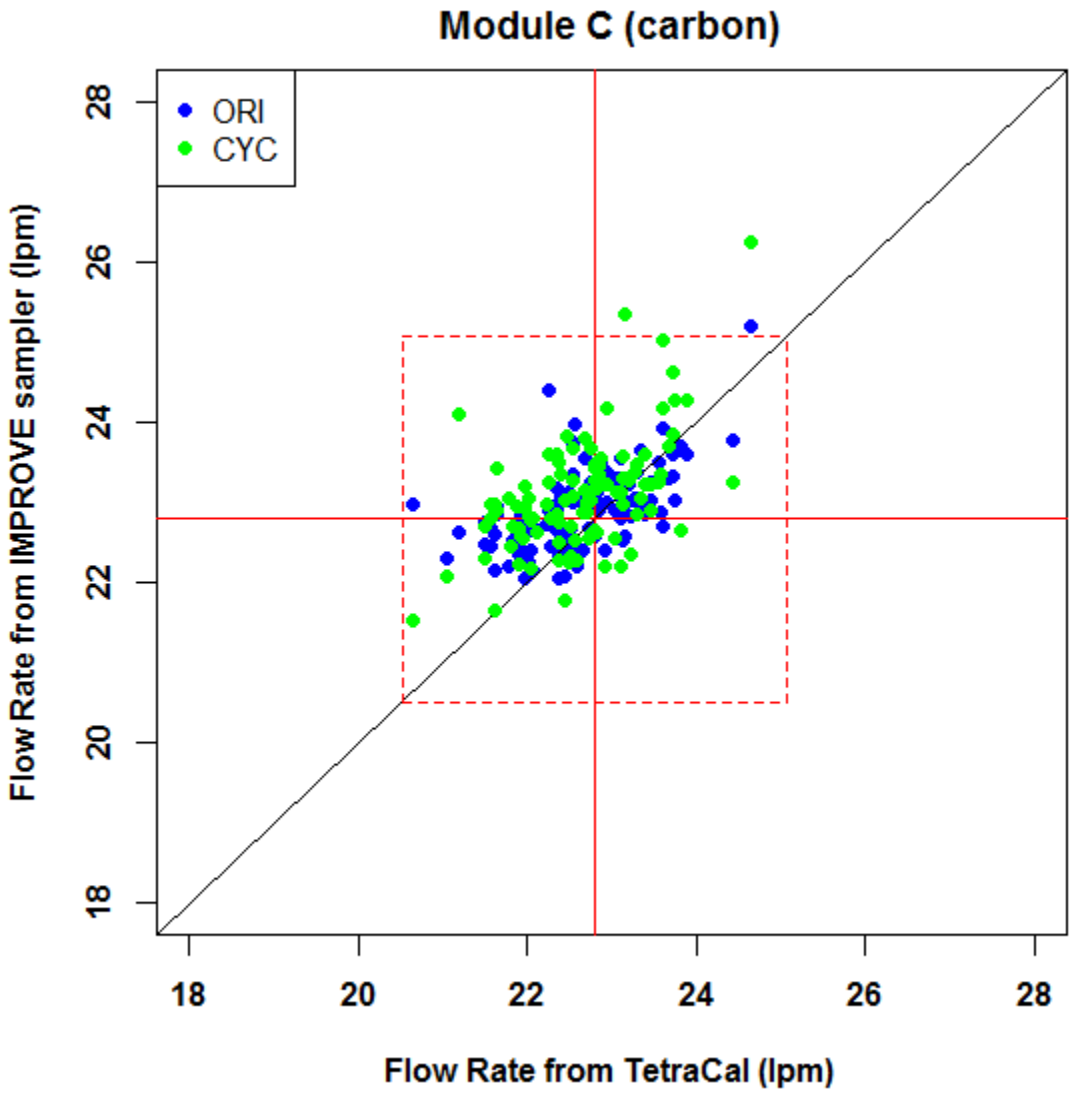
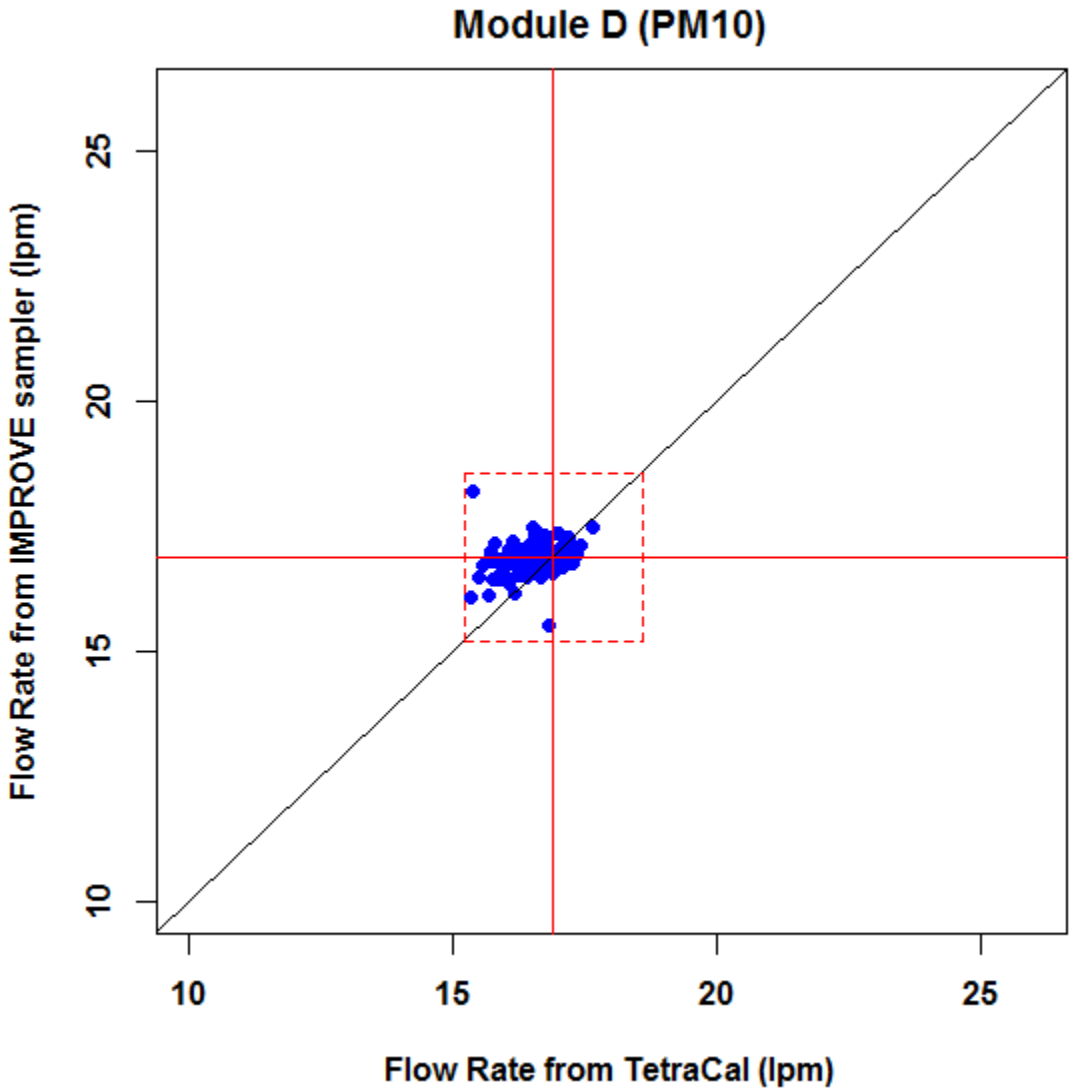


