EFTEON Standard Operating Procedures for routine maintenance

For more information, please contact:

The Expanded Freshwater and Terrestrial Environmental Observation Network

South African Environmental Observation Network

Address: 56 Florence Street, Colbyn, Pretoria, 0083, South Africa

EFTEON Manager: Dr Gregor Timothy Feig
Tel: +27 (0) 12 534 3507
Email: gregor@saeon.ac.za

EFTEON Chief Technician: Dr Kerneels Jaars
Tel: +27 (0) 12 534 3619
Email: kerneels@saeon.ac.za

EFTEON Manager: Dr Gregor Timothy Feig, Tel: +27 (0) 12 534 3507, Email: gregor@saeon.ac.za

EFTEON Chief Technician: Dr Kerneels Jaars, Tel: +27 (0) 12 534 3619, Email: kerneels@saeon.ac.za

The Expanded Freshwater and Terrestrial Environmental Observation Network

EFTEON Standard Operating Procedures for routine maintenance of Eddy Covariance Flux Towers

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1 Table of Contents

1 DOCUMENT CONTROL

Table 1: Version Amendment Schedule

Revision	Release Date	Responsible Person	Description of Change
1	June 2020	Dr Kerneels Jaars	Initial Release

Table 2: Approval and Control Schedule

Approved	Designation	Approval Date	Signature
Dr Gregor Feig	EFTEON Manager	June 2020	

2 PURPOSE AND APPLICABILITY

This standard operating procedure (SOP) details the procedures the field technicians must follow for routine maintenance of equipment in the EFTEON landscape sampling network. Routine site maintenance will occur weekly. Maintenance is solely the responsibility of the EFTEON field operations team, comprised of the landscape scientist and field technicians.

3 SUMMARY OF METHOD

Prior to routine maintenance, the field technician will review and summarize all of the information collected at the site during the previous days in order to characterize how well the site is functioning. The data recorded during weekly visits by the operators, as well as any problems detected during quality assurance procedures, will be incorporated into the site summary. This reference will be used to determine whether extra maintenance or troubleshooting is required at each site.

Routine site maintenance will be performed by EFTEON field technicians. During the site visits the batteries are checked; solar panels are checked and cleaned; radiation sensor lenses are checked and cleaned; the electronics are checked; cables flagged for replacement or repaired as needed; calibration equations are verified (and if necessary corrected). Operator training and review sessions, as well as any sensor/sampler upgrades, are also performed at this time.

4 HEALTH AND SAFETY WARNINGS

Be aware that various stinging insects, venomous creatures, and large mammals (such as wildebeest, elephants) can be found at many of the EFTEON sites. Be cautious when stepping in tall grass surrounding a site or when opening datalogger and battery boxes.

Maintenance requires cleaning of the radiation sensors, which typically requires accessing the tower. Safety ratings are assigned to classify fall risk at each site. These ratings range from “None,” “Low,” “Medium,” to “High.” The scientist and technician will meet to discuss the fall safety plan determined for accessing and cleaning the sensors. Everyone accessing the towers should have the relevant fall arrest training

Inclement weather may be an issue at some sites. If severe weather is impending, wait it out in the vehicle or reschedule the site visit.

Always carry a first aid kit. Report any injuries sustained on duty to the Landscape Scientist, EFTEON Manager and Chief Technician immediately.

Approptiate PPE must be worn including closed boots, long trousers and collored long sleave shirts. The technician should always have a wide brimmed hat to prevent sunburn. Tick repellent is recommended.

5 CAUTIONS

Access roads to EFTEON sites are locked after regular business hours. Be sure to communicate with any necessary staff how long the visit is expected to take to avoid being locked in the area.

Various land owners will have specific requirements to access sites on their property, these requirements will need to be adhered to

EFTEON sites are remote and require hiking to the site or driving off-road. Be sure to have detailed directions on how to get to a site that requires walking or off-road driving.

Birds, wasps and rodents sometimes make nests on the tower and enclosures. Check for this carefully, as this can cause issues during sampling and other health concerns. Report any infestations to the Landscpape Scientist, EFTEON Manager and Chief Technician immediately.

Care should be taken to lock the vehicle and secure work and personal equipment while at the site, especially if its an urban site.

