

# Standard Methods for Wind Erosion Research and Model Development

## Protocol for the National Wind Erosion Research Network

Nicholas P. Webb, Jeffrey E. Herrick, Justin W. Van Zee, Christopher H. Hugenholtz, Ted M. Zobeck, and Gregory S. Okin





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by Nicholas P. Webb<sup>1</sup>, Jeffrey E. Herrick<sup>1</sup>, Justin W. Van Zee<sup>1</sup>, Christopher H. Hugenholtz<sup>2</sup>, Ted M. Zobeck<sup>3</sup> and Gregory S. Okin<sup>4</sup>

<sup>1</sup> USDA-ARS Jornada Experimental Range  
Las Cruces, New Mexico

<sup>2</sup> Faculty of Environmental Design  
University of Calgary, Alberta, Canada

<sup>3</sup> USDA-ARS Wind Erosion and Water Conservation Research  
Lubbock, TX, USA

<sup>4</sup> Department of Geography, University of California  
Los Angeles, CA, USA

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# INTRODUCTION

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## 1. Objective

The objective of this document is to define standard methods for wind erosion research and model development as part of the National Wind Erosion Research Network. This network has three general aims: (1) provide data to support understanding of wind erosion rates across land use and land cover types and for different management practices, (2) support the development of an all-lands wind erosion model as a decision support tool for managing wind erosion and its impacts (Figure 1), and (3) encourage collaboration between the Network and research community in addressing these research challenges. **Research** that uses these standard methods will increase understanding of wind erosion processes necessary for both **management** and **model development**. The data will contribute to what is anticipated to be the largest and most geographically diverse standardized database for wind erosion model calibration (<https://winderosionnetwork.org>).

