NEON PREVENTIVE MAINTENANCE PROCEDURE: SOIL THROUGHFALL COLLECTOR

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See configuration management system for approval history.

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	06/22/2016	ECO-03820	Initial Release
B	09/21/2016	ECO-04165	Changed funnel and screen cleaning frequency from every 3 months to every 2 weeks to prevent blockages. Updated document to latest template.
C	01/04/2018	ECO-05318	Highlighted length of trough outside of collector and specified to leave rodent/debris screens during winterizing. Added Section 6 information and relevant infrastructure and remote monitoring maintenance activities in Section 5. Corrected and updated information and integrated new graphics and formatting. Added an appendix on how to power down a soil plot and a flood event section in Section 5. Reduced infrastructure-leveling requirement from 2 weeks to quarterly in Section 5. Updated Section 2, 3 and 4.
D	09/18/2019	ECO-06235	Clarifying that the soil erosion assessment is determined relative to the initial soil surface height, not sensor height.
E	12/01/2022	ECO-06923	Updated NEON logo and minor formatting fixes

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1 DESCRIPTION

1.1 Purpose

NEON sites host sensors that take measurements on air, water, soil, and sun. Regular maintenance of sensors and infrastructure is necessary for the continued operation of the observatory. It is important to identify small problems before they escalate.

This document establishes mandatory procedures and recommended practices for preventive maintenance of the **Throughfall Collector** to meet the objectives of the NEON project, and its respective stakeholder and end users.

1.2 Scope

Preventive Maintenance is the planned maintenance of sensors and infrastructure with the goal of ensuring that the instrument and/or infrastructure performs correctly to ensure the collection of the best available science, by preventing excess depreciation and impairment. This maintenance includes, but is not limited to, inspecting, calibrating, adjusting, cleaning, clearing, lubricating, repairing, and replacing, as appropriate. The procedures in this document are strictly preventive and do **not** address corrective actions.

This document addresses preventive maintenance procedures to maintain the Met One Tipping Bucket (370 Series), Precipitation Gauge for Throughfall collection (***CF06900000*** *Subsystem, Throughfall, Soil*) at applicable NEON Terrestrial Instrument System (TIS) sites. This includes preventive maintenance procedures and requirements for the Throughfall instrument, subsystem and supporting infrastructures.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

The following applicable documents (AD) contain mandatory requirements and/or supplementary information that are directly applicable to the topic and/or procedures herein. Visit the NEON Document Warehouse for electronic copies of these documents.

AD [01]	NEON.DOC.004300	Environmental, Health, Safety and Security (EHSS) Policy, Program and Management Plan
AD [02]	NEON.DOC.004301	EHSS Environmental Protection Manual
AD [03]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD [04]	NEON.DOC.001436	TIS Comm Interconnect Map
AD [05]	NEON.DOC.000804	Site Flora and Fauna Maintenance Plan
AD [06]	NEON.DOC.00XXXX	Site-specific Flora and Fauna Maintenance Plan
AD [06]	NEON.DOC.000367	NEON Sensor Command, Control and Configuration – Secondary Precipitation – Tipping Bucket
AD [07]	NEON.DOC.002490	Assembly, Secondary Precipitation Non-Heated
AD [09]	NEON.DOC.000769	Electrostatic Discharge Prevention Procedure
AD [09]	NEON.DOC.000864	NEON Installation Procedure: Soil Throughfall Collector
AD [10]	NEON.DOC.004454	Soil Throughfall Formal Verification Procedure
AD [11]	NEON.DOC.000779	TIS Soil Plot Layout

2.2 Reference Documents

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document.

RD [01]	NEON.DOC.000008	NEON Acronym List
RD [02]	NEON.DOC.000243	NEON Glossary of Terms
RD [03]	NEON.DOC.004257	All Systems Standard Operating Procedure: Decontamination of Sensors, Field Equipment, and Field Vehicles
RD [04]	NEON.DOC.002768	TIS Subsystem Architecture, Site Configuration and Subsystem Demand by Site - SCMB Baseline
RD [05]	NEON.DOC.004637	TIS Verification Checklist
RD [06]	NEON.DOC.000769	Electrostatic Discharge Prevention Procedure

2.3 External References

External references contain information pertinent to this document, but are not NEON configuration-controlled. Examples include manuals, brochures, technical notes, and external websites.

ER [01]	Met One Instruments, Inc. Rain. 370-380 Precipitation Gauges. *http://metone.com/meteorological-sensors-systems/rain/370-380/*

2.4 Acronyms

Acronym	Description
A/R	As Required
AC	Alternating Current
BONA	Caribou Creek – Poker Flats Watershed
CPER	Central Plains Experimental Range
Comm	Communication
LC	Location Controller
NA	Not Applicable
JSA	Job Safety Analysis
NOAA	National Oceanic and Atmospheric Administration
OCS	Office of Coast Survey
P/N	Product Number or Part Number
PoE	Power over Ethernet
QLS	Quantum Line Sensor
SP	Soil Plot
TALL	Talladega National Forest
V	Volts

2.5 Terminology

The use of common names for NEON instrumentation and subsystems vary across departments and domains. This section aims to clarify and associate the common names with the technical names herein. The aim of this section is to marry up terms under one name so Technicians are aware of the component referenced in the procedures herein, but also aware they may be called another term in a group discussion with headquarters or training staff.

SYNONYMOUS COMMON NAME(S)	NEON TECHNICAL REFERENCE NAME
Power Box, Comm Box, National Electrical Manufacturers Association (NEMA) Enclosure, Power/Comm Infrastructure, Combo Box, Arbor	**Device Post**
Tipping Bucket, Rain Gauge, Precipitation Collector, Tipping bucket on the tower	**Secondary Precipitation Gauge**
Tipping bucket in the soil plot, soil tipping bucket, soil precipitation gauge	**Throughfall Collector**
Throughfall Sensor, tipper	**Tipping Bucket or Mechanism**

3 SAFETY AND TRAINING

Personnel working at a NEON site must be compliant with safe fieldwork practices in AD [01] and AD [02]. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop work in unsafe conditions.

All technicians must complete safety training and procedure-specific training to ensure the safe implementation of this protocol per AD [03]. Refer to the site-specific EHSS plan via the NEON Safety document portal for electronic copies.

Preventive maintenance of TIS Soil Arrays may require the use of a special equipment to access the sensor subsystem assemblies. Follow Domain site-specific EHS plans via the Network Drive and NEON safety training procedures when conducting maintenance activities. Conduct a Job safety Analysis (JSA) prior to accessing the sensor subsystems onsite. Reference the Safety Office SharePoint portal for JSA templates and additional hazard identification information.

In the event the current method to conduct the procedures herein are no longer safe for use due to unforeseen or unknown site dynamics, consult with the NEON Safety Office via the NEON Project's Issue Management and Reporting System (i.e., JIRA or ServiceNow) for alternative methods to conduct TIS preventive/corrective maintenance and Sensor Refresh procedures.

4 SENSOR OVERVIEW (SENSORS ONLY)

4.1 Description

The NEON project has Throughfall Collectors across the continental and non-continental TIS sites to collect precipitation measurements through a variety of plant canopies. Throughfall is precipitation that passes through a plant canopy and travels straight to ground. Factors such as plant leaf and stem density, type and intensity of precipitation and duration of a precipitation event influence throughfall. It is an important component of an ecosystem's hydrology. In some ecosystems, throughfall changes rates of erosion by influencing sizes/speeds of water droplets reaching the soil surface. Local plant canopy has a high spatial variability across ecosystems (e.g., forest gaps and dense vegetation patches), which leads to variability in throughfall within an ecosystem. Each TIS site contains five soil plots to capture multiple measurements within the same ecosystem to estimate accurate rates of throughfall precipitation. There are typically five throughfall collectors per Core TIS site and four throughfall collectors per Relocatable TIS site.

The ideal throughfall precipitation measurement occurs on the soil surface; however, due to infrastructure constraints, NEON maintains the collector above the soil surface. The throughfall collector assembly has a maximum height of <0.5 m, which is a sufficient measurement level if the plant canopy surface area is above the collection area. Sites with grassland, desert, and tundra ecosystems consist of a plant canopy that is primarily below a collection area. As a result, these sites either do not have a throughfall collector or have one prior to the change in science requirements for the throughfall collectors at TIS sites.

The throughfall collector consists of a precipitation gauge (tipping bucket mechanism) within a protective housing that connects to four angled collection troughs (**Figure 1**). The tipping mechanism within the throughfall assembly is the same precipitation gauge sensor in the secondary precipitation unheated assembly.

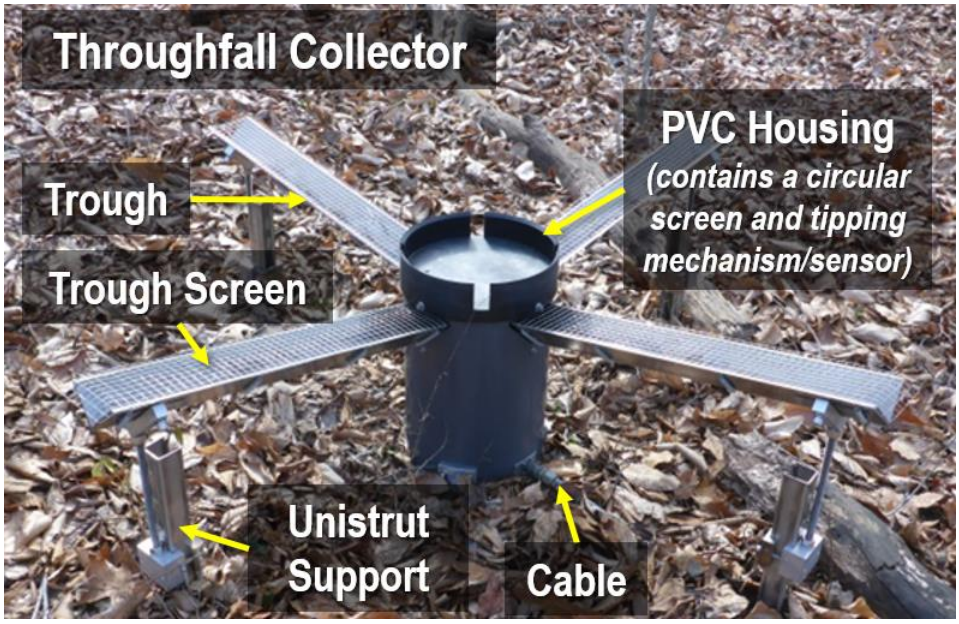

Figure 1. Throughfall Exterior Components.