Table 4. Summary Statistics for Module D for 2016-2018 audits.

Statistic	Audit Flow	ORI Flow	ORI % diff
Min.	-99.00	-99.00	0.000
1st Qu.	16.21	16.68	1.122
Median	16.50	16.88	2.282
Mean	13.88	14.22	2.849
3rd Qu.	16.89	17.07	4.298
Max.	17.64	17.49	8.878

Figure 5. Module C Flow Rate Comparison for 2016-2018 audits.



Sampler Vacuum

The vacuum pressure is measured by starting the pump for a given module, closing a ball valve, which prevents air flow through the system, and then reading the ORI transducer. This measurement is labeled MaxORI on the TSA form. It is indicative of pump strength, air leakage through the system, and proper transducer operation. The TSA test fails if the MaxORI pressure drop is less than 33mV; a pressure drop of 40mV is not uncommon. The TSA measurement is different from the MaxORI readings obtained during routine sample changes because the TSA test measures pressure drop through the entire sample train while during routine sample changes the pressure drop is measured from the solenoids to the pump. Vacuum pressure failures for 2016-2018 are reported in Table 6. In some cases, the IMPROVE MaxORI passed, while the TSA MaxORI test failed.

Temperature

The IMPROVE sampler temperature is monitored to accurately calculate sampler flow rates. During TSAs the sampler temperature is compared to the NIST traceable temperature of a BGI tetraCal Air Flow Calibrator. The TSA temperature fails if the temperature of the sampler and the tetraCal differ by more than 10 ˚C. No temperature failures were observed in 2016-2018. Temperature comparisons are reported in Table 5.

Sampler Time

The sampler time is compared to cell phone time and adjusted if the difference is greater than 5 minutes. Sampler time notes and comparisons are given in Table 5 and 6. In most cases, the auditor corrected time discrepancies. However, time failures at Weminuche (CO) and Mingo (MO) were noted, but the auditor did not correct the time discrepancies. In these two cases, the IMPROVE Operations contractor was informed of the clock status via the TSA audit forms.

Sampler Integrity and Siting Criteria

The TSAs ensure the sampler stands are maintained such that routine access does not pose a risk to the operator, the IMPROVE modules are protected from direct sunlight, and sample changes are protected during inclement weather. The IMPROVE modules are checked to ensure they are fastened securely to the structure, and inlet stacks are seated properly into each module. Electrical wiring and connections are visually examined and photos are taken. Problems are reported to the proper regional personnel and noted in the TSA notes section. The IMPROVE sampler siting criteria are thoroughly explained in SOP 126 (http://vista.cira.colostate.edu/Improve/particulate-monitoring-network/) and are not reiterated here. In general, the TSA process notes and documents site properties that can impede sampling aerosol of a regional background nature. Impediments include significant local sources of particulates (automotive, wood smoke, dust, etc.) or obstructions such as trees or buildings that

can hamper air flow to the sampler inlet. Problems are reported on the TSA form and the site operator is notified if corrective action is needed (e.g. trees trimmed or brush cleared).