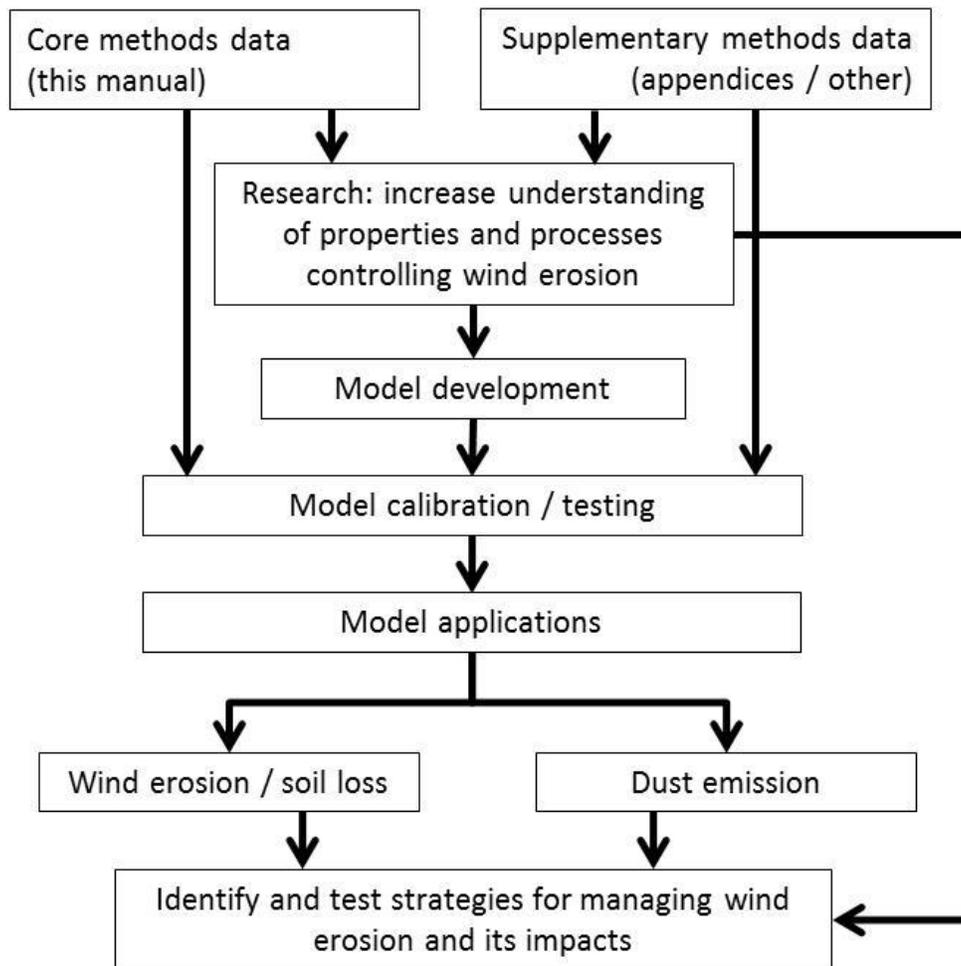


Figure 1: Network applications to wind erosion model development (calibration/testing) and application for understanding and managing wind erosion and its impacts.

*The sampling design presented in this document is for intensively instrumented research and calibration sites where replication is often not possible.* Common sampling approaches used in aeolian research do not provide robust data for wind erosion model development and calibration. Separate approaches can be applied by land managers and researchers who wish to monitor wind erosion through (a) the collection of data necessary to run wind erosion models, supported by (b) limited direct measurements of soil movement. For additional resources please see LandscapeToolbox.org, Herrick et al. (2015), or other monitoring design guides.

Finally, we note that understanding of wind erosion processes and technologies to measure them are continually changing. The methods protocol provided here will therefore be treated as a living document that will be updated and revised periodically over the course of the network.

## 2. Motivation

Public concern about wind erosion is high. This concern has arisen as a consequence of growing awareness of the impacts of wind erosion and dust emission on e.g., human health, agricultural productivity, highway safety, climate, and snowmelt runoff. Despite these concerns, wind erosion model development for management applications has been limited mostly to croplands. While a number of dust emission models are available, these do not adequately represent the impacts of land management. Furthermore, few datasets are available to support understanding of the likely impacts of land cover and land management change on wind erosion across land use systems (i.e., rangelands and croplands). Resolving this knowledge gap is important for addressing the multiple impacts of wind erosion and dust emission.

Field measurements of aeolian (wind) sediment transport rates are needed to quantify wind erosion so that the impacts can be assessed and best management practices can be identified and tested. However, it is impossible to directly measure all potential combinations of soil, vegetation and climate under which wind erosion could occur. Predictive models are required that enable assessments to be conducted across land use and land cover types. Data generated by the Network and others who adopt these methods will be used to improve existing models and develop new approaches to representing management impacts. This will be achieved by addressing one of the primary limitations of existing models: they have only been tested using *small, geographically limited datasets* which represent an incomplete set of field conditions. The ability to use multiple datasets for model calibration and testing is currently limited by a lack of *data standardization* (Barchyn et al., 2011).

Measurements of soil, vegetation and meteorological conditions, along with sediment flux data for a range of land uses and ecological settings, can be used to improve model calibration and testing. This is especially the case for rangelands, for which few models have been adequately tested. Calibrating models for both eroding and non-eroding locations is important to ensure that they accurately estimate erosion rates for the broad range of environmental conditions. While some level of flexibility in methods is clearly required to address the specific needs and objectives of individual studies, in many cases the long-term benefits of using standard protocols outweigh the costs (Toevs et al., 2012). The use of soil and vegetation methods that are already nationally adopted and internationally applied will dramatically increase the application of these models, allowing national estimates of wind erosion to be generated from existing datasets. For example, the USDA National Resources Inventory (NRI) alone collects vegetation cover and structure data at over 4,000 locations per year where soil surface texture has been determined.

### 3. Overview and scope

The methods described in this document support collection of the data necessary to evaluate wind erosion and to calibrate, test and run models for site-based wind erosion assessments. The document identifies and describes a **core set of standard methods** for assessments of wind erosion and its controlling factors. The core methods generate the *minimum data required* to calibrate and test wind erosion models. The methods capture the controls on aeolian sediment flux, are integrative of the many factors that influence wind erosion, can be collected accurately, and can be collected in a cost-effective way with sufficient precision for modeling.

The document also provides a set of **supplementary optional methods** (described in Section II). These methods can be used to provide more comprehensive data on wind erosion rates and their controlling factors, including soil surface characteristics (e.g., aggregate size distribution, and crusting) that influence wind erosion. It is recommended that these methods be used whenever practical.