The throughfall collector subsystem consists of the following components (**Figure 1** and **Figure 2**):

- Precipitation Gauge (unheated)
- PVC Collector Housing
- Troughs with Screens, Screen Clips & Springs and Unistrut supports (4x)
- Merlot Grape (12V) Data Logger

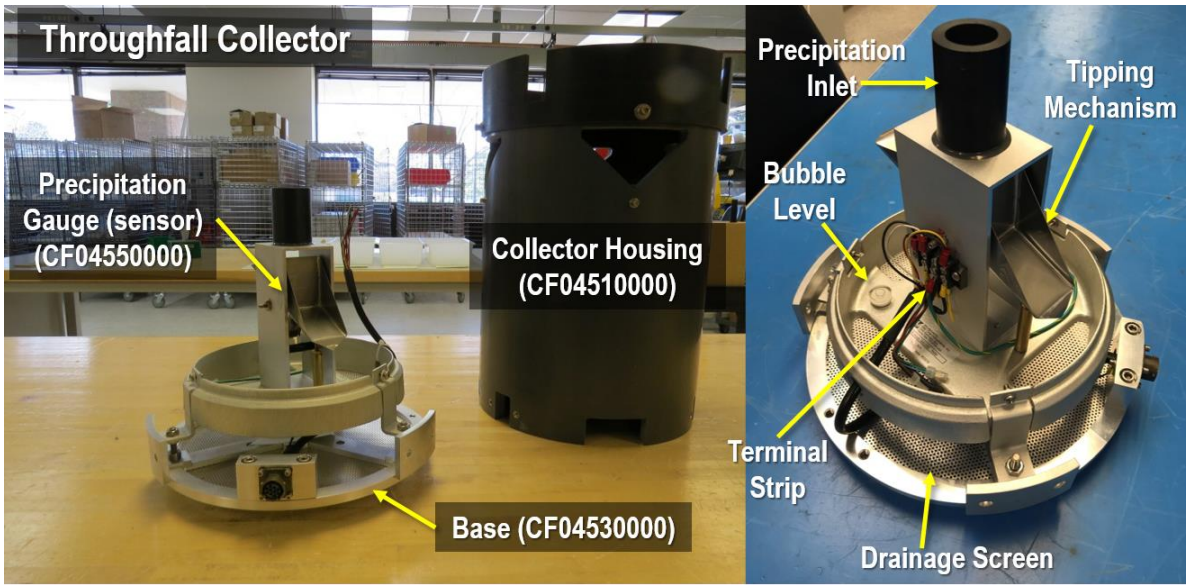

Figure 2. Throughfall Internal Components.

As of the date of Revision C, TIS sites maintaining throughfall collectors are in the process of receiving and installing screen retrofit kits (***CF04500010*** *Kit, Perforated Exclusion Screen*) to prevent

rodents/insects from seeking refuge in the collector housing via the troughs. **Figure 3** displays a retrofit kit (***0362330000*** *Screen, Exclusion, Perforated, Throughfall Collector*).

Figure 3. 0362330000 Screen, Exclusion, Perforated, Throughfall Collector.

This modification requires removing the collector-housing cap to access the troughs for screen installation, and to access the collector and tipping mechanism for preventive maintenance and/or annual sensor refresh.

4.2 Sensor Specific Handling Precautions

4.2.1 Instrument

The tipping bucket mechanism within the gauge is sensitive to impacts or shocks. Shocks or impacts can damage the tipping mechanism bearings, and may result in inaccurate measurements. Employ care to secure the buckets from tipping during inter- and intra-site transportation.

The tipping bucket must maintain vertical orientation during shipping and handling. If a sensor is found on its side or falls on its side, the sensor tipping mechanism bearing requires an on-the-spot evaluation to ensure proper bearing operation (the bucket should tip freely with a slight amount of play and remain aligned in the sensor housing).

When conducting onsite maintenance, do not remove the external housing of the sensor assembly during a precipitation event. Wait for a dry day or bring the entire assembly inside to dry off before proceeding with any maintenance activities.

4.2.2 Subsystem

Grapes contain ESD sensitive parts; therefore, all Grapes require ESD (antistatic) packaging and handling during inter- and intra-site transport, reception, and storage. As a rule, when handling (installing,

removing, and servicing) these electrical components, all Technicians must ground themselves. Reference AD [09]. Conduct Lockout/Tagout (LOTO) procedures to disable machinery or equipment to prevent the release of hazardous energy while performing service and maintenance activities.

4.3 Operation

The throughfall collector troughs direct liquid precipitation to the tipping bucket sensor. Within the sensor, water gathers in a two-sided tipping bucket (**Figure 2**) until it reaches a set amount that causes the container to tip, which creates a data stream recorded by the Location Controller (LC). Since a tip corresponds to a known quantity of water, this quantity multiplied by the summation of tips for a set time produces a total for the precipitation throughfall. After the tip, the water exits the sensor via drainage holes seen at the bottom of the sensor.

In order to have consistent throughfall measurements over time, it is important to maintain the collection area at a constant configuration. In practice, this means FOPS must maintain the troughs at the same angle per site-specific requirements to ensure the collection area is constant over time.

Note: Reference site-specific As-Built documentation to verify Throughfall assemblies at your site via the NEON Document Warehouse.

Mesh screens sit over the troughs during the non-snowy seasons (i.e., when solid precipitation is most likely to occur) to minimize the risk of debris clogging the inlets and reduce the buildup of contamination. The entire assembly is unheated to allow solid precipitation to accumulate in the troughs and melt once the environment reaches ambient temperatures. This enables the throughfall collector to measure solid precipitation as liquid precipitation. The measurement of solid throughfall precipitation is prone to greater collection uncertainties, such as wind impacts on snow accumulation on the assembly and differences in the timing of melting of snow on the assembly versus the surrounding snowpack.

5 INSPECTION AND PREVENTIVE MAINTENANCE

5.1 Equipment

Table 1. Equipment needed for Preventative Maintenance.

Item No.	Description	Quantity
Tools		
	7/16” Open End or Box Wrench	2
NEON, IT	NEON Laptop	1
	3/16” Allen Driver	1
MX109104	Level that can measure angles with ±1° accuracy (e.g., 10° from horizontal)	1
	Camera	1
	Spray Bottle filled with deionized or distilled water	1
	Channel Locks	1
Consumable items		
GENERIC	Lint free cloth	20
GENERIC	Cotton swabs	20
GENERIC	Sharpie Marker/Paint Pen	1
Resources		
	Terminal Emulator Program (TEP) (i.e., PuTTy, MobaXterm, other SSH/Telnet client)	

5.2 Subsystem Location and Access

All the sensors within the soil plots are making measurements of the environment immediately surrounding them. **Figure 4** provides an example of a soil plot in Domain 10 at the Central Plains Experimental Range (CPER) TIS site. (This site does not have a canopy and no longer uses a throughfall collector; however, this provides graphical overview of all soil plot sensors that reside at TIS sites.)

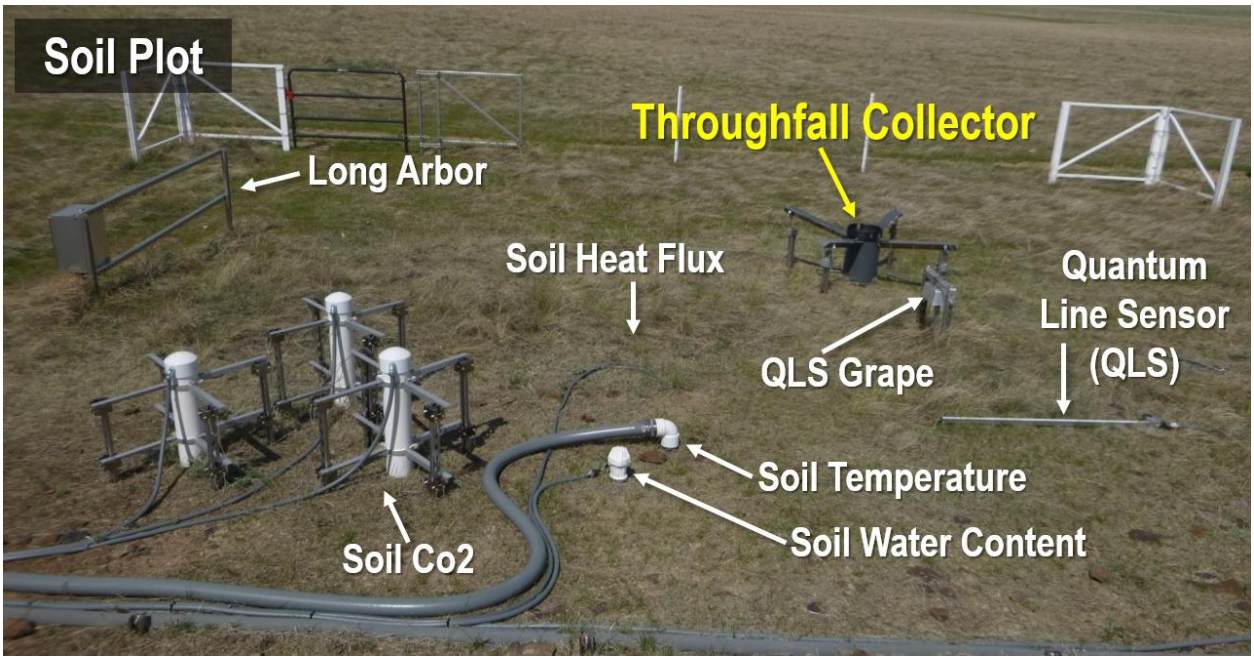

Figure 4. Soil Plot 1 (Domain 10, CPER) with Cattle Fencing (Not Shown: Device Post, Short Arbor, HMP and NRO1).

It is important that FOPS does not disturb the soil plot and surrounding area while conducting maintenance activities. The NEON project headquarters (HQ) recommends grouping sensor maintenance activities together to minimize influencing the surrounding area and reduce FOPS ecological footprint in each plot. Minimize the amount and frequency of trips in and out of each plot and surrounding area as much as possible.

Access to the soil plots shall follow the designated route that was established during site construction. Typically, this route starts at the staging area and follows a clearly marked path that passes the instrument hut before reaching the soil array path. The NEON project only permits foot traffic between the soil array path and each soil plot (i.e., no wheeled carts or other machinery), with the exception of equipment to perform maintenance to meet the conditions specified in the Flora and Fauna plans in AD [06] and AD [07]. For example, a rototiller to mimic plowing at an arable site.