6 INTERFERENCES

The EFTEON landscape aim is to provide and operate a network of instrumented landscape-level platforms for the South African environmental research community, focused on socially relevant terrestrial landscapes and their coupled hydrological systems. Therefore, the sites are located in remote areas. The sites should not be heavily influenced by local sources. If a new activity begins close to the site (if you can see or smell emissions when you are at the site), please inform the Landscape Scientist, EFTEON Manager and Chief Technicain of the possible interference at once. Examples of activities that might influence the air quality samples are:

- Fires
- Road or building construction
- Gas or diesel powered generator
- Increased traffic

- Mining operations or etc.

7 PERSONNEL DUTIES

The landscape scientist will:

- Oversee and maintain records of site and sensor operation
- Organize and schedule maintenance
- Review checks
- Oversee the training of field technicians

• Respond to any issues or concerns brought up by field technicians during maintenance

The field technician will:

- Perform routine site maintenance
- Perform site operator training and review sessions
- Maintain records on equipment repair and modification
- Update equipment inventory during site maintenance
- Report any issues or concerns in the field to the landscape scientist

8 EQUIPMENT AND SUPPLIES

The equipment list for site maintenance trips will vary depending on if it's routine maintenance or a monthly/quarterly and whether any new sensors will be installed during the trip. Because of this and due to the extensive amount of supplies needed, equipment lists will not be reported within this SOP. They can be located in ***Attachment 1, "Maintenance Packing Lists."***

9 PROCEDURAL STEPS

Field technicians perform routine site maintenance at east once per month. This visit to the site is an opportunity to flag non-vital sensors/sampler components for replacement, replace or update obsolete equipment, thoroughly clean each sensor, and test systems. It also allows trained personnel to inspect the site to ensure compliance with EFTEON sampling regulations and provides an excellent opportunity for personnel training.

9.1 Site Maintenance

Several processes need to be adhered to when conducting a site visit. The steps are captured in the routine maintenance logbook:

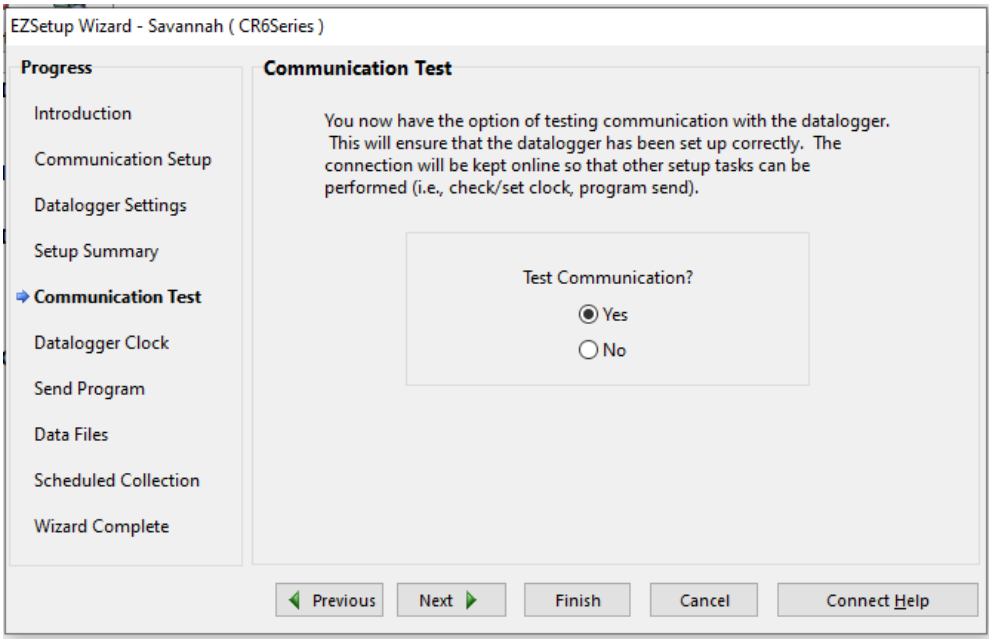
1. Field technicians prepare for site maintenance by contacting the custodian of the site, scheduling visit dates and times, and creating site flow check and maintenance kits.
2. Note time of arrival at the site.
3. ***Take a picture of the tower from the specifically mark position and height from the ground using a tripod set to a height of 1.5m .***
   - 3.1. Four inward views while standing approximately 50 meters away from the site; take pictures of the site looking N, E, S, and W, at markers that have been set up. Please refer to the Rephoto SA Manual
   - 3.2. Four outward views while standing with back against the tower and looking towards N, E, S, W
4. Observe all surrounding environmental conditions that could influence the operation of the site. These may include the evidence of burning in the vicinity of the site, construction activity, vandalism, footprints etc. These observations should be noted in the site report.
5. Check the integrity of the tower, datalogger enclosures, solar panels, and mast etc., for any structural damage. Note the condition of the tower and enclosures (e.g. are they rusted?).
6. Remove any accumulated detritus such as bird nests, fallen branches etc.
7. Unlock battery box and other enclosures. **Care should be taken when opening enclosures, sometimes snakes and other insects can crawl into enclosures.** Make notes if you see any nest or other strange things in the enclosure or on the tower
8. Check that all cables/wires are connected to the datalogger and no visual damages.
9. Check if the POWER LED on the data logger, it flashes 1 time every 10 seconds.
10. Check that the solar panels are charging the batteries.
11. Take out Simcard and check how much data there is with a phone, make a note.
12. ***Take out the microSD card and download data. Make a note. Remember to replace the microSD card.***
    - 12.1. Before removing a card from the data logger, disable the card by pressing the Eject button and wait for the green LED. You then have 15 seconds to remove the card before normal operations resume.
    - 12.2. Do not remove a memory card while the drive is active, or data corruption and damage to the card may result.
    - 12.3. Prevent data loss by collecting data before sending a program. Sending a program to the data logger often erases all data.

