Wisconsin Department of Natural Resources/Air Monitoring
Quality Assurance Project Plan for PurpleAir Sensor Study
QAPP 111.0

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By the signatures below, the Wisconsin Department of Natural Resources/Air Monitoring certifies that the information contained in this document is complete and accurate at the time of submittal to EPA Region 5

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Review and Revision History				
Revision	**Review/ Revision**	**Individual**	**Date**	**Comments**
0	NA	Jason Treutel	01/10/20	Initial Version

Review – Individual assigned has read document and provided suggestions on potential areas where updates may be needed and has evaluated the importance of making a revision.

Revision – Updates to document have been made and have gone through the review and approval process. If only a limited amount of changes have been made, note in the comments column.

A.2 Table of Contents

A.3 Overview

A.3.1 Disclaimers

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A.3.2 Definitions & Acronyms

Term	Definition
EPA	United States Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
PA-II	Low cost portable laser particle counter which measures PM_{10}, $PM_{2.5}$, and $PM_{1.0.}$
PurpleAir	Manufacturer of the PA-II
PM_{10}	Particulate matter 10 microns or smaller
$PM_{2.5}$	Particulate matter 2.5 microns or smaller
$PM_{1.0}$	Particulate matter 1.0 microns or smaller
QA	Quality Assurance
QAC	Quality Assurance Coordinator
QAPP	Quality Assurance Project Plan
QC	Quality Control
QMP	Quality Management Plan
SOP	Standard Operating Procedures
T640/T640X	FEM utilized by WDNR at study monitoring sites
WDNR	Wisconsin Department of Natural Resources

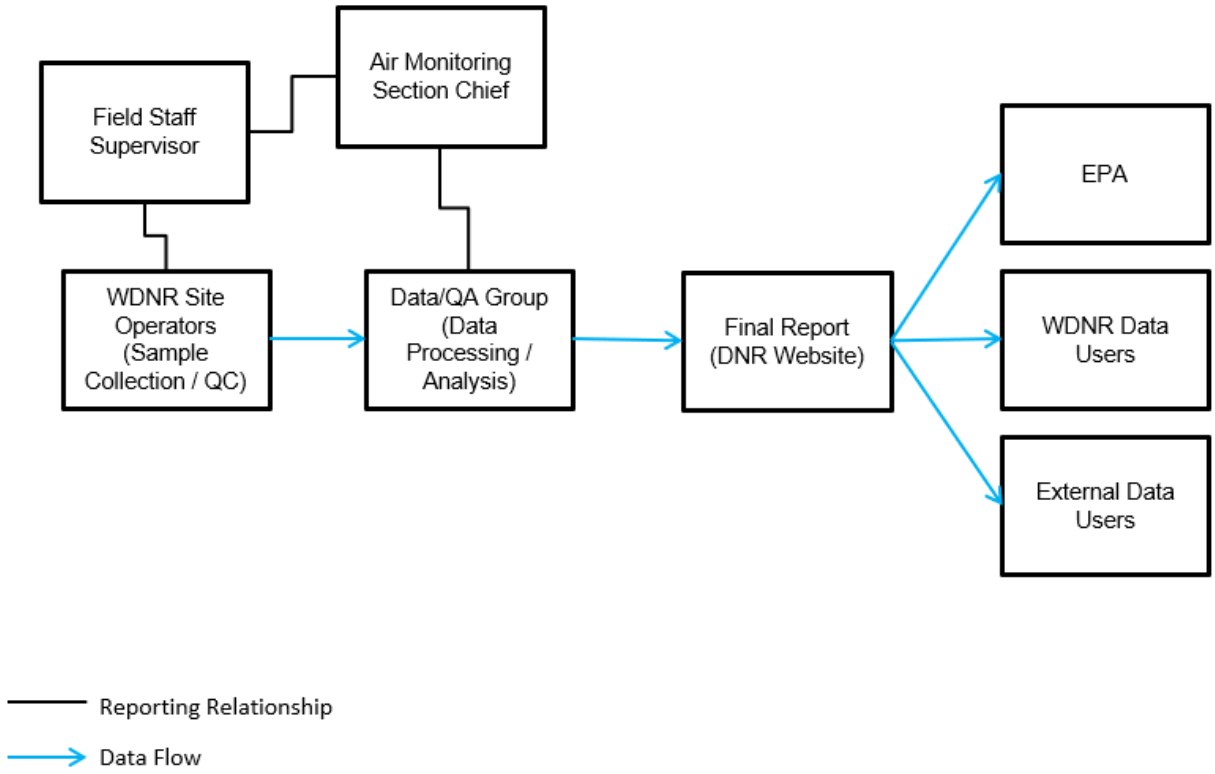
A.3.3 Distribution List

- Quality Assurance Office – US EPA Region 5
- Air Management Program Director - WDNR