Important: Once Technicians reach the device post at the relevant soil plot, they must walk towards the soil plot following the route of the conduit from the device post to the soil plot arbor remaining at least 1m (~3.3') outside of the soil plot at all times (see **Figure 5**). Always travel the shortest route towards the assembly that remains at least 1m outside of the soil plot.

Remain at least 1m outside of the plot unless maintenance activities requires close contact with a sensor. When approaching a soil plot, do not step or place tools on the ground within 30cm (~1') of any sensors within the soil plot to minimize disturbance to the soil and vegetation surrounding the sensor.

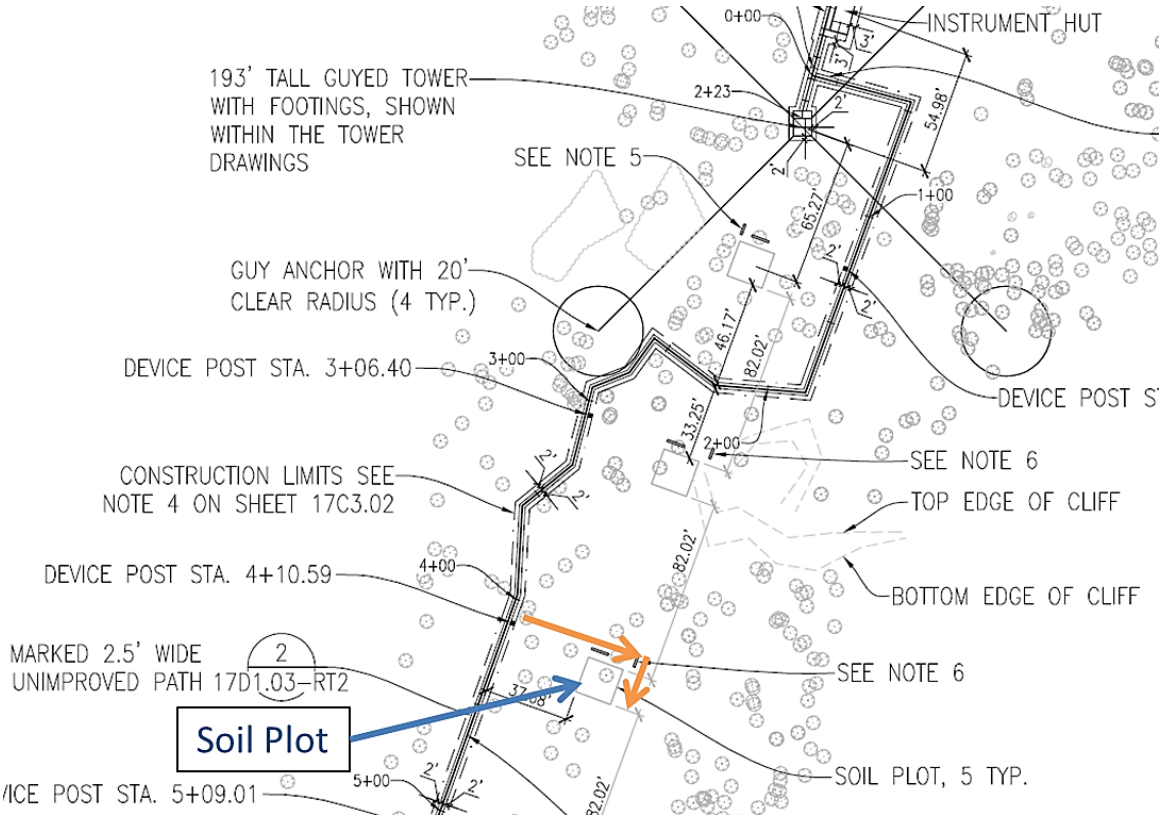

Figure 5. Walking Route Example Orange Arrows) From the Soil Array Path to A Soil Plot (D17 SOAP Civil Construction).

The throughfall collector is in the "Throughfall Section" of a TIS soil plot (reference AD [11]). Depending on the site, up to five throughfall collectors reside in the soil array, with up to one collector per soil plot. The throughfall collector is visible within each soil plot (**Figure 4**).

5.3 Maintenance Procedure

Table 2. Throughfall Maintenance Intervals.

Maintenance		Bi-weekly	Quarterly	Bi-Annual	Annual	As Needed	Type
Throughfall Collector							
	Remote Monitoring	X				X	P
	Visual Inspection	X				X	P
	Infrastructure (Trough, Screen, and Collector) Cleaning	X				X	P/R
	Infrastructure (Trough, Screen, and Collector) Leveling		X			X	P/R
	Sensor (Tipping Mechanism) Leveling & Cleaning	*X*	X			X	P/R

Maintenance		Bi-weekly	Quarterly	Bi-Annual	Annual	As Needed	Type
	Apply Anti-Seize		X				P
	Removal & Replacement of Trough Screens for Snowpack			X*			P
NOTE: The biweekly and annual inspections should be carried out regardless of whether they coincide or not. P = Preventive, R = Repair, X = Indicates preventive maintenance task time interval may increase due to environmental (season/weather) or unforeseen/unanticipated site factors. ***See Table 5.**							

5.3.1 Remote Monitoring

Verify TIS soil sensors are sending data to HQ via the SAS Report. For throughfall data streams that are missing/red via SAS, conduct a real time verification of each missing/failed data stream to double check if the data streams are online, but failing to transmit data streams to HQ. For the throughfall, data streams are present when the tipping mechanism is collecting live samples (**data streams do not show up unless the sensor is active during a weather event – only as it "tips"**). Otherwise, look up to view if the subsystem components have power. Conduct this check using a Terminal Emulator Program (TEP), such as PuTTy or MobaXterm, to connect to each Merlot Grape in the soil array. The data state of health presents indicators to focus preventive maintenance efforts; anomalies in the data or if the throughfall is off the network, it may dictate preventive maintenance tasks for investigation to determine if onsite corrective action is necessary. Use the Grape MAC address/Sensor EPROM ID with the command prompts in **Table 3**.

PRO TIP: *To perform these functions, Technicians must acquire the Grape MAC address and/or the EEPROM ID (from Maximo) of the sensor. Use this to verify function of Grapes and Sensors post-Sensor Refresh, too. Reference these from site sensor mapping documents and update these documents accordingly to have relevant information on hand.*

PuTTy Login Username: **user** | Password: **resuresu**

Table 3. View Grape and Sensor Data Streams (MAC and EPROM ID are Examples for this Command).

PuTTy Commands	Description
`vd | grep [MAC address]`	This displays the data from the grape with the MAC Address entered (e.g., using "7CE0440015FD"). Enter either in decimal or hexadecimal format. Use "**grep –i**" to ignore case.
`vd –s [sensor eeprom id]`	To view data from a sensor. For example "root@D23-HQTW-LC1:~# vd -s 3171982"
`vd –s [sensor eeprom id] –r [stream number]`	To view data from a sensor and specific data stream.

5.3.2 Visual Inspection

Conduct a bi-weekly visual inspection on the throughfall collector assembly and subsystem. Conduct following maintenance inspections.

Note: Do not stand or place tools on the ground closer than 30 cm (~1 foot) from the edge of the sensor location or any other sensor within the soil plot. Stand outside of the soil plot and observe the throughfall assembly unless you need to get closer to perform this task.

1. Inspect the assembly for noticeable soil erosion around the base where precipitation drains from the tipping mechanism every 2 weeks.

    a. If soil erosion around the throughfall collector is ≤5 mm deep relative to the initial soil surface (e.g., based on nearby soil that appears unaffected), do nothing.

    b. If soil erosion >5 mm relative to the initial soil surface, submit a ticket in the NEON project issue management system for science evaluation to determine corrective actions, if necessary. Photograph the erosion for the trouble ticket to enable a quicker evaluation response.

*Note: If snow or standing water is present, **DO NOT** perform this check.*

2. Visually inspect the assembly exterior. This includes the infrastructure (Unistrut supports), base (drain area) and subsystem (Merlot Grape and Cable) to determine if it is free from debris and plants every 2 weeks.

    a. Plants, including standing dead plants, that are simply touching part of the assembly, do not require any action. However, plants that appear to be at least partly dependent on the assembly for support (i.e., if the assembly was absent the plant would not be in its current position), should be gently moved unless this would disturb snow or ice accumulation in the troughs.

    a. If no debris or plants are present, do nothing.

    b. If debris or plants are present, are they directly above at least one of the troughs (i.e., likely affecting precipitation collection)?

        i. If no, remove the debris and place it as close as possible to the location where it would have fallen had the assembly not been present, as long as this location does not cause the debris to partially block a trough. For climbing plants that have attached to any parts of the assembly, detach and/or unwind them from the assembly as gently as possible (i.e., minimizing damage to the plant) so that they are no longer supported by the assembly.

ii. If yes, would removing the debris affect any snow or ice accumulation in the troughs?

1. If no, take a photo showing the debris and partially covered trough. If possible, the photo should be taken from directly above the affected trough to give an indication of the proportion of the collection area that was affected. Then remove the debris and place it as close as possible to the location where it would have fallen had the assembly not been present, as long as this location does not cause the debris to still partially block the trough. Submit a JIRA ticket including a description and photo of the affected area for TIS data quality reference.

2. If yes, take a photo showing the debris and partially covered trough if this can be achieved without affecting the snow or ice within the troughs. Leave the debris in place until it can be removed without affecting the snow or ice in the trough. Submit a JIRA ticket including a description and photo (if possible) of the affected area. Update the JIRA ticket once the debris has been removed for TIS data quality reference.

5.3.3 Infrastructure Leveling and Cleaning

Conduct the following procedure to level and clean the Throughfall Collector assembly.

1. Power down the sensor assembly. De-energize the entire Soil Plot Device Post per Appendix A – Power Down A SOIL PLOT Power Box and/or disconnect the RJF cable of the Merlot (12V) Grape (**Figure 6**) that powers the throughfall sensor before proceeding.