12.4. When the data logger is powered and a microSD card installed, the Act (Activity) LED will turn on according to card activity or status: **Red flash**: Card read/write activity; **Solid green**: Formatted card inserted, powered up. This LED also indicates it is OK to remove card. The **Eject** button must be pressed before removing a card to allow the data logger to store buffered data to the card and then power it off. **Solid orange**: Error; **Dim/flashing orange**: Card has been removed and has been out long enough that CPU memory has wrapped and data is being overwritten without being stored to the card.

13. ***Test wireless communication with EZSetup to the datalogger by using PC.***

13.1. Open the LoggerNet program, select **Setup** from the Main category on the toolbar.

13.2. Select the station that you want to do communication testing. Access the **Communication Test** step from the left side of the window.



13.3. Ensure the data logger is connected to the computer, select Yes to test communications, then click **Next** to initiate the test. If the test was unsuccessful check that the modems green LED is on.

13.4. With a successful connection, the **Datalogger Clock** window displays the time for both the data logger and the computer.

13.4.1. The **Adjusted Server Date/Time** displays the current reading of the clock for the computer or server running your data logger support software. If the **Datalogger Date/Time** and

Adjusted Server Date/Time don't match, you can set the data logger clock to the **Adjusted Server Date/Time** by clicking Set **Datalogger Clock**.

13.4.2. Use the Time Zone Offset to specify a positive or negative offset to apply to the computer time when setting the data logger clock. This offset will allow you to set the clock for a data logger that needs to be set to a different time zone than the time zone of the computer (or to accommodate for changes in daylight saving time).

13.5. Click **Next**. Check that the correct **Datalogger Program** is displayed. Don't send a program as the program is already in the logger. Click **Next**.

13.6. The **Datalogger Table Output Files** window displays the data tables available to be collected from the data logger and the output file name. By default, all data tables set up in the data logger program will be included for collection. Make note of the **Output File Name** and location. Select the option 'append to file' and rename the file if default is not wanted. Click **Next**.

13.7. Check **Scheduled Collection is not Enabled** to have LoggerNet automatically collect data from the data logger on the Collection Interval entered. When the Base Date and Time are in the past, scheduled collection will begin immediately after finishing the EZSetup wizard. Click **Next**.

13.8. Click **Finish**.

14. ***Set up a USB or RS-232 connection to begin communicating with data logger. Because these connections do not require configuration (like an IP address), you need only set up the communications between your computer and the data logger.***

14.1. Using data logger support software, launch the EZSetup Wizard. Click **Setup**  , click the View menu to ensure you are in the EZ (Simplified) view, then click on the site **Name** that you want to connect. Click **Next**.

14.2. If prompted, select the **Direct Connect** connection type and click **Next**

14.3. If this is the first time connecting this computer to a CR6 via USB, click **Install USB Driver**, select data logger, click **Install** and follow the prompts to install the USB drivers.

14.4. From the **COM Port** list, select the COM port used for the data logger.

14.5. USB and RS-232 connections do not typically require a COM Port Communication Delay - this allows time for the hardware devices to "wake up" and negotiate a communications link. Accept the default value of 00 seconds and click **Next**.