- Air Monitoring Section Chief - WDNR
- Air Monitoring Quality Assurance Coordinator (QAC) – WDNR [controlled copy]
- Air Guidance Module Manager – WDNR [electronic controlled copy]
- Air Monitoring Section Members - WDNR

A.4 Project/Task Organization

A.4.1 Organization Chart



A.4.2 Roles/Responsibilities

- Air Monitoring Section Chief is responsible for the creation and leadership for the project charter; management of Air Monitoring Data/QA staff; equipment purchasing approvals
- Field Staff Supervisor is responsible for the management of Air Monitoring Site operators, equipment purchasing
- WDNR site operators are assigned as primary leads for each WDNR-operated site and are responsible for: routine data collection, QC checks, instrument maintenance
- Data/QA Group is involved in many aspects of the network outside of site operations including: data processing and analysis, QC review, management of documentation structure and systems including QC records QMP/QAPPs/SOPs
- EPA is a potential audience for the final report; EPA provides guidelines on the use of sensors and sensor data

- WDNR data users include those involved in public outreach and are responsible for assisting with the development of a sensor study webpage where the data and assessment report may be housed for public use
- External data users may access the final report as a public record and may use it in cooperation with, or independent of, WDNR for a variety of purposes including: scientific research, issue advocacy, health-related studies

A.5 Problem Definition/Background

Low cost sensors are continually becoming more popular for personal use, research and even to augment regulatory networks. Low cost sensors are desirable because they can provide data for more locations and at finer time scales at a much lower cost than methods used for regulatory purposes. While the data from sensors are not designed to be used for regulatory purposes, they may be of sufficient quality to be used for qualitative purposes and potentially even for some quantitative purposes as long as data uncertainty is properly understood and communicated.

One of the more popular sensors currently being marketed is a particulate sensor produced by PurpleAir. PurpleAir markets a PA-II Dual Laser Air Sensor that uses a fan to draw ambient air past a pair of Plantower PMS5003 laser sensors that count particles and bins them in six size fractions between 0.3 and 10 µm in diameter. These particle counts are put through a proprietary algorithm to calculate particulate concentrations at the 1, 2.5 and 10 µm size fractions. Temperature and relative humidity sensors are incorporated to help provide information on potential meteorological effects on the data. PurpleAir also provides a website where data from its sensors are updated in real time. Due to the widespread availability of the Purple Air, a robust network across the U.S. and many other countries has already been developed.

The PA-II sensor has been evaluated by independent organizations and has been found to have a high precision within its methodology and good correlation to Federal Reference Method (FRM) and Federal Equivalent Method (FEM) equipment. Despite this good correlation, the relationship is typically biased higher than the regulatory method and results in poor agreement with FRM/FEM methods out of the box. This is a known limitation of the Purple Air.

Independent studies have suggested that correction factors may be developed to bring data produced by PurpleAir sensors into closer agreement with data produced by FRM/FEM methods. These correction factors are essentially regression models (or parts of those models) used to approximate FRM/FEM values based on sensor data input. Different studies have produced substantially different correction factors, raising concerns that there may be regionality or seasonality impacting the correction factors developed to date.

Meteorological conditions, specifically relative humidity, have been found to impact data produced by particulate sensors including the PA-II. Wisconsin has drastic variability in weather from month to month and has some regionality in weather, primarily due to influence of the Great Lakes. WDNR is interested in developing its own correction factor for PurpleAir sensors. While doing so, WDNR also is interested in determining if a single correction factor is appropriate for Wisconsin or if multiple correction factors dependent on region or season may be more appropriate.