Five sets of standard core methods are included: (1) site characterization, (2) site design and layout, (3) meteorological and wind erosion threshold measurements, (4) measurement of the horizontal (saltation) mass flux, and (5) land surface measurements including vegetation and soils. Land surface and meteorological measurements provide a basis for running models that predict wind erosion, while measures of aeolian sediment transport rates are also required for model calibration and testing.

The standard meteorological methods were selected based on the following criteria:

1. The methods meet the minimum requirements/assumptions of procedures for estimating state variables that are needed to model wind erosion (Shao, 2008).
2. Where appropriate the methods are consistent with World Meteorological Office (WMO) standards.
3. The methods follow commonly-used conventions adopted by the aeolian research community (Zobeck et al., 2003a).

The standard vegetation and soil methods were selected based on the following criteria:

1. Data can be used to directly or indirectly provide inputs to existing wind erosion models.
2. The methods are relatively simple, rapid and repeatable.
3. The methods are nationally adopted by the US Natural Resources Conservation Service (NRCS) and Bureau of Land Management (BLM) for rangeland monitoring.

Several measurements commonly used by wind erosion researchers, including measures of dynamic soil properties (e.g., dry aggregate size distribution) and the lateral cover of vegetation ( $\lambda$ ), were not selected for the core methods because they fall outside the scope of the measurements and fail to meet the second two criteria for soil and vegetation measurement. Some of these measurements may be important for croplands and have been included in the supplementary methods (Section II).

Measurements of vertical (dust) flux are also currently omitted from the core methods because of the large cost associated with measurement at all network locations. However, due to the importance of these data for model development and calibration, researchers are strongly urged to include them as a supplementary method where possible (Zobeck et al, 2003). It is intended that continuous dust concentration measurements be included at all National Wind Erosion Research Network sites in the future.

#### 4. Data standardization requirements

The goal of developing a protocol for measuring wind erosion, and its controlling factors, is to enable the development of a standardized database of information that can be used in wind erosion model calibration, testing and application. The data standards outlined in the core methods must be followed to ensure that measurements of wind erosion processes and controls can be reliably compared among sites and cross-site calibration and testing of wind erosion models can be conducted.

In line with the standardized data collection, it is important that all reporting of site descriptions and management practices, transect data, sediment fluxes and meteorological data is carried out using a common reporting structure. This will facilitate data transfer and utility in the model calibration and testing processes, and sharing of data among the network sites. Data reporting conventions for each of these information and data types are provided in Part 10 of the core methods.

**Quality assurance** (QA) and **quality control** (QC) provide data integrity and are required for all methods described in this manual.

- QA and QC protocols are described in: Herrick et al. (2015) *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems, 2nd Edition* (<https://www.landscapetoolbox.org/manuals/monitoring-manual/>)

## SECTION I – Core methods for wind erosion research and model development

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### 5. Site location and description

This manual provides methods that can be used to quantify land surface and meteorological properties that control wind erosion, enabling improved understanding of land use and management impacts on wind erosion and wind erosion model calibration and testing across land cover types. This requires that sites be established in cropland, rangeland and desert systems so that model development can be conducted for a broad set of environmental conditions and management practices.

- *Rangeland and desert sites* should be located within a single ecological site and a single vegetation community (e.g., grassland, mixed grass-shrubland or shrubland), and preferably with low slopes (< 3%). Sites that are either ‘representative’ of the eroding landscape, or are particularly sensitive to local management practices, are suitable.
- *Cropland sites* should be located in cultivated fields, preferably with low slopes, and management regimes (crop types and management treatments) that reflect common practice in the surrounding area.
- Both rangeland and cropland sites should be located within homogeneous land cover types that cover an area *>1ha in size for croplands and >5 ha in size for rangelands*.
- For site selection soil texture can be estimated in the field following Appendix I or the LandPKS app (<https://landpotential.org/>).
- Some locations may require permission to erect towers if in the vicinity of an airport. This should be investigated and permission obtained during the site selection process. Appropriate Federal Aviation Administration (FAA) regulations should be followed.