Table 5. Measured Audit Values

Site	Code	Aud Date	Cal Date	AudTime	IMPTime	AudTmp	IMPTmp	AudModA	VacModA	MagModA	AudModB	VacModB	MagModB	AudModC	VacModC	MagModC	AudModD	VacModD
Mt Baldy, AZ	BALD	7/27/16	6/26/16	9:04	9:08	23.4	24.3	22.3	22.77	22.82	22.17	22.83	22.26	22.72	22.69	22.55	16.53	16.82
Meadview, AZ	MEAD	6/7/16	5/26/14	11:51	11:53	38.5	38.4	21.76	23.59	23.06	22.72	24.37	23.69	22.26	24.42	23.6	15.77	17.17
Saguro West, AZ	SAWE	7/7/16	3/23/15	12:04	12:05	38.4	39.5	22.95	23.44	23.12	23.01	23.48	23.74	23.15	22.58	25.37	16.97	17.38
Sycamore Canyon, AZ	SYCA	8/24/16	6/28/16	12:35	12:33	30.6	32.9	22.92	23.16	23.03	22.86	23.38	23.75	23.13	22.87	23.58	16.49	17.08
Great Sand Dunes, CO	GRSA	5/16/16	7/23/15	9:35	9:31	11.3	13.3	21.39	22.34	22.49	21.42	22.74	22.74	23.17	23.02	23.3	15.56	16.75
Mesa Verde, CO	MEVE	5/17/16	7/22/15	9:12	9:10	14.1	15.2	21.7	22.37	22.7	21.3	22.35	22.75	21.65	22.97	22.91	15.95	16.69
White River, CO	WHRI	6/22/16	7/24/15	11:25	11:26	26.3	28.1	22.14	22.85	23.03	22.38	23.06	23.09	22.4	23.05	23.36	15.93	16.71
Rocky Mountain, CO	ROMO	7/6/16	7/27/15	9:10	9:09	24.6	23.3	22.14	22.79	22.92	22.62	22.96	23.13	22.81	23.05	23.29	16.36	16.82
Shamrock Mine, CO	SHMI	9/27/16	7/20/15	10:46	10:45	21.6	21.6	22.05	22.92	22.48	22.2	23.06	22.76	22.46	22.55	23.83	16.22	17.05
Mount Zirkel, CO	MOZI	9/13/16	7/28/15	11:09	11:09	14.6	14.6	21.82	21.09	22.95	22	22.38	22.56	21.8	22.45	22.45	16.38	16.51
Martha's Vinyard, MA	MAVI	6/22/16	7/16/14	10:41	10:41	25.9	26.3	22.71	22.95	23.13	23.26	24	24.01	22.54	23.02	23.08	-99	-99
Linville Gorge, NC	LIGO	3/29/16	6/20/15	12:12	12:13	14.8	16.8	21.92	22.59	22.45	21.74	22.41	22.97	21.57	22.45	22.8	16.3	16.82
Okeefenokee, FL	OKFE	7/12/16	2/27/15	11:36	11:36	36.9	41.8	23.49	23.62	22.28	25.06	23.54	24.2	23.82	23.7	22.67	17.41	17.12
Rocky Mountain, CO	ROMO	7/6/16	7/27/15	9:10	9:09	24.6	23.3	22.14	22.94	23.08	22.62	23.11	23.3	22.81	23.2	23.48	16.36	16.93
Linville Gorge, NC	LIGO	5/24/16	6/20/15	11:51	11:51	21.7	23	22.28	23.02	23.06	21.88	23.07	23.06	22.44	23.05	23.03	16.49	16.93
Flat Tops, CO	FLTO	8/5/16	7/29/15	8:46	8:44	19.5	20	22.56	23.07	22.17	22.34	22.94	22.89	22.82	23.25	23.18	15.84	16.45
Canyon Lands, UT	CANY	8/8/16	7/30/15	7:56	7:55	31.1	32.8	22.69	27.38	23.2	22.86	23.48	23.28	22.55	23.76	23.69	16.55	17.39
Capital Reef, UT	CAPI	8/3/16	8/2/15	8:40	8:40	24.8	26	23.01	23.14	22.95	22.47	22.7	22.64	23.21	23.24	23.29	17.08	17.13
Great Basin, UT	GRBA	8/11/16	8/20/15	11:30	11:31	27.3	29.7	22.75	23.11	23.39	22.51	23.14	23.29	23.6	23.94	24.19	16.54	17.29
Zion Canyon, UT	ZICA	8/15/16	8/4/15	8:24	8:24	27.5	26.9	22.57	23.21	23.57	22.33	23.11	23.33	22.69	23.57	23.8	16.14	17.23
Bryce Canyon, UT	BRCA	8/16/16	8/3/15	8:20	8:21	20.6	22.2	22.51	23.01	22.87	21.83	22.73	23.02	22.7	23.03	22.89	16.47	16.69
Weminuche, CO	WEMI	8/18/16	7/21/15	7:50	7:47	16.2	13.5	22.54	22.55	22.51	21.93	22.12	22.53	22.84	22.97	23.47	15.86	16.53
Boulder Lake, WY	BOLA	9/22/16	8/25/16	9:25	9:24	15.3	15.3	22.6	22.81	22.9	21.79	22.62	22.63	22.54	23.35	23.28	16	16.87
Bridger Wilderness, WY	BRID	9/23/16	8/24/16	9:13	9:13	10.2	10.5	22.2	22.49	22.36	21.8	22.79	23.36	21.96	22.94	23.21	15.73	16.82
Yellowstone, WY	YELL	9/27/16	8/26/16	11:12	11:12	16.6	19.4	22.57	22.74	22.89	22.66	22.74	22.97	23.1	22.82	23.14	16.37	16.56
North Absoroka, WY	NOAB	10/4/16	8/27/16	7:55	7:56	6.7	7.7	22.27	22.66	22.42	22.41	22.78	23.1	22.71	23.06	23.02	-99	-99
Northern Cheyenne, MT	NOCH	10/5/16	9/15/15	10:15	10:16	6.8	5.4	22.81	22.22	23.42	22.71	21.84	22.91	23.73	23.34	24.63	16.64	16.48
Thunder Basin, WY	THBA	10/7/16	9/17/15	10:16	10:17	10.5	10.6	22.62	22.4	22.76	22.37	21.93	22.59	22.35	23.18	23.6	17.09	16.7
Wheeler Peak, NM	WHPE	10/31/16	7/22/15	10:03	10:06	7.8	7.2	22.36	22.21	22.69	22.04	22.3	22.45	22.37	22.05	22.76	16.32	16.64
San Pedro Parks, NM	SAPE	11/3/16	7/17/15	7:29	7:28	4.5	5	22.08	22.27	22.61	20.56	21.95	21.64	22.07	22.16	22.82	16.13	16.79
Bosque del Apache, NM	BOAP	11/4/16	7/16/15	8:45	8:42	13.1	15.1	21.86	22.4	23.5	21.44	22.01	22.39	20.65	22.99	21.54	16.32	16.82
Gila Cliffs, NM	GICL	11/8/16	7/15/15	9:34	9:33	14.1	17.6	21.76	22.58	22.74	22.07	22.5	24.55	22.11	22.65	22.64	15.92	16.64
Gaudalupe Mnts, TX	GUMO	11/9/16	7/11/15	9:40	9:40	13	11.8	22.19	22.19	23.26	21.63	22.17	23.7	21.88	22.51	22.97	16.44	16.97
Big Bend, TX	BIBE	11/10/16	7/9/15	10:18	10:20	15.7	15.2	22.06	22.32	23.15	20.64	22.09	21.37	22.01	22.25	23.05	16.76	16.67
Salt Creek, NM	SACR	11/15/16	7/12/15	10:30	11:28	20.2	18.9	22.14	22.92	23.32	22.19	22.8	23.19	24.64	25.2	26.25	17.24	16.88
White Mnt, NM	WHIT	11/16/16	7/13/15	9:44	9:41	17.8	18.5	21.94	22.98	22.53	22.23	22.67	22.32	22.76	23.06	23.04	16.61	16.79
Bandalier, NM	BAND	11/17/16	7/18/15	9:39	9:38	13.7	16	21.73	24.28	22.79	21.54	22.66	22.65	21.57	22.69	22.99	16.21	16.94
Aqua Tibia, CA	AGTI	4/20/17	5/12/16	8:27	8:24	28.3	27.5	22.94	23.31	23.28	23.02	22.98	23.57	22.84	22.91	23.37	17.18	17.31
Hance, AZ	HANC	4/5/17	6/24/16	10:25	10:22	9.5	9.3	22.4	22.38	23.3	22.1	22.39	22.54	21.98	22.06	22.93	15.47	16.48
Great Sand Dunes, CO	GRSA	4/30/17	7/23/15	12:27	12:25	13.5	15.3	22.04	23.05	22.56	21.86	23.06	22.98	23.47	23.26	22.9	16.03	17.06
Ikes Backbone, AZ	IKBA	4/6/17	3/5/16	11:11	11:13	22.6	20.8	23.69	23.24	23.63	23.29	22.84	23.12	23.57	22.89	23.35	17.33	16.94
Joshua Tree, CA	JOSH	5/5/17	5/11/16	7:16	7:12	25.8	25.2	23.16	23.3	22.79	22.58	22.92	22.35	23.13	23.02	23.31	16.75	17.04
Mt Baldy, AZ	BALD	5/11/17	6/26/16	10:54	10:48	15.1	12.7	22.56	22.67	22.57	22.11	22.41	22.02	22.45	22.08	21.79	16.47	16.64
Petrified Forest, AZ	PEFO	4/3/17	6/27/16	8:48	8:48	12.7	12	22.91	22.7	23.28	21.88	22.64	22.66	21.89	22.35	22.69	16.48	16.78