14.6. The baud rate and PakBus address must match the hardware settings for your data logger. The default PakBus address is 1. A USB connection does not require a baud rate selection. RS-232 connections default to 115200 baud.

14.7. By default, the data logger does not use a security code or a PakBus encryption key. Therefore, the Security Code can be set to 0 and the PakBus Encryption Key can be left blank. If either setting has been changed, enter the new code or key

14.8. Click Next.

14.9. Review the Setup Summary. If you need to make changes, click Previous to return to a previous window and change the settings.

15. Select the Main category and **Connect**  on the LoggerNet toolbar, select the data logger from the Stations list, then click **Connect**  . To disconnect, click **Disconnect** 

15.1. Click **Station Status**  to view the Summary tab.

15.2. **Save**  the **Summary** and **Status Table** as **_StationName_Date**.

15.2.1. Do troubleshoot of the errors and then clear. Common errors are: **Watchdog errors, Results for last program compiled, Skipped scans, Skipped records, Variable out of bounds and Battery voltage**

15.3. Select a table to view using the **Table Monitor**.

15.4. Check the working status of all sensors and record the values of the parameters as indicated in Maintenance Logbook.

15.5. Before leaving the site check that all sensors are running and remote connection to data logger is possible

9.2 Tipping Bucket Rain Guage

9.2.1 Maintenance

During each site visit, inspect to ensure that the funnel and bucket are relatively free of dust, leaves, twigs, spider webs, and insect and bird nests. **DO NOT** remove nesting insects or animals by spraying insecticide because this may damage the plastic and sensors. To clean the funnel, follow these steps:

1. Slide the funnel up and off the white bucket.
2. Rinse the funnel using water, ensuring that the inlet is clean (it may be necessary to insert a small screwdriver to clean out any obstructions .
3. Check that the tipping bucket is free from obstructins and tips easily
4. Reinstall the funnel by sliding it down onto the white bucket.

Verify the tipping bucket assembly moves freely, and that the data logger records each bucket tip. Check that the rain gauge is perfectly level (there is a levelling bubble inside the instrument).

9.2.2 Calibration

Monthly, or if the rain gauge has been tampered with, perform a field calibration on site. Perform this calibration check after completing other tasks, such as cleaning and checking the level of your rain gauge. Check the calibration by pouring a set amount of water into the rain gauge at a set flow rate to simulate rainfall at a specific rate per hour.

1. Calibrate the rain gauge by decanting (373 ml) using a plastic bottle or saline drip bag so that the water drips out over about 1 hour.
2. The logger should record approximately 100 tips. Write this number of tips down and record it in the calibration file.
3. Make a note of the date and your actions in the maintenance logbook.

If factory calibration is required, contact Campbell Scientific.

Reference Documents: https://s.campbellsci.com/documents/us/manuals/te525.pdf and references therein

9.3 Air Temperature and Relative Humidity (RH) sensor and shield

9.3.1 Maintenance

The sensor is designed to operate for an extended period with minimum maintenance. However, it can be damaged by untrained personnel attempting disassembly or calibration.

Once every three months, clean the temperature/RH (radiation) shield using a soft, clean, damp cloth.

If the shield is very dirty, follow these steps:

1. Remove the two screws that hold the shield to the bottom of the crossarm, and gently lower the assembly. Set the screws aside.
2. Gently pull the temperature/RH sensor out from inside the shield. Allow the sensor to hang from the crossarm.
3. Clean the shield in a bucket of soapy water using a soft brush.
4. Rinse the shield with water.
5. Allow the shield to dry completely.
6. Reassemble the shield onto the temperature/RH sensor and crossarm by screwing in the two screws.

9.3.2 Calibration Verfication

On every routine site visit the output of the Temperature and humidity sensors is to be verified. This is to be done using the temperature pressure humidity transfer standard (Vaisalla (model xxxx)).