An initial site characterization is required when establishing a National Wind Erosion Research Network site. The assessment should include a detailed description of the site.

*For new sites:*

- Refer to details of core data required for site characterization in: Herrick et al. (2015) *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems, 2nd Edition* (<https://www.landscapetoolbox.org/manuals/monitoring-manual/>).
- The location of all equipment and fences should be recorded with a professional grade GPS (<0.5 m accuracy). For rangeland sites a template of the site equipment layout will be provided as an ArcGIS shapefile.

#### 5.1 Land management records

Local land management can have a significant effect on site conditions, including the erodibility of the site and actual wind erosion rates. To account for management impacts on wind erosion the following characteristics should be recorded at the time of site establishment and whenever they change over time.

- Land use and management activities and timing (e.g., crop management practices)
- Implementation of tillage tools (e.g., type, application, soil ridge height and spacing)
- Livestock stocking rates (include range if actual numbers are unknown)
- Recent known disturbances (e.g., fire, livestock activity in close proximity to plot)

- Distance to nearest known watering point, feeding point or other locations where livestock congregate
- Appendix II provides example forms that should be used to record management practices at rangeland and cropland sites.
- Cropland and Rangeland Management Recording Sheets can be accessed online on the Documents page at <https://winderosionnetwork.org> and should be uploaded to the Data Submission Portal at the end of every month or as management actions occur.

## 6. Field site design and layout

The site design should support both the local and Network objectives. The design process should consider local environmental conditions and management practices at individual sites (Zobeck et al., 2003a).

Note: Details of the equipment listed in this section and sampling protocols are provided in Part 7 and Part 8 of this manual.

### 6.1 Measuring wind erosion in croplands

For network sites in croplands the field sampling design illustrated in Figure 2 should be employed. The field sampling design for cropland sites should accommodate field management practices (i.e., tillage, crop management, harvesting). Therefore, the following are required when establishing cropland sites:

- Cropland sites will occupy a 1 ha area within a field under homogeneous management.
- A field length of at least 300 m is desirable to measure horizontal sediment mass flux at transport capacity (Zobeck et al., 2003a).
- Where possible, fields should be selected with the greatest fetch (distance travelled by wind before reaching the tower) oriented toward the direction of the most frequently erosive winds.
- The meteorological tower may be located at the downwind edge (Figure 2) or center (Figure 3) of the site so that the aerodynamic roughness height can be estimated for the upwind eroding field.
- A saltating particle counter (Sensit) should be positioned as far upwind of the meteorological tower in the field as is practical.
- A rain gauge should be mounted on a post at 1.5 m height and located so that it does not obstruct other sensors, and is not obstructed by the 10 m tower (4-5 m away).

*A robust sampling design for measuring the horizontal sediment mass flux is essential for effective model calibration and testing.* A robust sampling design will enable the variance in sediment transport to be measured, providing confidence in the magnitude of sediment flux measured within the Network sites. If the variance is not quantified, the sediment flux measurements will not provide a sound basis for model calibration. The most effective sampling design for croplands will inevitably result from trade-offs with the most practical design that can be implemented alongside management activities. Populating a field with a large number of sediment sampler masts can be untenable in some situations. However, the samplers can be removed during management operations and replaced afterwards at the same locations in the field.

A set of 27 Modified Wilson and Cooke (MWAC) sampler masts should be used to provide an estimate of the horizontal sediment mass flux within the site, enabling reliable comparison of sediment transport rates among the network sites and estimation of the net wind erosion occurring at each site.

- The MWAC masts should be positioned across a 1 ha site within a field according to a stratified-random sampling design, with stratification provided by a regular 3 x 3 grid.
- Three MWAC masts should be randomly located within each grid cell (Figure 2).

This sampling design will enable the variance in horizontal sediment mass flux within the grid cells, and the variance for the 1 ha site to be estimated. This will ensure that the magnitude and variability in aeolian sediment transport at a site can be obtained with confidence for model development.