Phoenix, AZ	PHOE	5/8/17	3/26/17	10:58	10:59	33.4	29.3	24.16	23.4	23.95	23.98	22.92	24.2	23.61	22.71	25.04	17.64	17.48
San Gorgonio, CA	SAGO	4/21/17	5/10/16	8:44	8:43	26.3	24.3	23.75	23.36	23.49	23.4	23.02	23.69	23.47	23.03	23.24	17.25	17.09
Sierra Ancha, AZ	SIAN	4/11/17	6/25/16	9:33	9:36	21.1	22.8	22.51	22.88	22.88	22.72	22.95	23.23	22.37	22.37	22.29	16.67	16.89
Sycamore Canyon, AZ	SYCA	4/4/17	6/28/16	9:54	9:56	11.1	17.2	21.96	22.96	22.73	21.2	22.23	22.5	22.37	22.73	23.52	15.64	16.8
Tonto Nat. Mon., AZ	TONT	5/9/17	10/24/15	9:34	9:34	18.1	21.5	22.99	23.2	23.47	23.09	22.72	23.46	22.95	23	23.24	16.72	17.35
Bondville ,IL	BOND	9/14/17	6/16/16	8:34	8:34	22.2	20.3	22.89	23.12	23.23	22.24	22.87	22.62	22.04	22.42	22.78	17.01	16.98
Brigantine, NJ	BRIG	9/20/17	10/19/16	9:14	9:08	24.4	24.8	23.22	23.36	23.3	22.9	23.06	22.49	23.11	23.57	23.14	17	17.39
Cedar Bluff, KS	CEBL	9/29/17	7/27/16	8:03	7:55	19.4	18.1	22.8	22.73	23.58	22.19	22.51	22.82	21.95	22.41	22.55	16.9	16.73
Dolly Sods, WV	DOSO	9/18/17	6/8/17	8:08	8:08	17.3	18.6	22.97	22.76	22.73	22.44	22.41	22.03	22.58	22.2	22.28	16.9	16.59
Frostburg Reservoir, MD	FRRE	9/19/17	6/9/17	10:33	10:31	28.1	28.9	23.41	23.25	23.19	24.62	22.43	24.69	23.12	22.53	22.99	17.36	17.08
Great Smokies, TN	GRSM	9/26/17	5/1/17	10:50	10:51	26.6	26.3	22.88	23.07	23.12	22.56	22.65	23.27	22.75	22.68	22.6	17.12	17.07
James River Face, VA	JARI	9/22/17	6/6/17	7:53	7:56	20.7	23.7	22.79	22.84	22.92	22.79	22.92	23	22.51	22.41	22.33	17.11	17.01
Lake Sugema, IA	LASU	9/13/17	6/17/16	10:45	10:44	28.1	29.1	22.98	23.15	23	23.12	23.51	22.12	21.89	22.77	22.23	17.2	17.22
Mamoth Cave, KY	MACA	9/27/17	4/27/17	8:31	8:30	25.2	22.9	23.51	23.05	23.04	23.76	23.22	22.74	23.23	22.83	22.35	17.28	17.01
Nebraska NF, NE	NEBR	9/11/17	1/26/17	9:08	9:07	24.6	25	22.79	22.92	21.79	23.26	23.03	24.6	22.95	23.38	24.18	16.78	17.03
Quaker City, OH	QUCY	9/15/17	6/10/17	10:15	10:14	23.1	22.3	22.91	22.95	23.41	22.9	22.72	22.32	21.5	22.48	22.7	16.85	16.86
Shenandoah, VA	SHEN	9/21/17	6/7/17	9:20	9:20	22.4	22	23.22	22.8	22.95	23.29	22.68	22.57	22.66	22.41	22.88	17.27	16.79
Tall Grass Prairie, KS	TALL	9/28/17	7/26/16	10:05	10:02	24.4	27.9	22.65	23.2	22.78	22.59	23	23.13	22.05	22.65	22.18	16.62	17.01
Viking Lake, IA	VILA	9/29/17	6/18/16	8:20	8:22	22.1	24.1	22.51	23.18	23.48	22.33	23.25	22.76	22.38	22.63	22.51	16.63	16.94
Rocky Mountain, CO	ROMO	8/4/17	6/22/17	10:11	10:11	21.4	22	22.8	22.8	22.9	23.3	23	22.8	23.1	23.1	22.2	16.4	17
Flat Tops, CO	FLTO	9/5/17	6/24/17	17:02	17:01	31.1	32.9	22.65	22.69	23.19	22.97	23.3	23.36	22.69	22.99	23.17	15.73	16.45
Mesa Verde, CO	MEVE	5/24/17	7/22/15	10:38	10:38	26.2	23.3	22.34	22.93	23.1	22.12	22.93	22.99	21.5	22.77	22.31	16.42	17.12
Mount Zirkle, CO	MOZI	9/21/17	8/7/17	12:12	12:12	15.6	16.7	22.74	22.59	22.3	23.24	23.25	22.89	23.56	23.51	23.26	16.45	16.67