1. Position the portable sensor next to the RH sensor ensuring that it is not exposed to direct solar heating
2. Check the output reading on the TPH TS and compare it to the readings on the logger.
3. Record the values from both the logger and the transfer standard
4. Record the difference in both the temperature and humidity

Table 3 Quality Objectives for the temperature and humidity calibration verification

	Recorded deviation		
	Accept	Flag data and check	Remove sensor
Humidity	0-2%	2-5%	>5%
Temperature	0.5°C	0.5-1°C	>1°C

Barometric pressure	0-2%	2-5%	>5%

9.3.3 Calibration

Every 3 months Inspect the sensor for proper operation, follow these steps:

1. To verify correct wiring and test the basic sensor operation, blow on the sensor. The moisture in your breath should cause the relative humidity reading to rise.
2. To ensure proper operation, check the output data against a relative humidity and temperature measuring device such the Temperature, pressure and humidity transfer standard. Local weather service data should be used only as a guideline since relative humidity and temperature can vary significantly over short distances and over brief periods of time

Reference Documents: https://s.campbellsci.com/documents/us/manuals/083e.pdf and references therein

9.4 Wind Speed and Wind Direction Sensor

9.4.1 Maintenance

Every month do a visual/audio inspection of the anemometer at low wind speeds. Verify that the cup assembly and wind vane rotate freely. Inspect the sensor for physical damage.

The frequency at which the sensor needs to be maintained can also depend upon the environment in which site is located.

1. For a windy, dusty environment, the sensor requires maintenance once every six months.
2. For an environment with a moderate amount of wind, sensor maintenance is required once a year.
3. For an environment with minimal wind, you may only need to perform sensor maintenance once every two years.

Replace the anemometer bearings when they become noisy, or the wind speed threshold increases above an acceptable level. The condition of the bearings can be checked with a paper clip as described in the R.M. Young 03002 manual (https://s.campbellsci.com/documents/us/manuals/rm_young-03002-manual.pdf).

The potentiometer has a life expectancy of fifty million revolutions. As it becomes worn, the element can produce noisy signals or become nonlinear. Replace the potentiometer when the noise or nonlinearity becomes unacceptable

Reference Documents: https://s.campbellsci.com/documents/us/manuals/03002.pdf and references therein

9.5 LI190R Quantum Sensor

9.5.1 Maintenance

Keep the sensor clean and treat it as a scientific instrument to maintain the accuracy of the calibration. The vertical edge of the diffuser must be kept clean to maintain appropriate cosine correction.

Once a month clean the sensor only with water and/or mild detergent such as dishwashing soap. Vinegar can also be used to remove hard water deposits from the diffuser element if necessary.

Do not use alcohol, organic solvents, abrasives, or strong detergents to clean the diffuser element. Exposure to alcohol or organic solvents harm the acrylic materials of the sensor, which will adversely affect the cosine response of the sensor

9.5.2 Calibration

Recalibrate the LI190R every two years. Send the entire sensor and cable to Campbell Scientific for recalibration. Along with a calibration certificate, a new heat shrink label will be put on the cable with the new calibration value.
Reference Documents: https://s.campbellsci.com/documents/us/manuals/li190r.pdf and references therein

9.6 CNR4 Net Radiometer

9.6.1 Maintenance

The CNR4 is weatherproof and intended for continuous outdoor use. The materials used in the pyranometer and the pyrgeometer are robust and require little maintenance. For optimal results, however, proper care must be taken.

Dirty domes and windows can reduce the radiometer readings. **Once a month clean the windows and domes using distilled water or alcohol as a cleaning solution, being careful not to scratch the windows and domes during cleaning.**

The CNR4 has a drying cartridge inside the sensor to help keep the electronics dry. Replace the drying cartridge every 6 to12 months. See the manual on how to change cartridges.

9.6.2 Calibration

For quality assurance of the measured data, the manufacturer recommends the CNR4 be recalibrated on a regular schedule by an authorized Kipp & Zonen calibration facility. The CNR4 should be recalibrated every two years. Alternatively, one can check the sensor calibration by letting a higher standard run parallel to it over a two-day period and, then, comparing the results. For comparison of pyranometers, one should use a clear day. For comparison of pyrgeometers, one should compare the nighttime results. If the deviations are greater than 6%, the sensor should be recalibrated.

Reference Documents: https://s.campbellsci.com/documents/us/manuals/cnr4.pdf and references therein

9.7 Integrated CO_2/H_2O Open-Path Gas Analyzer and 3D Sonic Anemometer

9.7.1 Routine Maintenance

Once a month check the humidity indicator card in the EC100 enclosure. If the highest dot has turned pink, replace or recharge the desiccant bags.

Make sure the LED Status Lights on the EC100 panel are green. If not, verify that all connections are secure and that the instruments are powered. Also check the individual diagnostic bits for the specific fault. See TABLE 10-2, Bits in the Sonic Diagnostic Flag and TABLE 10-3, Bits in the Gas Diagnostic Flag in reference document for more information

9.7.2 Wick Maintenance

Once a month check that sonic and gas analyzer wicks are still attached and clean. Remove the wicks during periods where snow or freezing rain may be expected. The wicks will accumulate snow or freezing rain, resulting in blockage of the sonic signals and optical path. See reference document for more information on installing wicks.