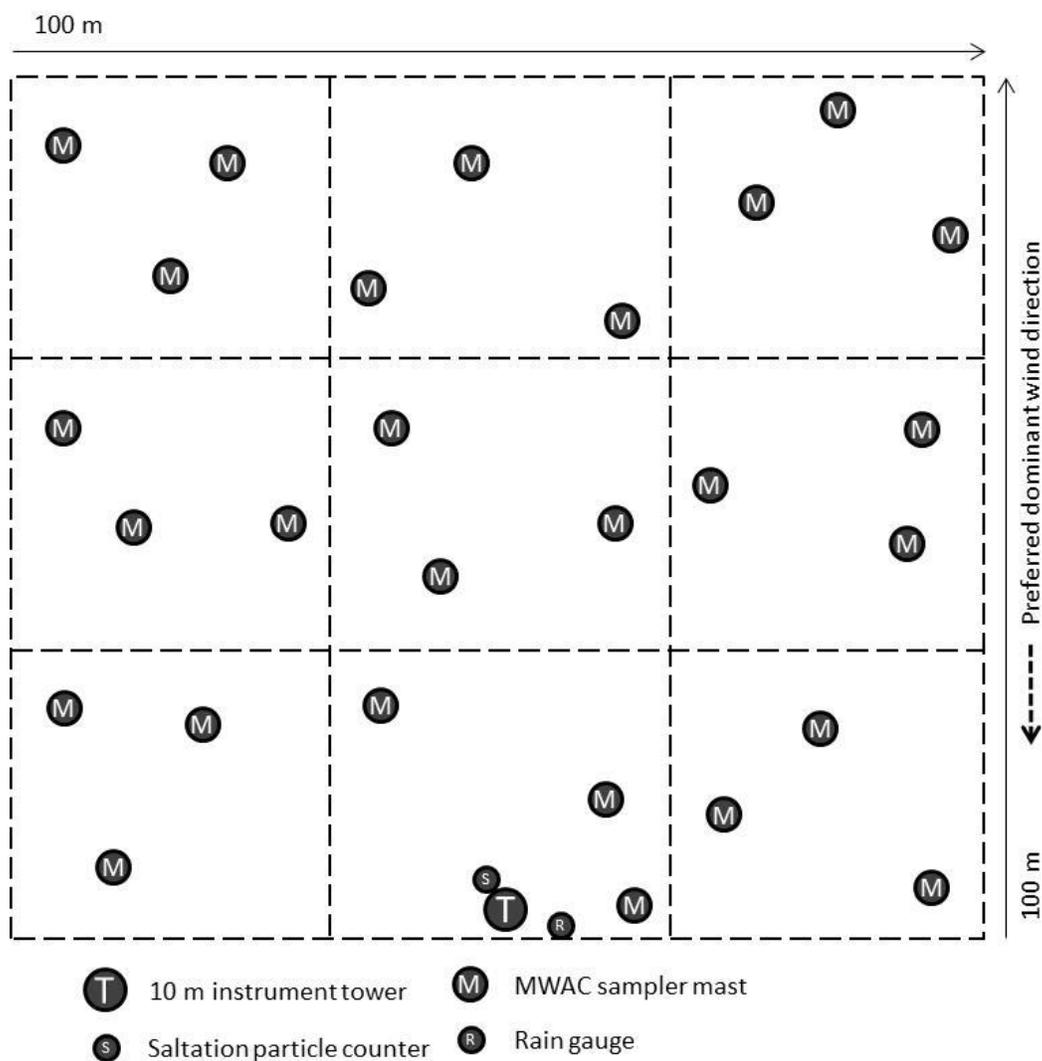


Figure 2: Site design for croplands. Note: rotating 1-m MWAC sampler masts (Figure 7) can be removed as required during management operations, but should be replaced as quickly as possible (within several hours) to their original locations as many management operations result in a temporary increase in soil erodibility. A random distribution for the MWAC sampler masts should be generated on a per site basis.

## 6.2 Measuring wind erosion in rangelands

For network sites in rangelands the field sampling design illustrated in Figure 3 should be employed. Individual equipment can be fenced to prevent damage from livestock, but if not practical then the entire site can be enclosed. Fencing equipment individually will enable livestock disturbance effects on the soil and vegetation to be measured. Fencing should strike a balance between protecting infrastructure while also minimizing disturbance to wind flow and attracting unwanted disturbance from livestock. As such we recommend the use of wire fencing (example in Figure 4) instead of plastic or wooden fencing.