Weminuche, CO	WEMI	5/24/17	7/21/15	8:18	8:10	18.1	22.1	22.31	22.92	23	21.78	22.46	22.44	21.92	22.86	22.58	15.71	17.02
White River, CO	WHRI	9/18/17	6/25/17	12:06	12:06	16.5	16.6	22.17	22.64	22.59	23.06	22.72	22.79	23.38	22.96	23.23	16.19	16.68
Hercules Glades, MO	HEGL	5/24/17	8/3/16	8:38	8:37	15	17.4	22.07	22.82	23.19	21.79	22.73	22.79	21.05	22.32	22.08	16.22	16.89
Mingo, MO	MING	5/23/17	8/4/16	10:36	10:26	25.3	29.3	22.51	22.93	24.29	22.73	22.11	23.83	22.81	22.59	23.43	17.02	16.97
Meadview, AZ	MEAD	7/6/17	6/23/16	11:39	11:38	44.5	46.5	22.3	23.1	23.99	22.5	23.02	24.45	21.2	22.64	24.11	16.5	17.49
Medicine Lake, MT	MELA	3/13/18	8/25/17	8:22	8:10	-4.5	-0.5	21.3	21.95	22.65	21.79	22.54	23.34	22.34	22.67	23.61	16.03	16.36
Stilwell, OK	STIL	4/3/18	8/2/16	10:51	10:51	19.3	24.4	22.53	23.4	23.46	22.67	23.43	22.43	22.74	23.25	23.68	16.62	17.36
Upper Buffalo, AR	UPBU	4/3/18	7/31/16	17:00	17:00	9.9	11.8	22.04	22.78	23.02	22.03	22.6	23.31	21.61	22.62	22.98	15.33	16.1
Sipsey Wilderness, AL	SIPS	4/5/18	5/2/17	9:17	9:11	13.8	15.5	22.03	22.56	22.43	22.57	22.69	22.9	22.27	22.45	22.81	16.55	16.79
Cohutta Wilderness, GA	COHU	4/6/18	5/1/17	10:33	10:36	13.3	16.6	22.47	23	22.72	22.04	22.68	22.24	22.51	22.69	22.7	16.22	16.52
Shining Rock, NC	SHRO	4/9/18	4/30/17	9:30	9:32	3.8	3.3	21.92	21.83	22.53	21.9	22.36	22.35	22.28	22.75	22.81	16.26	16.65
Swan Quarter, NC	SWAN	4/10/18	2/26/17	9:23	9:23	15.5	12.1	23.11	22.57	22.95	23.09	22.68	23.08	22.92	22.4	22.2	16.91	16.76
Cape Romain, SC	ROMA	4/12/18	2/28/17	8:35	8:29	16	12.3	22.58	22.28	22.69	23.26	22.99	22.54	23.4	22.87	23.61	16.75	16.68
Okefenokee, GA	OKEF	4/13/18	3/2/17	9:13	9:11	24	24.4	22.96	22.78	22.91	23.41	23.18	22.94	23.29	23	22.86	17.3	17.08
Everglades, FL	EVER	4/16/18	3/6/17	8:35	8:32	25.3	22	22.99	22.99	22.91	22.57	22.58	22.28	23.67	23.32	23.7	16.74	17.19
Chassahowitzka, FL	CHAS	4/17/18	3/4/17	10:12	10:17	23.9	27.1	22.87	23.22	23.13	22.38	22.78	22.68	23.35	23.67	23.06	16.87	17.01
Saint Marks, FL	SAMA	4/18/18	3/3/17	9:34	9:29	21.4	19.7	22.95	22.98	22.64	23.1	22.8	23.36	23.72	23.61	23.85	16.62	16.71
Breton Island, LA	BRIS	4/19/18	8/6/16	9:31	9:25	24.8	20.6	22.8	23.26	23.85	22.03	23.37	22.84	22.82	23.13	22.64	16.76	17.12
Caney Creek, AR	CACR	4/23/18	8/1/16	8:52	9:57	16	14.6	22.08	22.81	22.9	24.32	22.33	21.31	21.83	22.53	22.72	16.81	15.55
Wichita Mountains, OK	WIMO	4/24/18	7/29/16	9:07	9:04	19	23.4	22.1	23.26	22.84	21.88	22.66	22.62	22.02	22.8	22.83	16.39	17.1
Wind Cave, SD	WICA1	9/12/18	9/1/17	9:22	9:31	25.1	23	23.53	23.12	23.61	21.18	23.1	21.57	23.74	23.04	24.29	16.29	16.58
Badlands, SD	BADL1	9/12/18	8/31/17	3:46	3:48	32.5	28.6	23.58	23.24	23.01	23.9	23.6	23.51	24.43	23.79	23.27	15.35	18.2
Great River Bluffs,MN	GRRI1	9/14/18	6/23/18	11:28	11:28	30.6	34.6	22.64	23.47	23.03	22.64	23.26	22.88	22.56	23.99	22.53	16.73	17.29
Potawatomi, WI	FCPC1	9/17/18	6/24/18	8:38	8:38	26.8	26.3	22.53	22.95	22.79	22.75	22.85	22.96	23.07	23.32	23.13	16.75	16.72