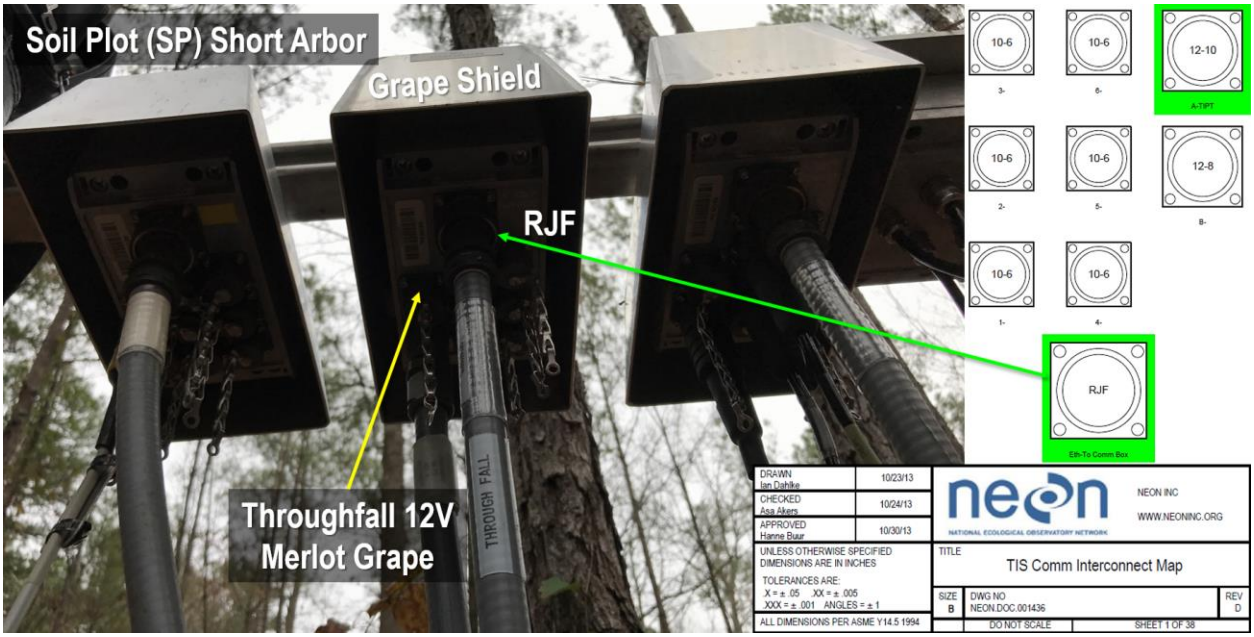

Figure 6. Throughfall Collect Merlot (12V) Grape (AD [04]).

5.3.3.1 Infrastructure Cleaning Procedure

Check for any debris (foliage, bugs, etc.) accumulation in the screens or trough collectors. Remove large pieces of debris that may cause blockages in the assembly.

Note: If snow or ice is present within the trough, skip this step until it melts.

If debris/dirt accumulation is present in the collector or on screens, conduct the follow steps to clean the Throughfall Collector:

Figure 7. Remove Screens to Clean Collector.

1. Power down the system when cleaning the collector area to prevent the tipping mechanism from collecting measurements from debris and/or DI water triggering the tipping mechanism. *Reference Section 8 Appendix A – Power Down A SOIL PLOT Power Box or remove the RJF Cable from the Throughfall 12V Merlot Grape. Employ ESD protocols per RD [06].*

2. Remove the troughs to remove the collector screens under the cap. *Reference* ***Table 4. Throughfall Collector Infrastructure Removal****.*

3. Remove the screen clips, springs, and screens (**Figure 7** and **Figure 8**).

Figure 8. Remove Trough Screen Clips.

4. Carefully clean the screens separately with distilled or DI water and a lint-free cloth.
5. Place a dry lint-free cloth immediately downslope of the area to be cleaned to soak up any excess moisture.
6. Spray the debris and surrounding area in the trough with distilled or deionized water allowing it to soak in and loosen the material.
7. Continue spraying with distilled or deionized water, attempting to loosen and remove the debris with the water. Replace the downslope cloth with a fresh cloth if it becomes saturated.
8. If the material remains, use a lint-free cloth to aid in loosening and removing the debris. Use only gentle pressure and continue spraying with water.
9. Once the collector is free of dirt and debris, rinse the collector thoroughly with distilled or deionized water while soaking up the rinse water.
10. Dry components with a lint-free cloth and reassemble.
11. Return power to the sensor.

5.3.3.2 Infrastructure Leveling Procedure

1. Check that the trough slope is correct quarterly, after significant weather events and post-Sensor Refresh. *Skip this step if this cannot occur without disturbing snow or ice in the trough.*
    a. Hold a digital level along the underside of each trough to determine if the angle of the trough towards the sensor is 10° ±1° above horizontal (**Figure 9**).

i. If yes, do nothing.

ii. If no, submit a ticket in the NEON project Issue Management and Reporting System with a description specifying the soil plot number, the angle of the trough(s) relative to horizontal, and the number of troughs out of angle for TIS data quality reference.

2. Check that the trough angle is correct quarterly, after significant weather events and post-Sensor Refresh. *Skip this step if this cannot occur without disturbing snow or ice in the trough.*

    a. Place a digital level across each trough (i.e., from one side of the trough to the other) to determine if the trough collection opening is horizontal ±1° (**Figure 9**).

        i. If yes, do nothing.

        ii. If no, submit a ticket in the NEON project Issue Management and Reporting System with a description specifying the soil plot number, the angle of the trough(s) relative to horizontal, and the number of troughs out of angle for TIS data quality reference.

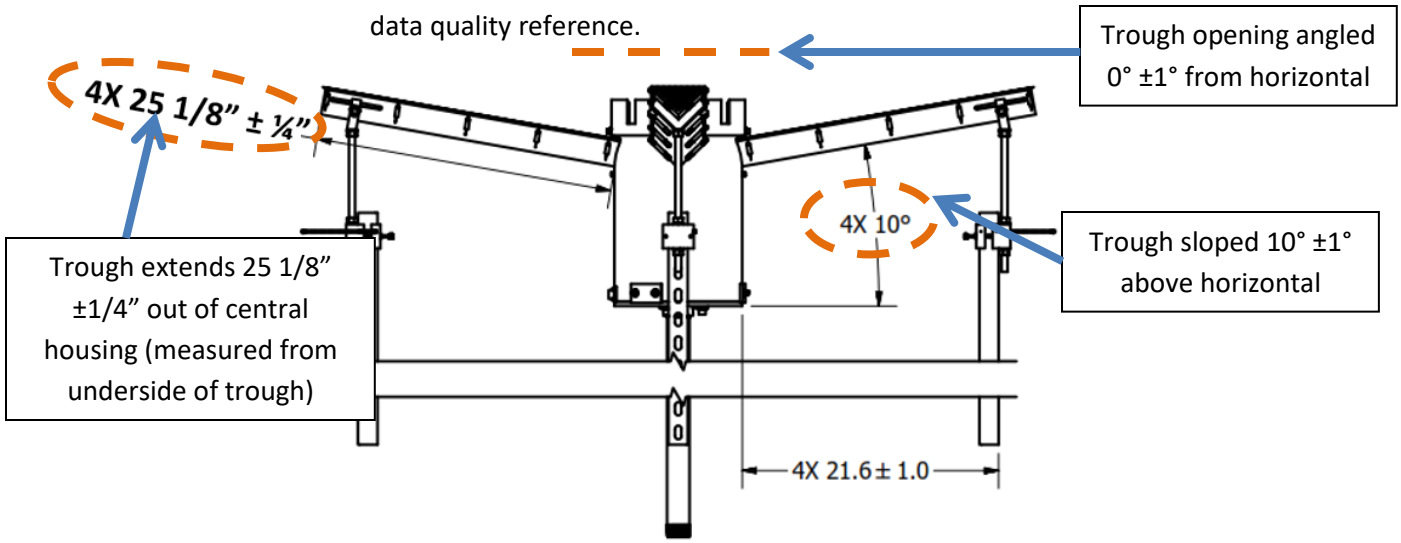

Figure 9. The troughs should be angled 10° above horizontal towards the sensor and the trough opening should be horizontal.

3. Check that the sensor housing is level ±5° quarterly, after significant weather events and post-Sensor Refresh. If the housing is free of snow and ice, do this by placing a level on the top of the housing. If snow or ice is present on the housing, visually judge whether the housing appears level.

    a. If level ±5°, do nothing

b. If not level ±5°, submit a ticket in the NEON project Issue Management and Reporting System specifying the soil plot number of the sensor, and angle of the housing (approximate, if based on visual assessment), and a photo.

Proceed to other co-scheduled maintenance tasks. If this is the final task, conduct the following actions:

4. Carefully reinstall screens. Ensure both sit flat before re-inserting the retaining clips or springs.

5. Reconnect all cables. Connect the RJF cable to the Merlot Grape last. Re-energize the site by flipping the breakers on the device post. Employ ESD protocols per RD [06].

PRO TIP: Mark the location of the troughs where they meet the Collector housing cap post-leveling/alignment with a sharpie marker or paint pen to conduct visual checks from farther away to monitor alignment in between quarterly leveling verification and enable a quick re-assembly of these components.

5.3.4 Sensor Leveling and Cleaning

This section addresses the Met One Tipping Bucket (370 Series), Precipitation Gauge (tipping mechanism inside the Throughfall Collector).

5.3.4.1 Sensor Leveling Procedure

1. Measure the level across the top of the collector body (find #10 in **Figure 10**). Determine whether the throughfall collector body and tipping bucket sensor is level ±2° in horizontal orthogonal directions by placing a digital level across the tipping bucket top opening.
    i. If yes, do nothing.
    ii. If no, submit a ticket in the NEON project Issue Management and Reporting System with a description specifying the soil plot number and the angle of the sensor for TIS data quality reference.

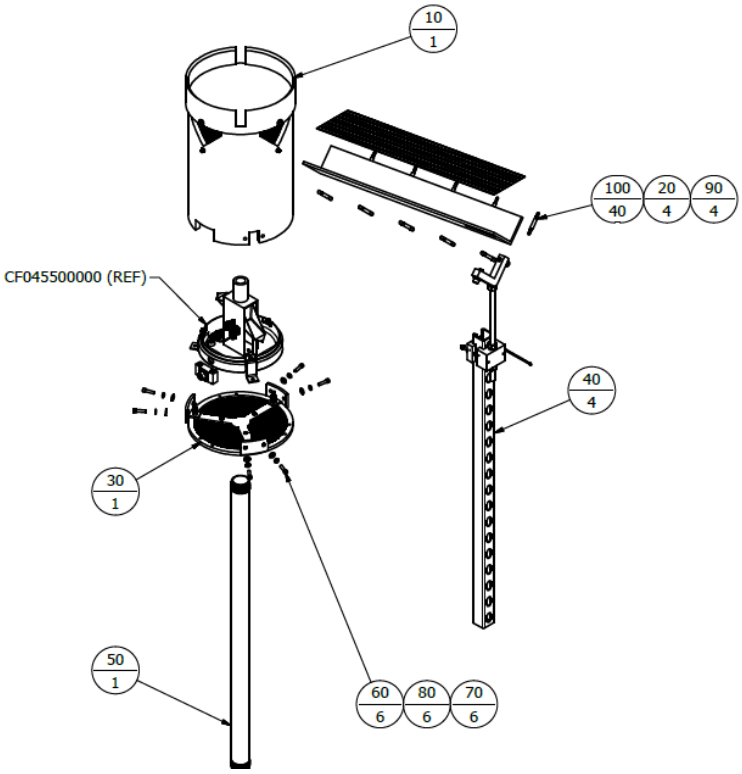

Figure 10. Exploded View of Throughfall Collector Assembly.