Objectives for the PA-II study will include:

- Assessment of precision among PA-II sensors by evaluating periods of sensor collocation
- Assessment of correlation between PA-II and FEM data at WDNR-operated sites
- Assessment of accuracy of PA-II data compared to FEM data at WDNR-operated sites
- Development of a statewide correction factor for PA-II data and assessment of any changes in the accuracy of corrected versus uncorrected values compared to FEM data at WDNR operated sites
- Comparison of site-based versus statewide correction factors to determine the sensitivity of correction factors to Wisconsin regionality
- Comparison of seasonally-derived versus statewide correction factors to determine the sensitivity of correction factors to Wisconsin seasonality

A.6 Project/Task Description

WDNR's study of the PA-II sensor is intended to include, but may not be limited to, the following activities:

- Field
    - Purchase five PA-II sensors with Wi-Fi capability
    - Develop operation procedures for the sensors including setup, operation and data acquisition
    - Perform initial collocation study by deploying all five PA-II sensors at the Appleton monitoring site for 7-10 days
    - Deploy sensors to four WDNR monitoring sites for 2019 to compare against T640 and T640X data for $PM_{2.5}$; may also compare against T640X data for PM_{10}
        - Appleton (T640)
        - Eau Claire (T640)
        - Madison East (T640)
        - Waukesha (T640X) (primary PA-II vs. PA-II collocation)
    - Move the PA-II collocation to each of the monitoring sites for periods of at least 7 days during the course of the one-year deployment to evaluate continuing precision
    - Perform final collocation study by deploying all five PA-II sensors at the Appleton monitoring site for 7-10 days
- QA/Data
    - Perform initial assessment of within-method collocation (PurpleAir vs. PurpleAir)
    - Develop data gathering/cleaning methods and tools for interpreting the data
    - Develop a statewide correction factor after one year of data collection
    - Perform final assessment of within-method (PurpleAir vs. PurpleAir) collocation; characterize any changes in sensor precision over one year of operation
    - Assess regional correction factors versus statewide correction factor based on full year of data
    - Assess statewide seasonal correction factors versus the statewide correction factor based on a full year of data
- Communication and Outreach
    - Develop a report summarizing the data and assessments from the PA-II study

- Develop materials for citizen science projects and individuals utilizing sensor-based data for studies and personal purposes
- Work with PurpleAir to determine if a WDNR correction factor can and should be added to the PurpleAir website

A.7 Quality Objectives and Criteria

WDNR's study of PurpleAir sensors will include evaluation of precision within the method and evaluation of correlation and accuracy versus regulatory FEMs. Correction factors will be developed for the study and separate correction factors for each site and season to assess regional and seasonal differences. These correction factors will be assessed against each other to determine if a single year-round, statewide correction factor is appropriate or if regional and/or temporal considerations should also be included.

A.7.1 Sensor Precision

Precision of the PA-II sensors will be evaluated to provide information regarding the degree of variability that is typical both within a sensor (comparing channel A to channel B) as well as among different sensors (comparing collocated sensors). Both types of comparisons will be made before and after the study. Short-term collocations will also take place throughout the study, as one PA-II sensor is rotated across the state to collocate with four permanent sensors. In addition, A/B channel comparisons may be done retrospectively at different intervals throughout the study if post-study versus pre-study A/B channel comparisons indicate changes in within-sensor precision over the course of the study.

Within-method precision assessments to be made based on 24-hour daily data include:

- Comparison of daily A versus B channel data for each sensor
- Comparison of sensor 1, 2, 3, 4, and 5 versus the sensor average for A channel only, B channel only, and A/B channel average (minimum of four sensors with valid data to make the comparison)
- Determination of any trend in collocation assessment over the course of the one year study (before, during, after)
- Determination of any time-base effects on trend in collocation assessment by repeating assessment using 1-hour data

A.7.2 Assess Data Screening Rules

Business rules may be developed that would identify a threshold of A/B channel disagreement to screen the data from the data set (e.g., if preliminary review of sensor A/B data shows instances when the channels do not agree). To evaluate the effectiveness of a data screening business rule, the analysis being conducted in this study may be repeated with screened and unscreened data.