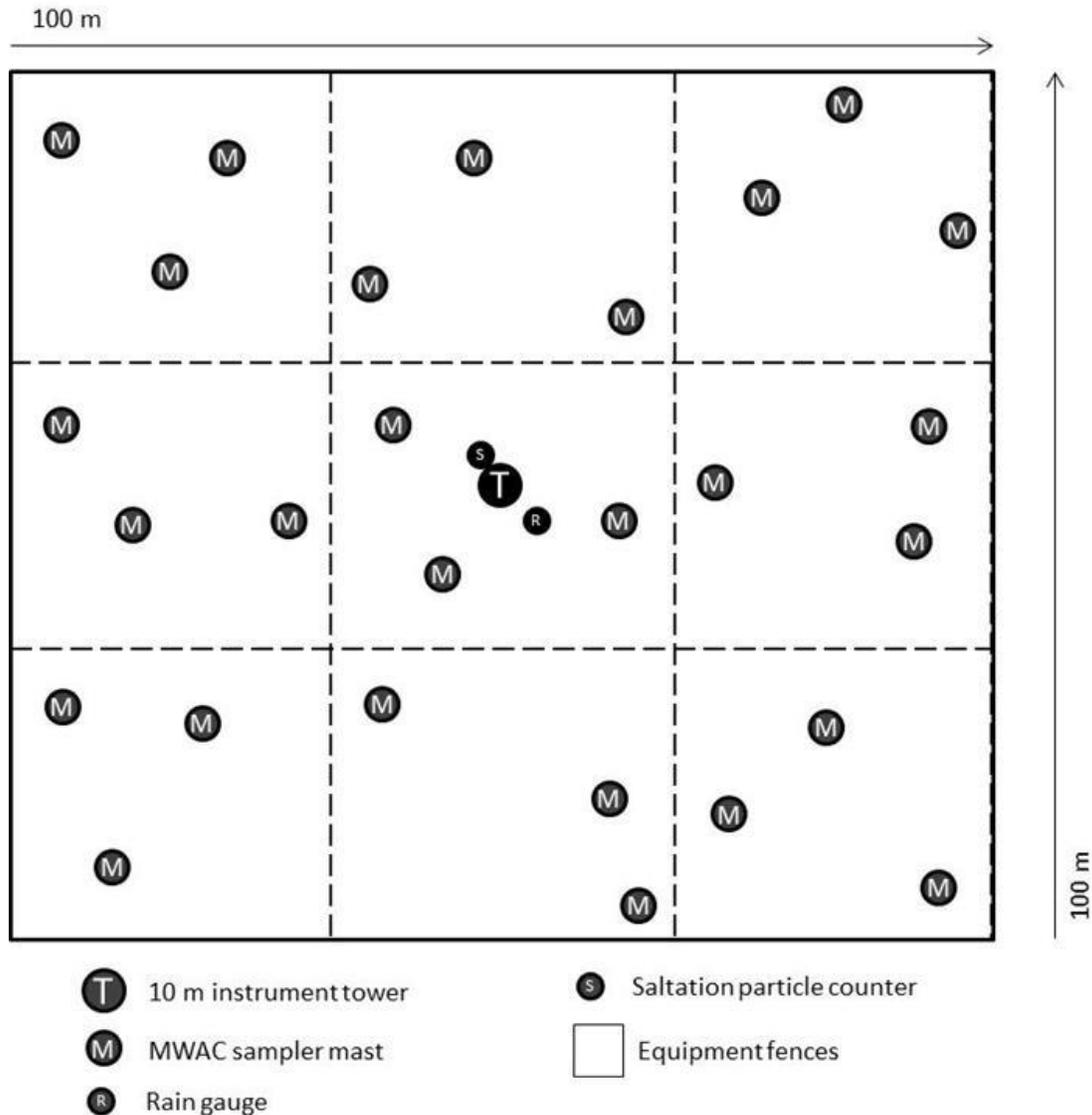


Figure 3: Site design for rangeland sites. Note: A random distribution for the MWAC sampler masts should be generated on a per site basis. Note: If fenced individually, rotating 1-m MWAC sampler masts (Figure 7) should be enclosed with fences using wide mesh cattle fence. It is important to use wide mesh so as not to disrupt the wind and sediment flow into the MWAC samplers. Mesh fencing can also be easily removed if needed.