Spare wick should be kept as part of the standard field kit

9.7.3 Gas-Analyzer Window Cleaning

The windows of the analyzer should be cleaned if the signal strength for CO_2 or H_2O drops below 0.7 or 70% of the original value. These values may be monitored in the output data, or they can be viewed with ECMon. To clean the windows, use isopropyl alcohol (2-propanol/isopropanol) and a cotton swab or a non-scratching tissue or cloth. Verify that following cleaning the signal strengths are restored to values close to 1.0 (>0.9).

9.7.4 Calibration

Every 3 months Zero and Span should be done. See the reference document for detail information on how to calibrate the IRGASON

9.7.5 Replacing Desiccant and Scrubber Bottles

If more than two years have passed since replacing the desiccant-scrubber bottles within the IRGASON, or if the zero-and-span readings have drifted excessively, the bottles should be replaced.

Reference Documents: https://s.campbellsci.com/documents/us/ manuals/irgason.pdf and references therein.

Wind speed and direction

Reference Documents	https://s.campbellsci.com/documents/us/manuals/03001.pdf
Method	Determination of wind speed by (cup or propeller) anemometer and wind direction by bi-directional wind vanes. Units with no moving parts (ultrasonic, solid-state methods) have not been commonly used for routine monitoring but can be considered after a proper evaluation.
OPERATION, SERVICE AND MAINTENANCE	
Operation, service and maintenance of the anemometer and wind vanes should in accordance with the INSTRUMENT MANUFACTURER'S OPERATING MANUAL unless otherwise mentioned	
ADDITIONAL EQUIPMENT	
Recommend a spare anemometer as a preventative maintenance measure	
INSTRUMENTATION QA/QC REQUIREMENT	
INTERNAL PERFORMANCE CHECK	Daily
DESCRIPTION: In this application, an internal performance check is defined as a QA/QC procedure carried out by inspecting the wind speed and direction data once per day. These checks are required to remotely assess, in a qualitative sense, performance of the wind speed and direction data measurement and collection system and to ensure adherence to ministry QA/QC requirements and reporting practices	
REQUIREMENT: Wind speed and direction data are to be inspected daily to check for extreme values (e.g., unusually high/low wind speeds, constant wind directions for sustained periods, etc.), or for values which do not appear to agree with forecasted or observed wind conditions. The results of these data checks could suggest anemometer/wind vane failure (damaged anemometer, worn out bearings, missing cups, frozen wind vane, etc.). The results of these checks which could suggest system/equipment problems should be acted on as required and documented for data validation purposes.	

EXTERNAL PERFORMANCE CHECK AND CALIBRATION	Monthly (first level inspection) and at least once a year (second level inspection)
DESCRIPTION: In this application, an external performance check and calibration are defined as a QA/QC procedure carried out by the operator, such as physical inspections of the equipment (monthly), or calibration checks (once per year or as recommended by the manufacturer, whichever comes first). It is highly recommended to change the anemometer every year to prevent failure due to bearing ware.	
REQUIREMENT: The first level of inspection is visual/audio (anemometer and vane can be looked at directly or through binoculars/telescope to check for physical damage or signs of erratic behaviour). The second level of inspection is a "hands on" check which requires removal of the anemometer/wind vane from the tower/mast for further testing/calibration (e.g., bearings replacement, calibration test). Conservatively, technicians should not wait for failures and as part of a preventative maintenance program and it is recommended that they have a spare unit on hand and consider replacing/refurbishing the active unit annually. The calibration equipment must be certified against a reference or equivalent standard, and traceable to recognized national primary standards. The results of the external performance check/calibration must be recorded and the documentation available for inspection and/or submission to ministry to ensure adherence to ministry QA/QC and reporting practices.	
AUDIT	Annually or bi-annually
DESCRIPTION: An audit will be performed by the ministry every one to two years.	
REQUIREMENT: Corrective action (e.g., anemometer and/or wind vane repairs/ replacement, data correction, etc.) will be required by the technician if the audit results show non conformance with acceptable operation, service and maintenance requirements. The corrective action must be recorded and reported to the ministry as soon as practical to ensure adherence to ministry QA/QC and reporting practices.	