Note: Apply anti-seize to the ¼-20 Screws (Find 60 in Figure 10) quarterly.

5.3.4.2 Sensor Cleaning Procedure

If the troughs and housing are free of snow and ice, verify the sensor is clean every 2 weeks. *If snow or ice is present within the troughs, wait until it melts before performing this check. Reference **Table 4** to remove the sensor infrastructure to access the Throughfall tipping bucket/mechanism.*

Table 4. Throughfall Collector Infrastructure Removal.

STEP 1 | Power down the sensor assembly. De-energize the entire Soil Plot Device Post per Appendix A – Power Down A SOIL PLOT Power Box and/or disconnect the RJF cable of the Merlot (12V) Grape (**Figure 6**) that powers the Throughfall sensor before proceeding.	
 **Figure 11.** Remove Housing Cap.	**STEP 2** | Remove the sensor cap to access the Collector interior screens and perforated exclusion screens by removing the four retaining screws with a 3/16" allen driver (**Figure 11**). These screws use rubber washers (remember this for reinstallation). Remove the housing cap by lifting it up. *PRO TIP: Use the throughfall housing cap as an informal bucket for small tools and parts when conducting direct maintenance on the throughfall sensor. Place this 30cm away from the sensors when conducting maintenance inside a soil plot.*
 **Figure 12.** Remove Four Perforated Exclusion Screens.	**STEP 3** | Remove the four perforated exclusion screens and clips from the troughs (**Figure 12**). *PRO TIP: Use channel locks to tighten these screen clips if they loosen over time.*

Figure 13. Remove Four Troughs.

STEP 4 | Remove the four troughs leading into the collector. Remove by loosening the two screws securing the troughs to the Unistrut supports using ¾" allen wrench (**Figure 13**).

PRO TIP: Use anti-seize and hand tighten only for easier removal of the troughs from the supports.

Important: Do *not* place the troughs within 30cm of any other sensor in the soil plot.

Figure 14. Remove Screen Clips to Remove Screen from Troughs.

STEP 5 | The screens do not require removal for this procedure; however, in the event the screens require additional cleaning or are using this table to clean the screens (and/or conduct sensor refresh on the sensor), remove the three screen springs to remove the screen from each trough (**Figure 14**).

Figure 15. Remove Collector Body from Sensor Base.

STEP 6 | Remove the collector body from the sensor base. Remove six screws at the base of the Throughfall (**Figure 15**) and lift straight up.

Lift the housing base up and set it aside 30cm away from other sensors in the soil plot.

After removing the throughfall housing from the base, clean the collector and tipping bucket.

1. Reference Section 5.3.3 to clean the Collector. If dust or debris are present in the collector, trough and/or screens visually inspect the tipping mechanism (**Figure 16**). The amount of debris accumulation in the infrastructure may act as potential early warning indicator or warning indicator that the tipping mechanism requires cleaning.

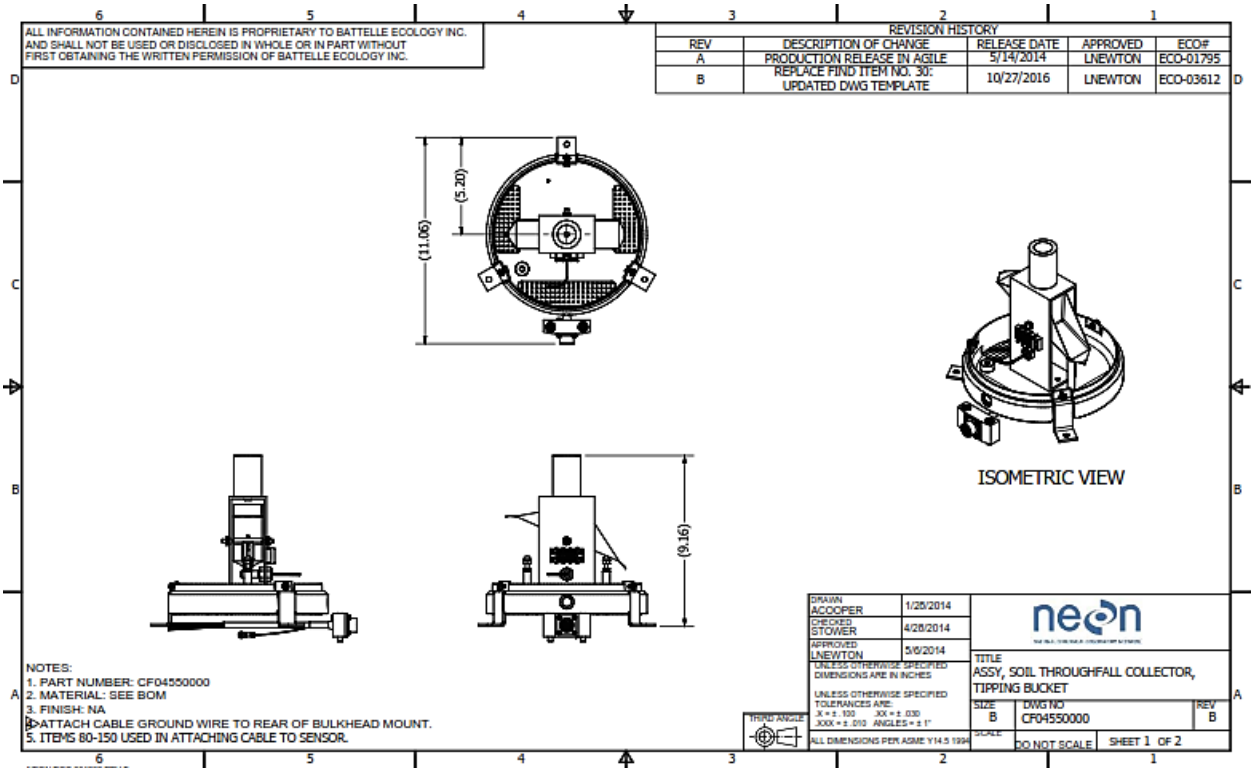

Figure 16. Inspect Tipping Bucket & Mechanical Tipping Mechanism.

2. Remove any loose debris from the tipping mechanism and from the inside of the sensor. If any material is stuck to the tipping mechanism, conduct the following cleaning procedures:

   a. Spray a small amount of distilled or deionized water inside one of the tipping buckets allowing it to "soak in" and loosen the debris.

   b. Use a cotton swab to aid in loosening and removing the debris. Use only gentle pressure and continue spraying with water.

   c. Once the tipping bucket is clean, dry with a lint-free cloth.

   d. Repeat for the second bucket.

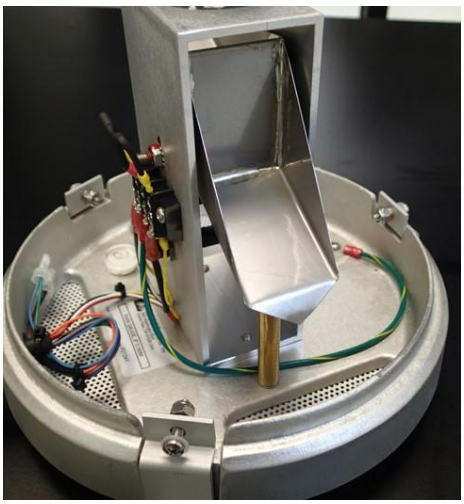

Figure 17. Tipping Bucket Tipping Mechanism.

3. Inspect and test the mechanical operation of tipping mechanism (i.e., the bearing integrity) and inspect for corrosion (see **Figure 17** for an up-close picture of the tipping mechanism).

4. **VERIFY POWER IS OFF FOR THIS STEP.** Inspect electrical connections are snug (using a #2 Philips head on all the terminals in **Figure 18**).

    a. Visually inspect for evidence of corrosion on any of the terminals.

5. Apply anti-seize compound to the six ¼-20 screws that connect the body to the base before re-assembling, quarterly.

    b. Torque all six screws to 1/6 turn past finger-tight with an allen wrench.

6. Reassemble the throughfall assembly using the reverse order of **Table 4**.

7. Reconnect all cables. Connect the RJF cable to the Merlot Grape last. Re-energize the site by flipping the breakers on the device post.

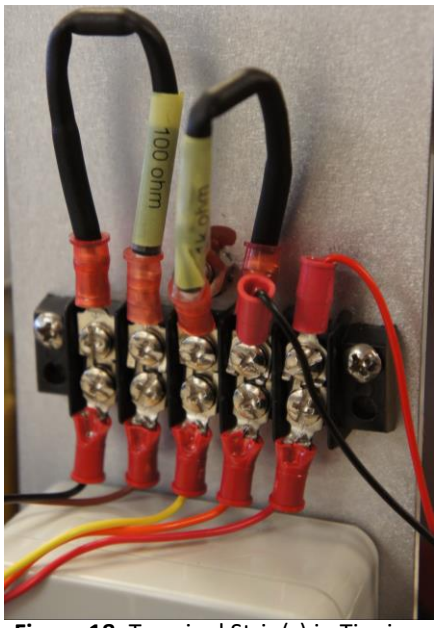

Figure 18. Terminal Strip(s) in Tipping Bucket.

5.3.5 Throughfall Winterization Requirement

5.3.5.1 Removal and Replacement of Trough Screens

At TIS sites that regularly receive snow, remove the mesh screens that cover each trough within one week of the start of the local area snow season, if the troughs are free of snow or ice at this time. ***Do not remove the perforated extrusion screens.*** **Figure 19** displays the screens requiring annual removal/re-installation.