A.7.3 Sensor / Regulatory Method Correlation and Accuracy

The assessment of the PurpleAir data versus regulatory instruments will primarily be done on daily averages because the PM standards are based on daily measurements; shorter time frames

such as hourly will also be examined. These comparisons will include assessments of both the correlation and accuracy of the sensor versus regulatory data. These assessments will be performed on different data subsets as described in following sections.

- Correlation will be assessed by comparing PA-II daily and hourly averages versus T640/T640X daily and hourly averages
    - Daily averages will be compared if data from both sources are ≥ 75% complete (75% of possible hourly averages are complete)
    - Hourly averages will be compared if data from both sources are ≥ 75% complete
        - PurpleAir sensors data will utilize the average of the A and B channels (A+B)/2 when available or may substitute data from either channel when one is missing

- Accuracy will be assessed by comparing direct difference and percent difference
    - Direct difference will use PA-II – Regulatory for complete daily and hourly averages
    - Percent difference will use (PA-II – Regulatory)/Regulatory for complete daily and hourly averages where both values are greater than or equal to 3.0 ug/m^3

A.7.4 Determine and Assess Statewide Correction Factor

The desired outcome of the study will be to develop a statewide correction factor that can be utilized year-round, throughout the state of Wisconsin.

- Correction Factor development and assessment based on 24-hour daily data
    - Assign data to two groups
        - Groups
            - Training data set – 75-90% of scheduled data
            - Test data set – 25-10% of scheduled data
                - Test data should be taken from across all sites and seasons (e.g., stratified random sample across sites and seasons)
    - Assess training and test data sets for sensor versus FEM agreement
        - Determine average of the daily differences
        - Determine standard deviation of the daily differences
    - Develop correction factor using training data set
        - Linear regression of sensor versus FEM data
    - Assess correction factor
        - Compare observed FEM versus corrected sensor data for both the training data and test data sets
            - Determine average of the daily differences
            - Determine standard deviation of the daily differences

A.7.5 Determine and Assess Site-Based Correction Factors

It is understood that particulate characteristics may vary from location to location. To determine if a statewide correction factor is appropriate, site-based correction factors will be developed and compared to the statewide correction factor to determine if results are sufficiently different (≥

10%) to warrant separate regional correction factors.

- Correction Factor assessment for Regional variability
    - If samples sizes are sufficient (> 50% complete for a month or the study, with a minimum of ten samples per stratum), use the training and test data groups from 7.4 but keep the data from the sites separate; otherwise, do not separate out a test data group
        - Develop site-specific correction factors using site-specific training data sets using the techniques from A.7.4
    - Assess site-specific correction factors by applying the site-specific correction to both the site-specific training and test data sets
        - Determine average of the daily differences
        - Determine standard deviation of the daily differences
    - Assess the statewide correction factor for each site
        - Determine average of the daily differences calculated in A.7.4. but by site, for both training and test data sets
        - Determine standard deviation of the daily differences calculated in A.7.4. but by site for both training and test data sets
    - Compare the averages of the site-level daily differences and standard deviations from the statewide and site-based correction factors. Determine if and how differences between observed and predicted vary between approaches.

A.7.6 Determine and Assess Seasonal-Based Correction Factors

It is understood that particulate characteristics may vary from season to season. To determine if a year-round correction factor is appropriate, season-based correction factors will be developed at the statewide level and compared to the statewide correction factor based on a full year of data to determine if results are sufficiently (≥ 10%) different to warrant separate seasonal correction factors. Depending on analysis results and data completeness, this process may be repeated on monthly data sets.

- Correction Factor assessment for seasonal variability
    - If samples sizes are sufficient (>50% complete for a month or the study, with a minimum of ten daily and 30 hourly samples per stratum), use the training and test data groups from 7.4 but keep the seasonal data separate; otherwise do not separate out a test data group
        - Develop season-specific correction factors using season-specific testing data sets and the techniques from A.7.4
    - Assess season-specific correction factors by applying the season-specific correction to the season-specific test data sets
        - Determine average of the daily differences
        - Determine standard deviation of the daily differences
    - Assess the full-year correction factor for each season
        - Determine average of the daily differences calculated in A.7.4. but by season, for both training and test data sets
        - Determine standard deviation of the daily differences calculated in A.7.4.

but by season for both training and test data sets

- Compare the averages of the season-level daily differences and standard deviations from the full-year and seasonal correction factors. Determine if and how differences between observed and predicted vary between approaches.