Seney, MI	SENE	9/18/18	6/25/18	10:06	10:06	16.2	14.2	22.46	22.33	22.37	21.75	21.7	22.33	22.79	22.62	22.65	16.15	16.19
Isle Royal, MI	ISLE	9/19/18	6/26/18	9:12	9:14	16.9	15.1	22.75	22.69	22.58	21.84	22.42	22.02	23.27	23.05	23.39	16.9	16.76
Boundary Waters, MN	BOWA	9/20/18	6/29/18	8:26	8:26	14.4	14.6	22.38	23.02	21.95	21.66	22.26	22.16	22.35	22.98	22.84	16.55	16.97
Voyageurs, MN	VOYA	9/21/18	6/28/18	11:16	11:16	12.6	8.7	22.18	22.56	23.56	22.68	22.87	23.72	22.25	22.92	23.26	16.27	16.65
Lostwood, ND	LOST	9/24/18	8/26/17	8:38	8:30	10.3	10.2	22.53	22.68	22.85	21.55	21.71	22.13	23.89	23.61	24.29	16.3	16.69
Theodore Roosevelt, ND	THEO	9/25/18	8/28/17	9:38	9:39	9.1	8	22.11	22.38	22.57	22.52	22.54	22.79	22.23	22.74	22.98	16.35	16.74
Fort Peck, MT	FOPE	9/25/18	8/27/18	3:24	4:22	17.7	16.1	22.46	22.53	22.75	23.28	23.26	24.11	22.49	23.14	22.26	16.51	16.77
UL Bend, MT	ULBE	9/27/18	8/15/18	8:40	8:40	9	8.7	21.63	22.48	23.51	21.7	22.73	23.13	21.64	22.86	23.44	15.88	16.87
Gates of the Mtns, MT	GAMO	9/28/18	8/15/18	11:00	11:00	9.6	4	21.63	21.9	22.86	21.87	22.19	22.67	21.61	22.17	21.66	15.93	16.45
Monture Station, MT	MONT	10/1/18	8/17/18	11:26	11:26	13	8	21.12	21.46	21.6	21.48	21.86	22.34	21.78	22.2	23.05	15.68	16.13
Sula, MT	SULA	10/2/18	9/15/17	10:46	10:36	16.5	17	22.54	22.44	22.11	25.64	24.53	25.17	23.04	22.92	22.57	15.91	16.72
Sawtooth, ID	SAWT	10/3/18	9/11/17	8:51	8:52	12	16.2	22.5	22.67	22.79	22.32	23.08	23.06	22.35	22.9	22.87	15.99	16.54
Craters of the Moon, ID	CRMO	10/3/18	9/10/18	2:16	2:07	21.1	19.9	22.19	22.92	22.86	23.68	23.93	22.37	22.86	23.48	23.57	16.29	16.96
Mt Zirkel, CO	MOZI	10/5/18	8/7/17	9:46	9:43	2.7	4.2	21.99	22.2	21.72	21.93	22.16	22.41	23.29	23.39	23.49	16.05	16.46