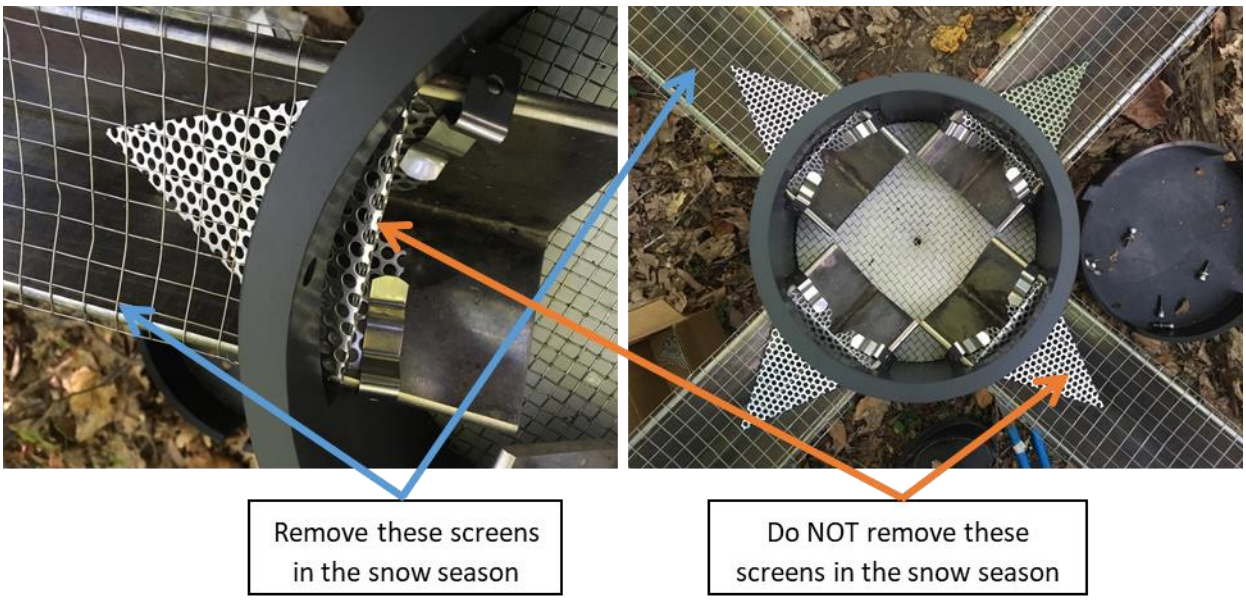

Figure 19. Remove Trough Screens, Not Perforated Extrusion Screens for Snowpack/Ice.

The purpose of removing the trough screens is to allow snow to accumulate directly inside the troughs and to minimize losses due to wind blowing away snow that would have otherwise accumulated on top of the mesh screens. However, it is understood that instances will exist where snowfall occurs while the screens are still in place, and that even with the screens removed, measurements may still incur losses due to wind, particularly as snow depth on top of the trough increases. **Table 5** contains dates to remove and re-install the screen based on the National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey (OCS) median date of first and last measurable snowfall. Use **Table 5** to estimate monitoring timeframes in conjunction with local weather patterns to determine the best timeframe to remove the screens.

PRO TIP: Remove the Secondary Precipitation screens on the tower and/or at nearby Aquatic sites at the same time.

Table 5. Throughfall Trough Screen Removal/Reinstallation Dates.

Domain	Site	Removal Date	Reinstallation Date
1	BART	8-Nov	8-Apr
1	HARV	8-Dec	23-Mar
2	SCBI	8-Dec	8-Mar
2	SERC	23-Dec	14-Feb
2	BLAN	8-Dec	8-Mar
3	OSBS	NA	NA
3	DSNY	NA	NA
3	JERC	NA	NA
4	GUAN	NA	NA
4	LAJA	NA	NA
5	UNDE	8-Nov	8-Apr

Domain	Site	Removal Date	Reinstallation Date
5	TREE	8-Nov	8-Apr
5	STEI	8-Nov	8-Apr
6	KONZ	8-Dec	8-Mar
6	KONA	8-Dec	8-Mar
6	UKFS	8-Dec	8-Mar
7	ORNL	31-Dec	14-Feb
7	GSNP	23-Dec	14-Feb
7	MLBS	8-Dec	8-Mar
8	TALL	NA	NA
8	DELA	NA	NA
8	LENO	NA	NA
9	WOOD	1-Nov	8-Apr
9	DCFS	1-Nov	8-Apr
9	NOGP	1-Nov	8-Apr
10	CPER	15-Oct	23-Apr
10	STER	8-Nov	8-Apr
10	RMNP	15-Oct	23-Apr
11	CLBJ	31-Dec	14-Feb
11	OAES	23-Dec	14-Feb
12	YELL	8-Nov	8-Apr
13	NIWO	15-Oct	23-Apr
13	MOAB	23-Nov	8-Apr
14	SRER	NA	NA
14	JORN	23-Dec	14-Feb
15	ONAQ	23-Nov	8-Apr
16	WREF	8-Dec	14-Feb
16	ABBY	8-Dec	14-Feb
17	SJER	NA	NA
17	SOAP	23-Nov	8-Apr
17	TEAK	8-Nov	23-Apr
18	TOOL	8-Sep	15-Jun
18	BARR	23-Sep	15-Jun
19	HEAL	5-Oct	25-Apr
19	DEJU	5-Oct	25-Apr
19	BONA	5-Oct	25-Apr
20	PUUM	NA	NA

Note: Dates are subject to change as additional insight on weather patterns are experienced.

Submit a ticket in the NEON Issue Management and Reporting System to notify Science of the actual removal and reinstallation dates using information from **Table 5** and local weather forecasts applicable for each TIS site requiring removal/reinstallation. Provide a brief justification if the removal/reinstallation date varies by a week. Include the local weather report/forecast in the ticket.

5.4 Throughfall Flood Event Requirements

For TIS sites with throughfall collectors that are subject to predictable flood events, remove the throughfall collector, its Grape and Cables. The Tipping Bucket/Mechanism is not waterproof.

1. Submit a ticket in the NEON project Issue Management and Reporting System to inform HQ staff of a flood event affecting a TIS site for data quality purposes and to resolve any unanticipated issues with the removal process.

2. Power down Soil Array. *Reference Section 8 Appendix A – Power Down A SOIL PLOT Power Box.*

3. If the flood event is for a short duration (within a biweekly visit):

    a. Cap the Grape connections and Cables and leave them onsite.

    b. Drape Cables a few feet above the anticipated flood level.

    c. Remove the throughfall collector housing, tipping mechanism and troughs. Reference **Table 4.** Throughfall Collector Infrastructure Removal.

    d. The Unistrut supports may remain.

4. If the flood event is over a long duration (over a month):

    a. Cap the Grape connections and remove the Grape form the Arbor. Follow ESD protocols per RD [06] for handling and transporting Grapes.

    b. Cap and coil the Cables to store them at the Domain office.

    c. Remove the throughfall collector housing, tipping mechanism and troughs. Reference **Table 4.** Throughfall Collector Infrastructure Removal.

    d. The Unistrut supports may remain.

6 REMOVAL AND REPLACEMENT (SUBSYSTEM ONLY)

6.1 Equipment

Table 6. Equipment needed for Preventative Maintenance.

Item No.	Description	Quantity
Tools		
	#2 Philips head screwdriver	1
	7/16” Open End / Box Wrench	2
	3/16” Allen Driver	1
MX109104	Level that can measure angles with ≤1° accuracy (e.g., 10° from horizontal)	1
	Camera	1
	Spray Bottle filled with deionized or distilled water	1
Consumable items		
	Lint free cloth	20
	Cotton swabs	20
	ESD Bag (for Grape)	1
MX112377	Size #33 Rubber bands (for securing tipping mechanism)	10

Note: When working on power systems, use tools with insulated handles. Always shutdown the power prior to removing or replacing any components. Do not hot-swap (Power is ON) any component or sensor connections at TIS sites.

6.2 Removal and Replacement Procedure

The Field Operations Domain Manager is responsible for managing the removal and replacement of the sensors onsite for preventive maintenance and/or sensor swaps and manages field calibration and validation of sensors, as appropriate. The NEON project Calibration, Validation and Audit Laboratory (CVAL) is responsible for the calibration and validation of select sensors and manages Domain sensor refresh (swap) schedules.

To minimize data downtime and optimize the availability of sound data, coordinate instrumentation and subsystem annual calibration, validation and preventive maintenance requirements to occur within the

same timeframe. See **Table 7** for sensor refresh requirements for the subsystem infrastructure on the Throughfall Collector.

Table 7. TIS Sensor Refresh Requirements.

	LOCATION		TIMEFRAME			
	CVAL	*FIELD*	*BIWEEKLY*	*ANNUAL*	*NA*	COMMENTS
Throughfall Collector Sensor	X			X		
Merlot (12V) Grape	X			X		Follow ESD protocol

6.2.1 Assembly Field Inspection

Prior to field deployment, verify the structural integrity of the Secondary Precipitation Gauge. Ensure the tipping mechanism has **not** been damaged during shipment to the domain office.

1. Remove the tipping mechanism from the sensor housing.
    a. Using a #2 Philips driver, loosen the three screws that fasten the collector to sensor base two full turns (do **not** completely remove).
    b. Rotate collector counter-clockwise and lift collector straight up.
2. Examine the tipping mechanism for any interference between the tipping bucket and sensor body, and check for interference or excessive play in the bearing. Excessive play is defined as the tipping mechanism cone that sets in the bearing (in sensor body) being able to move more than .5mm away from the tipping axis.
    a. If either are apparent, document with photos, attach a red tag (see **Figure 21.** Red Rejected Tag for Defective Assets (MX104219)) and return to HQ for repair.
    b. If no interference or excessive play are present, proceed with sensor swap per annual refresh schedule.

6.2.2 Throughfall Removal/Replacement Procedure

Remove the throughfall collector from the soil plot using the following procedure.

1. De-energize the entire soil plot per Appendix A – Power Down A SOIL PLOT Power Box.
2. Disconnect the RJF cable going into the Throughfall Merlot Grape.
3. Disconnect remaining power and communications cables connecting sensor to NEON project infrastructure (i.e., 12-3 power cable).
4. Remove the tipping bucket sensor from the throughfall collector. *Reference **Table 4** in Section 5.3.4.2 Sensor Cleaning Procedure.*

Note: Only perform this step if the Sensor is shielded from ambient precipitation and no snow or ice accumulation is present on the collector or troughs. If this is not possible, delay this step until conditions improve.