A.8 Special Training/Certification

PurpleAir sensors are intended for use by the general public while receiving a basic level of support from the PurpleAir manufacturer. WDNR site operators will be responsible for installing and operating the sensors.

Training requirements vary depending on the role being performed. Training should include but is not limited to:

- WDNR QA/Data staff analyzing PurpleAir data: Should be familiar with the PurpleAir Sensor Study QAPP, PurpleAir data retrieval, data analysis tools and statistics
- WDNR Site Operators operating PurpleAir sensors: Should be familiar with the PurpleAir Sensor Study QAPP, PurpleAir sensor installation, general siting criteria for collocation of particulate samplers found in 40 CFR Part 58.
- WDNR Field Lead: Should be familiar with the PurpleAir Sensor Study QAPP, PurpleAir sensor installation, PurpleAir data retrieval, general siting criteria for collocation of particulate samplers

A.9 Documents and Records

The WDNR-related documents are created and maintained per WDNRs Retention Disposal Authorization document and Documentation SOP.

A.9.1 QMP/QAPPs/SOPs

Final versions of the QMP, QAPPs and SOPs are maintained on an electronic file share (Airmon) which is accessible to WDNR employees with access to the shared network. Control of these documents is managed by the air monitoring QAC or designee. Archived versions of retired documents will be maintained.

When a new or revised document is finalized, it is sent as an attachment to all appropriate personnel or a notification is sent advising staff as to where it may be accessed.

Only one paper copy is retained by the QAC for the purpose of maintaining a record of signatures of finalized documentation. Any other paper copy is the responsibility of the holder to replace when updated versions of the document are announced via email.

A.9.2 Data

A file share accessible by the Field Lead and QA staff will be used to house the data and the resulting analysis tools, outputs and reports. This files share is expected include:

- Raw data downloaded from PurpleAir sensors

- R programs used to aggregate and evaluate PurpleAir data
- R programs used to compare PurpleAir data with FEM data
- Data output from R programs
- Analysis documents in Excel

A.9.3 Reports

At a minimum, reports generated from this study will be stored in the file share alongside the data and will be made available on request. Reports may also be linked on WDNR websites at the discretion of the WDNR Air Management Program Director.

B. Data Generation and Acquisition

B.1 Sampling Process Design (Experimental Design)

Five PurpleAir sensors will be purchased and deployed to four sites following an initial collocation study. These sites are distributed across the state and have continuous FEM methods operating that the PurpleAir sensors will be compared to. The sites and collocated equipment have been identified as:

- Appleton – T640 (2)
- Eau Claire – T640
- Madison East – T640
- Waukesha – T640X

The sensors and the collocated FEMs sample on a continuous basis. Data will be integrated and evaluated in daily and hourly averages. The project period will facilitate site deployments lasting for one full year. Further evaluation of the sensors may require deployments beyond one year.

A fifth sensor for QA purposes will be located at Waukesha but then moved to the other sites on a quarterly basis to assess method precision over the course of project period.

B.2 Sampling Methods

The T640/T640X samplers are already in place as part of a regulatory program and will not require any alterations in operations. They will follow the practices defined in the Low-Vol PM2.5 and PM10 – Filter Based and Continuous QAPP and T640X SOP.

PurpleAir sensors operate passively and do not require any operations activity beyond installation and data telemetry. Data will be reviewed on a weekly basis to confirm each sensor's A and B channels are reading similarly. If a malfunction becomes apparent through the data, the sensor will be physically inspected for any signs of damage or blockage. The Field Lead will be responsible for consultation with the PurpleAir manufacturer in any situation where a remedy is not readily apparent.

B.3 Sample Handling and Custody

The PurpleAir and T640 methods perform in situ measurements and do not produce any physical samples. No sample handling or chain of custody procedures are required.

B.4 Analytical Methods

The PurpleAir and T640 methods perform in situ measurements and do not produce any physical samples which require analysis.