Table 6. Audit Summary Results

Site	Date	Issues/Notes	Follow up Required	Priority (H,M,L)	Actions Taken	Follow Up Results
Linville Gorge,NC	3/29/16	EPA region 4 audit no problems reported - a tree was removed	N			
Great Sand Dunes,CO	5/16/16	State of Colorado audit - no problems reported	N			
Mesa Verde,CO	5/17/16	State of Colorado audit - no problems reported	N			
Linville Gorge,NC	5/24/16	All pass	N			
Meadview,AZ	6/7/16	State of Arizona audit - no sampler problems reported, however, there is new consruction (grading a lot nearby)	N			
White River,CO	6/22/16	State of Colorado audit - no problems reported	N			
Martha's Vinyard,MA	6/22/16	EPA Region 1 audit - module D was not removable	N			
Rocky Mountain,CO	7/6/16	State of Colorado audit - no problems reported	N			
Rocky Mountain,CO	7/6/16	All pass.	N			
Saguro West,AZ	7/7/16	State of Arizona audit - no problems reported	N			
Okeefenokee,GA	7/12/16	EPA Region 4 audit no problems reported	N			
Mt Baldy,AZ	7/27/16	State of Arizona audit - no problems reported	N			
Capital Reef,UT	8/3/16	Control Module was not operating upon arrival. After getting it started all the modules passed flow checks. There is a tree relatively close.	Y	High	report to UCD	
Flat Tops,CO	8/5/16	State of Colorado audit - no problems reported	N			
Canyon Lands,UT	8/8/16	Module A orifice transducer failed (both max vac and flow rate)	Y	High	report to UCD	
Great Basin,NV	8/11/16	All pass. There is a tree pretty close that needs trimming.	Y	Low	contact site operator	
Zion Canyon,UT	8/15/16	Reset clock. All else passed.	N			
Bryce Canyon,UT	8/16/16	Reset clock. All else passed.	N			
Weminuche,CO	8/18/16	Module B MaxOri failed. Sampler stand is unstable and trees are too close and too tall.	Y	High	contacted site operator and Forest sevice representative	stand has been rebuilt verified 4/26/19
Sycamore Canyon,AZ	8/24/16	State of Arizona audit - no problems reported	N			
Mount Zirkel,CO	9/13/16	State of Colorado audit - no problems reported	N			

Boulder Lake,WY	9/22/16	Wrong plug installed in B module T. It was open to atmoshere so some sample air not going through denuder. Last Maintenance 8/25/16.	**N**		replaced T plug (9/22/16)	
Bridger Wilderness,WY	9/23/16	All pass.	**N**			
Shamrock Mine,CO	9/27/16	State of Colorado audit - no problems reported	**N**			
YellowstoneWY	9/27/16	All pass.	**N**			
North Absoroka,WY	10/4/16	Could not remove channel D module. All else pases.	**Y**	Low	will repeat audit at another time	
Northern Cheyenne,MT	10/5/16	All pass. Lots of mouse droppings (could be cleaner)	**Y**	Low	report to site operator	
Thunder Basin,WY	10/7/16	Reset the clock. C module failed vacumn test.	**Y**	Medium	report to UCD	
Wheeler Peak,NM	10/31/16	Trees are too large (no unopbstructed flow to sampler). All flows pass. Sampler subjected to diesel exaust from ski lift when not running on electricity	**Y**	High	report to site operator and FS representative	
San Pedro Parks,NM	11/3/16	Mod A MaxOri failed, Mod B operating at 10% limit for flow rate failure.	**Y**	Medium	report to UCD	
Bosque del Apache,NM	11/4/16	Module C Ori flow failed. All else passed. Power line stress relief	**Y**	Medium	report to UCD	
Gila Cliffs,NM	11/8/16	Module B cyclone flow rate failed.	**Y**	Medium	report to UCD	
Gaudalupe Mnts,TX	11/9/16	Module B cyclone flow rate failed.	**Y**	Medium	report to UCD	
Big Bend,TX	11/10/16	All pass.	**N**			
Salt Creek,NM	11/15/16	Reset time.	**N**			
White Mnt,NM	11/16/16	MaxOri failed Mod A.	**Y**	Medium	report to UCD	
Bandalier,NM	11/17/16	Module A ORI transducer not working (MaxORI and ORI flow calculation failed).	**Y**	Medium	report to UCD	
Petrified Forest	4/3/17	All pass.	**N**			
Sycamore Canyon	4/4/17	All Pass	**N**			
Hance,AZ	4/5/17	Trees need to be trimmed (southeast side). All modules passed but D flow rate is 8.5% and 7% off.	**Y**	Medium	emailed operator	
Ikes Backbone,AZ	4/6/17	All Pass.	**N**			
Sierra Ancha	4/11/17	All Pass	**N**			
Aqua Tibia,CA	4/20/17	All Pass	**N**			
Great Sand Dunes,CO	4/30/17	All Pass. Tree needs trimming. Did auditor training.	**Y**	Low	emailed operator	
San Gorgonio	5/3/17	All Pass	**N**			