5. Conduct decontamination on the collector, troughs and screens. *Reference Section 5.3.3.*

6. Using a #33 rubber band, secure the tipping mechanism for shipping and handling (**Figure 20**).

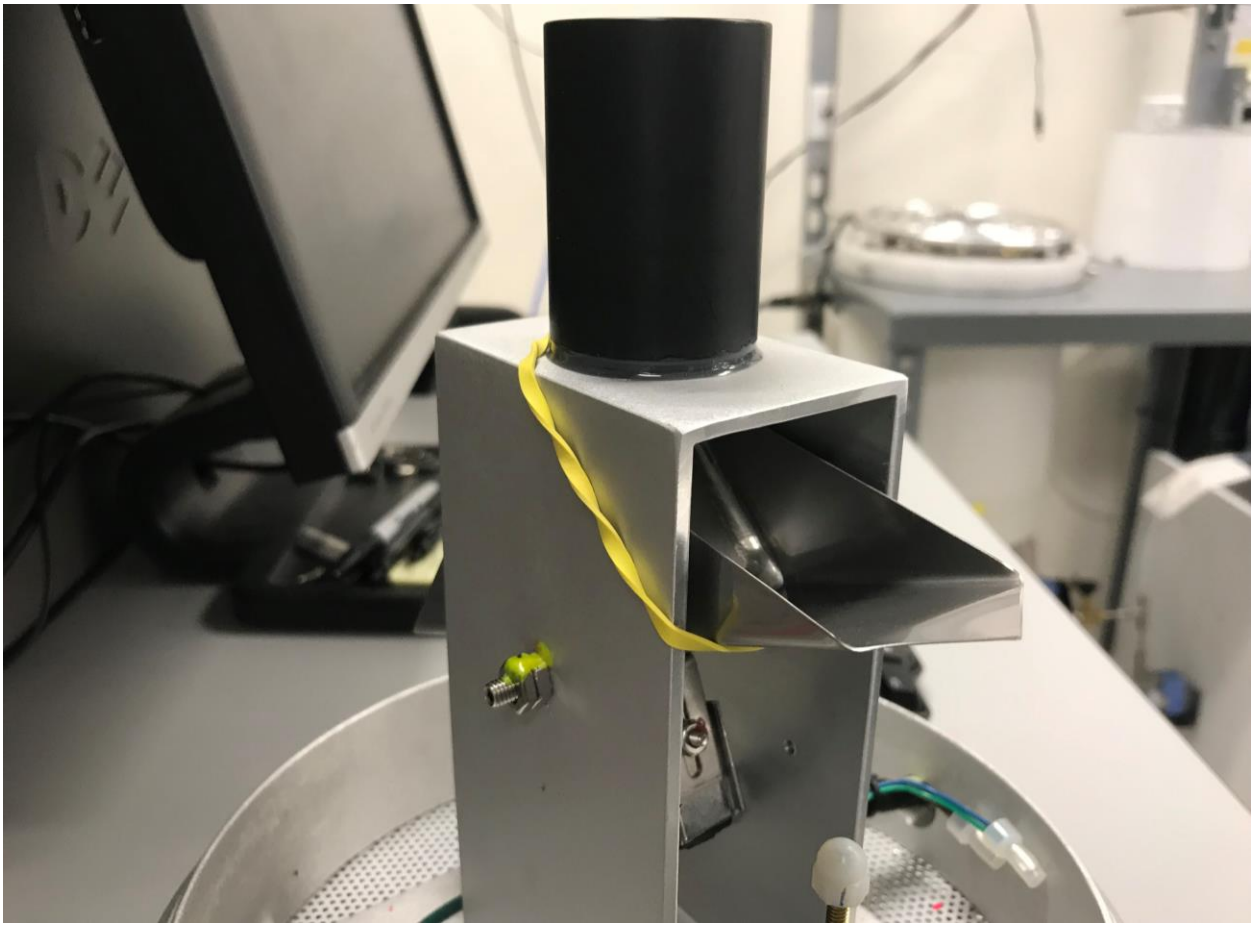

Figure 20. Use Rubber Band to Constrain Tipping Mechanism for Transport/Shipping.

7. Conduct decontamination on the sensor housing.

8. Install new (refresh) throughfall collector sensor in the place of the old sensor (swap sensor).

    a. Remove any materials used to constrain the tipping mechanism during shipment and handling (save and/or re-use, if in good condition).

Important: Do not pull or yank the band/cord from mechanism.

b. Reinstall the throughfall collector. *Reference **Table 4** in Section 5.3.4.2 Sensor Cleaning Procedure in reverse order.*

9. Level and align throughfall in accordance with Science Requirements and Site-Specific Requirements.

10. Re-connect RJF cable to Grape

11. Re-energize the soil plot.

6.2.3 Grape Removal/Replacement Procedure

1. Employ ESD protocols when handling Grapes. Reference AD [09].

2. Power down the site at the Soil Plot Device Post.

    a. Reference Appendix A – Power Down A SOIL PLOT Power Box.

3. Disconnect the armored Ethernet cable connecting to the RJF/Eth to Comm connection (reference **Figure 6**).

4. Disconnect sensor connections.

5. Remove the Merlot Grape from the Grape Shield. Remove the four screws that affix the Grape to the Grape Shield using a hex wrench. If there is a need to remove the Grape Shield from the pipe, remove the Grape Shield mount/clamp using a 3/16” hex wrench.

PRO TIP: It is easier to reinstall the Grape in the Grape Sheild when the mount is removed from the infrastructure.

6. Place dust caps on Amphenol connectors of old Grape.

7. Reinstall new Grape to the Grape Shield by threading the four screws that affix the Grape to the Grape Shield using a hex wrench.

8. Remove dust caps on sensor connectors and Eth-To-Comm connector. Re-connect sensor and armored Ethernet cable in accordance with AD [04].

9. Re-energize the site and verify Grape and Throughfall Collector function. Connect locally to the Soil Plot Arbor/Instrument Hut or from the Domain using a TEP and **Table 3**.

6.3 Cleaning & Packaging of Returned Sensor

Field Operations staff clean, package, and ship the sensors back to the CVAL at the NEON project HQ (Battelle Ecology) for annual sensor swap/calibration requirements. (Please note: if a sensor is defective, submit a trouble ticket and affix a red tag with the trouble ticket number on it.) Clean the Grape (also

known as decontamination; *Reference RD [03])* by removing all biologics from the device prior to capping the connections and placing in ESD packaging.

Please remove all arachnids and/or insects from tower instruments prior to packing and shipping. Reference AD [03].

For the cleaning and packaging of the throughfall collector sensor and the associated Merlot Grape post-removal, conduct the following steps:

1. Check mounting holes for spiders and spider webs. Remove biologics and clean connectors.
2. Cap all connectors.
3. Conduct decontamination per RD [03]and remove any additional biologics from the devices.
4. Pack sensor assembly in original box and packaging from the sensor manufacturer or what was provided via CVAL (e.g., pelican case or other packaging). Pack 12V grape in an ESD bag.
5. Update asset records via the NEON's project Asset Management and Logistic Tracking System (e.g., All devices in transit to HQ shall be moved to TRANSIT in Maximo). NEON HQ, Logistics Warehouse (LOGWAR) receives the Grapes for refresh and distributes to CVAL.

Note: In general, to minimize errors for CI, all devices leaving a CFGLOC must move to SITE first, then TRANSIT/DxxSUPPORT.

6. Provide an electronic packing list to CVAL with the Box number and Asset Tag number (14-digit Property Tag ID ("Property of") number) of each item. CVAL uses this information to verify items via LOGWAR/general HQ distribution of shipments.
7. Prepare a Bill of Lading.

For any Non-CVAL initiated sensor returns, please notify CVAL of the return.

For Sensor Refresh, package sensor items via packaging from CVAL HQ with packing list or per guidance via the Issue Management System and return to the NEON project HQ using the following address:

BATTELLE ECOLOGY, **ATTN: CVAL**
1685 38TH STREET, SUITE 100
BOULDER, CO 80301

Only include sensors/subsystems for refresh. Additional equipment must ship separately as they may require attention from other NEON HQ departments. Sensor refresh shipments go direct to CVAL. If sensors are shipping to HQ to address a trouble ticket, per guidance via the Issue Management System, return to the NEON project HQ using the following address:

BATTELLE ECOLOGY, **ATTN: REPAIR LAB**
1685 38TH STREET, SUITE 100
BOULDER, CO 80301

6.4 Sensor Refresh Record Management of Assets

In addition to the physical movement of devices, the sensor refresh process requires dedicated and accurate record management of asset movement and location.

6.4.1 NEON Asset Management and Logistic Tracking System Requirements

Technicians must update the instrumentation records via the NEON's project Asset Management and Logistic Tracking System (MAXIMO). NEON HQ must maintain accurate record keeping on the location, date, and time offline of an instrument to ensure NEON HQ, Computer Infrastructure, Data Products, and CVAL are aware to apply the correct algorithms, calibrations, and processing factors. Ensure the CFG location reflects the current site of the sensor. All devices leaving a CFGLOC must move to SITE first, then TRANSIT/DxxSUPPORT.

7 ISSUE REPORTING OUTPUTS

FOPS must report issues encountered while conducting preventive maintenance in the NEON project Issue Management/Reporting System. To ensure a quick response and remedy to an issue, please include as much information and detail, as possible. This includes, but is not limited, to the following:

- Domain and Site name
- Date and Time
- Technician Full Name
- Issue Narrative (detailed narrative of the issue, specific location of issue on tower infrastructure, relevant 2nd/3rd order effects to infrastructure, possible cause [e.g., weather event, obstruction, human activity])
- Multiple Photographs (to capture vantage points/perspectives for remote diagnostic)
- Provide Part Number/Manufacturer Information, EPROM ID, Asset Tags, IP /MAC Address, etc.
- Provide Diagnostic Information (from firmware, if applicable), such as error codes, values, etc. Provide screenshots.

Table 8. Throughfall Collector Metadata Output Checklist.

Issue Reporting Datasheet		
Datasheet field	**Entry**	
NEON Site Code		
Maintenance Date		
Maintenance Technician		
Preventive Maintenance	**Issue Noted**	**Issue Summary**
Cables & Connectors - Condition Check	☐	
Sensor - Condition Check	☐	
Sensor - Configuration Check	☐	
Sensor – Clean	☐	
Sensor – Level/Alignment Check	☐	
Mesh screens removed?	☐	Yes: ☐ Date:
Mesh screens re-installed?	☐	Yes: ☐ Date:
Environmental Information	☐	
Notes		

Ship all defective equipment/assets with a red “Rejected” tag. **Figure 21** displays the minimum information requirements for each tag.