B.5 Quality Control

T640 quality control will be operated following the practices defined in the Low-Vol PM2.5 and PM10 – Filter Based and Continuous QAPP and T640X SOP. These practices include:

- Leak checks
- Flow, temperature and pressure verifications
- PMT verifications

The PurpleAir sensors do not have flow requirements. The sensor package includes a temperature and relative humidity sensor, but the measurements are not dependent on these values.

PurpleAir A and B channel graphs will be reviewed on a weekly basis to identify potential sensor failure. Temperature and relative humidity information will be evaluated only to determine if the readings are sensical. The data from these sensors is only expected to be used anecdotally to determine if there are temperature or relative humidity conditions that cause correlation and accuracy to improve or degrade.

B.6 Instrument/Equipment Testing, Inspection and Maintenance

T640 testing, inspection and maintenance will follow the practices defined in the Low-Vol PM2.5 and PM10 – Filter Based and Continuous QAPP and T640X SOP.

The five PurpleAir sensors will be collocated at the same site prior to the start of the year-long study to determine if they are functioning properly and reading similarly out of the box. Sensors will be configured to report to the PurpleAir website as private network sensors. These may be turned to public at the discretion of the Air Monitoring Section Chief.

Once installed at individual sites the sensors will be visually inspected on a monthly basis by site operators to ensure general cleanliness. Otherwise PurpleAir sensors are expected to be maintenance free.

B.7 Instrument/Equipment Calibration and Frequency

T640 calibration activities will follow the practices defined in the Low-Vol PM2.5 and PM10 –

Filter Based and Continuous QAPP and T640X SOP.

PurpleAir sensors have no calibration requirements for normal operation and cannot be challenged by standards in a meaningful way. Collocation studies and the evaluation of the agreement of the A and B channels are the only way to gauge the performance of these sensors. Collocation will be conducted at the beginning and end of the study and periodically throughout. A weekly check of A and B channel comparisons will take place to observe if major channel disagreement has become pervasive indicating a sensor malfunction. Further analysis or investigation will take place if any issues are present.

B.8 Inspection/Acceptance of Supplies and Consumables

The PurpleAir equipment does not require any supplies and consumables. The T640 requires span dust that is purchased and inspected as part of normal operations.

B.9 Non-Direct Measurements

Limited meteorology data can be obtained from the T640 or PurpleAir sensors. Additional meteorology information may be obtained from onsite meteorological equipment or from nearby stations which are operated by WDNR or other entities.

B.10 Data Management

Data records for the T640s are generated throughout the data collection and QA process. Data are generated by samplers, logged using an on-site or off-site computer program, transmitted to a central server database for review and processing and ultimately sent to AQS. Data retrieved from site loggers are reviewed on a periodic basis and again in detail during the monthly data review. Data submitted to AQS are reviewed upon submittal and again in detail during the annual data certification process. Any errors or data abnormalities detected are investigated and resolved.

Data records for PurpleAir are sent to the PurpleAir website in real time. These data will be reviewed weekly on the PurpleAir website and downloaded monthly to a WDNR file share. Precursory review of the data min/max information will be done on a monthly basis. Otherwise the data will be reviewed as part of the correlation and accuracy analysis of this study.

Data screening rules may be proposed and evaluated as part of this study.

C Assessment and Oversight

C.1 Assessments and Response Actions

Preliminary method collocation data will be evaluated early in the study to help define expectations of precision and accuracy.

PurpleAir/T640 collocation data may have preliminary evaluations performed as often as

quarterly to help refine analytical tools and provide initial impressions. If a change is determined to be necessary as a result of these reviews, the study plan may be modified if needed.

C.2 Reports to Management

This study is being conducted for internal purposes. It is expected to provide a report that will be shared with management at the conclusion of the study. Management will determine if and how the study results will be shared with external entities.

D Data Validation and Usability

D.1 Data Review, Verification and Validation

The criteria used to review and validate data have been detailed in the above sections, predominantly in A.7 and B.5.

D.2 Verification and Validation Methods

[Reserved]

D.3 Reconciliation with User Requirements

[Reserved]

APPENDIX A: References

Quality Assurance Project Plan: $PM_{2.5}$ and Low Volume PM_{10} Networks QAPP 1.0

Standard Operating Procedure: TAPI T640X Particulate Monitor SOP 4.3