Joshua Tree,CA	5/5/17	All Pass.	**N**			
Phoenix	5/8/17	All pass. Did auditor training.	**N**			
Tonto NM, AZ	5/9/17	All Pass; Electricity is provided to samplers via extension cord.	**N**			
Mount Baldy, AZ	5/11/17	Reset clock. All module flow rates passed.	**N**			
Mingo, MO	5/23/17	Time off. All pass.	**N**			
Hercules Glades,MO	5/24/17	All pass.	**N**			
Mesa Verde,CO	5/24/17	All Pass	**N**			
Weminuche	5/24/17	Time off. All pass.	**N**			
Meadview,AZ	7/6/17	Module C cyc flow rate failed.	**Y**	Medium	notified UCD via TSA	
Rocky Mountain	8/4/17	All pass. New controller works well for audits.	**N**			
Flat Tops,CO	9/5/17	All Pass	**N**			
Nebraska NF	9/11/17	All Pass	**N**			
Lake Sugema,IO	9/13/17	All Pass. Auditor training for MO.	**N**			
Bondville,IL	9/14/17	All Pass	**N**			
Quaker City	9/15/17	MaxOri failed (29.6 mv should be > 33) All else passes. The sampler MaxOri all passed.	**Y**	Medium	notified UCD via TSA	
Dolly Sods,VA	9/18/17	All Pass	**N**			
White River	9/18/17	All pass.	**N**			
Frostburg Reservoir,MD	9/19/17	Reset Clock (for auditor training); All flow checks pass but the B module flow rate is high; Did auditor training. Sample day.	**N**			
Brigantine,NJ	9/20/17	Reset Clock; All flow checks pass; Did auditor training.	**N**			
Mount Zirkle,CO	9/21/17	All Pass	**N**			
Shenandoah	9/21/17	All Pass	**N**			
James River Face,VA	9/22/17	All Pass	**N**			
Great Smoky Mts,TN	9/26/17	All Pass	**N**			
Mamoth Cave,KT	9/27/17	All Pass	**N**			
Tall Grass Prairie	9/28/17	Reset Clock; All modules pass.	**N**			
Cedar Bluff,KS	9/29/17	Reset Clock; All flow checks pass	**N**			
Viking Lake	9/29/17	Module C stack was not seated into the cyclone T properly. Sampler stand moves (sways) too much. All module flows passed.	**Y**	Medium	email state representative	
Medicine Lake, MT	3/13/18	Reset the clock; All pass.	**N**			
Stilwell, OK	4/3/18	Leak in roof over Module D	**Y**	Low	Discussed with operators	
Upper Buffalo, AR	4/3/18	Reset clock; D module flow rate is 9% low (almost failure)	**N**			
Sypsey, AL	4/5/18	Reset clock	**Y**			

Cohutta, GA	4/6/18	Reset clock; Quite a bit of mouse droppings but samplers are running properly.	**N**			
Shining Rock, NC	4/9/18	Reset clock	**N**			
Swanquarter, NC	4/10/18	All pass.	**N**			
Cape Romain, SC	4/12/18	Reset clock; The drip lines of two large trees are only 12 and 16 feet from the shelter hence the site is not in compliance with IMPROVE Quality assurance project plan.	**Y**	Medium	email FWS representative	
Okefenokee, GA	4/13/18	The sampler is running well; they will soon be upgrading power to resolve outage issues do to circiut overload.	**N**			
Everglades, FL	4/16/18	The sampler screen was not operating upon arrival although there was power to the sampler - sampler stand is in need of repair.	**Y**	Medium	report to site operator and NPS representative	Sampler stand was rebuilt.
Chasahowitzka, FL	4/17/18	The drip line of trees on the south side of the sampler are about 30 feet from the encloser; these trees are around 20 feet too tall for compliance with QAPP. This is not a criticle issue because there is still 270 degrees of unhindered air flow around the sampler, however, it would be best to trim trees when posible.	**N**	Low	report to site operator	
Saint Marks, FL	4/18/18	The drip line of trees on the north side of the shelter are about 20 feet from the sampler; these trees are around 10 feet too tall for compliance with QAPP. This is not a criticle issue because there is still 270 degrees of unhindered air flow around the sampler, however, it would be best to trim trees when posible.	**N**	Low	report to site operator	
Breton Island, LA	4/19/18	Reset clock; Module C sampler box is rusted through; it needs replacement.	**Y**	Medium	report to UCD	
Caney Creek, AR	4/23/18	Reset clock (it was on daylight savings time); PM10 inlet glass is broken; Module B cyclone flow rate failed; brush around shelter needs trimming	**Y**	Medium	report to UCD and site operator	brush has been cleared
Wichita Mountains, OK	4/24/18	reset clock	**N**			
Wind Cave,SD	9/12/18	All pass.	**N**			
Badlands,SD	9/12/18	Module D Failed. All else looks good.	**Y**	Medium	report to UCD	
Great River Bluffs,MN	9/14/18	Sampler was not operating upon arrival (e-bax issue). Trees encroaching on sampler (they were removed by operator).	**Y**	Low	report to site operator	tree removed

Potawatomi,WI	9/17/18	All Pass.	**N**			
Seney, MI	9/18/18	All Pass.	**N**			
Isle Royal, MI	9/19/18	The tree to the east needs to be removed. The control module needs to be lowered for safety.	**Y**	Medium	report to site operator and NPS representative	tree removed
Boundary Waters,MN	9/20/18	All pass.	**N**			
Voyaguers,MN	9/21/18	Trees are starting to encroach on sampler.	**Y**	Low	report to site operator	
Lostwood,ND	9/24/18	All pass.	**N**			
Theodore Roosevelt,ND	9/25/18	All pass.	**N**			
Fort Peck, MT	9/25/18	All pass.	**N**			
UL Bend, MT	9/27/18	All pass.	**N**			
Gates of the Mtns,MT	9/28/18	All pass.	**N**			
Monture,MT	10/1/18	There are a couple trees that might be impacting sampling.	**N**			
Sula,MT	10/2/18	Reset time. Adjusted Module B flow rate.	**Y**	Low	report to UCD	
Sawtooth, ID	10/3/18	Some pumps not operating when I arrived, however all flow rates passed.	**Y**			
Craters of the Moon,ID	10/3/18	Reset clock - all else passed.	**N**			
Mt Zirkel,CO	10/4/18	All pass.	**N**			