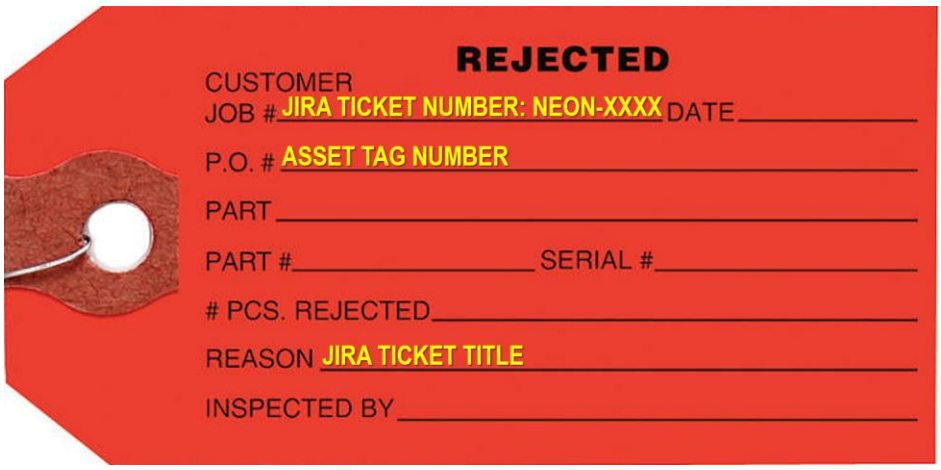

Figure 21. Red Rejected Tag for Defective Assets (MX104219).

8 APPENDIX A – POWER DOWN A SOIL PLOT POWER BOX

Powering down the soil plot enables Technicians to perform work with less hazard to themselves and to the equipment. It also mitigates requiring NEON Headquarters to conduct data quality analysis when Technicians are onsite close enough to the sensors to influence data collection.

1. Power down the plot from the Soil Plot Device Post Power Box.

    a. Open the Power Box using a Philips head screwdriver (**Figure 22**).

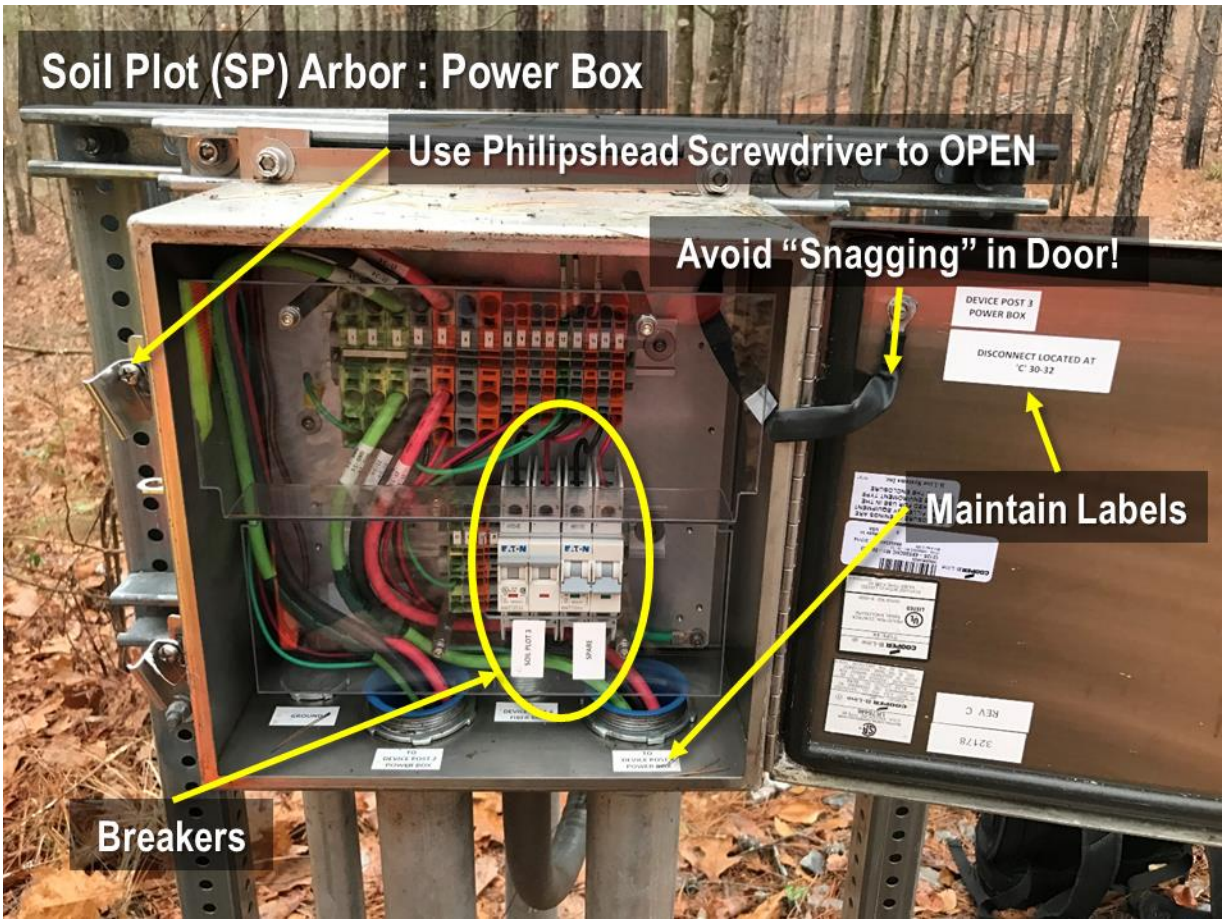

Figure 22. Open Soil Plot Device Post Power Box (D08 TALL).

    b. Flip both breakers from RED to GREEN to de-energize the sensors (**Figure 23**).

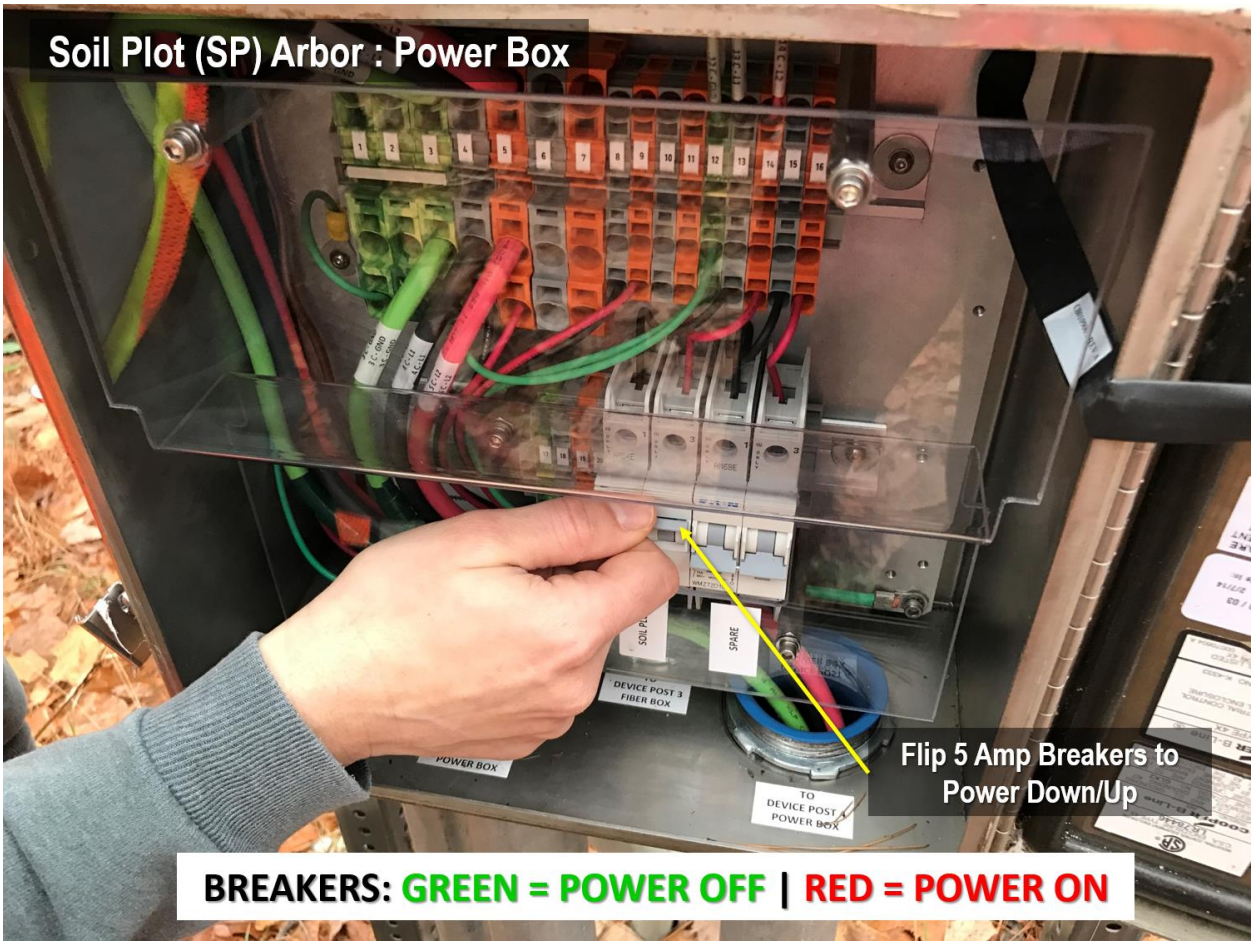

Figure 23. Flip 5Amp Breakers (D08 TALL).

c. Conduct LOTO procedures and proceed with the Preventive Maintenance, Sensor Refresh and/or Corrective Maintenance.

If there is a need to remove a single sensor assembly onsite, then power down the sensor assembly from its Grape. Remove the Ethernet cable from the Merlot Grape RJF/Eth-To-Comm connector before disconnecting or connecting sensor connections.

9 SOURCES

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Portilla, Benjamin. NEON-9743: Implementation of Throughfall Screen Retrofit as required by ECO-04713. September 12, 2017. https://neoninc.atlassian.net/browse/NEON-9743 accessed December 05, 2017.

SanClements, Mike. NEON-3457: Stop Install of throughfall at grassland sites. August 09, 2016. https://neoninc.atlassian.net/browse/NEON-3457 accessed December 05, 2017.

Hand Model(s): Genevieve Faria