- Rangeland sites will occupy a 1 ha area within a >5 ha homogeneous land cover type and within the same ecological site.
- A 10 m meteorological tower should be located at the center of the site so that measurements of soil, vegetation and sediment mass flux can be referenced to the central condition of the site.
- A saltating particle counter (Sensit) should be located away from significant obstructions near the tower. The Sensit should be positioned on the upwind side of the meteorological tower in the direction of the most frequently erosive winds, and in the center of a plant canopy interspace (gap) if vegetation is present. The instrument should be mounted such that the sensor sits 0.05 m above the soil surface.
- A rain gauge should be mounted on a post at 1.5 m height and located so that it does not obstruct other sensors, and is not obstructed by the 10 m tower.

*A robust sampling design for measuring the horizontal sediment mass flux is essential for effective model calibration and testing.* A robust sampling design will enable the variance in sediment transport to be measured, providing certainty in the magnitude of sediment flux measured within and among the Network sites. If the variance is not quantified then the sediment flux measurements will not provide a sound basis for model calibration.

A set of 27 MWAC sampler masts should be used to provide an estimate of the horizontal sediment mass flux within the site, enabling reliable comparison of sediment transport rates among the network sites and the net wind erosion occurring at each site.

- The MWAC masts should be positioned across the site according to a stratified-random sampling design, with stratification provided by a regular 3 x 3 grid (Figure 3).
- Three MWAC masts should be randomly located within each grid cell.
- Where MWAC sampler locations fall immediately on vegetation, another random location should be selected for the sampler to ensure that it can rotate freely in the wind.

This sampling design will enable the variance in horizontal sediment mass flux within the grid cells, and the variance for the 1 ha site to be estimated. This will ensure that the magnitude and variability in aeolian sediment transport at a site can be obtained with confidence for model development.

## **7. Meteorological equipment and sampling**

Both research and model development (calibration and testing) require measurement of the meteorological conditions that drive wind erosion. Core variables include: rainfall, relative humidity (RH), temperature (measured as a vertical profile) and wind velocity (also measured as a profile). These parameters are needed to estimate the aerodynamic roughness height ( $z_0$ ) of the surface, the wind shear velocity ( $u^*$ ), and the threshold shear velocity ( $u_t^*$ ) for soil entrainment by wind.

## 7.1 Equipment requirements

Measurements of the meteorological variables should be obtained using an automatic weather station. Instruments/sensors for the weather station should be mounted on a 10 m tower, with the objective of measuring a vertical profile of the variables. The heights (vertical spacing) of the anemometers should be adjusted to suit the height of the standing roughness (vegetation or bare soil) at the site (Zobeck et al., 2003a). Anemometers should be spaced more closely near the surface to detect the wind profile change due to surface drag (Law of the Wall). Table 1 outlines the minimum sensor requirements for the weather station.

**Table 1:** Meteorological sensors and details for mounting on 10 m mast

Sensor / Instrument	Details / Position / Orientation
<ul style="list-style-type: none"> <li>Rain gauge (1) – to measure precipitation quantity and intensity (e.g., tipping bucket type)</li> </ul>	<ul style="list-style-type: none"> <li>Mounted on post 4 m from instrument tower at 1.5 m height above the ground surface</li> </ul>
<ul style="list-style-type: none"> <li>Shielded temperature sensors (2) and shielded temperature/relative humidity sensor (1)</li> </ul>	<ul style="list-style-type: none"> <li>Temperature mounted at 2 m and 10 m and Temp/RH mounted at 5 m above ground surface on north side of tower</li> </ul>
<ul style="list-style-type: none"> <li>Anemometer and wind vane (1) – to measure wind velocity and direction</li> </ul>	<ul style="list-style-type: none"> <li>Mounted so that anemometer cups sit at 10 m height above surface on south side of tower</li> </ul>
<ul style="list-style-type: none"> <li>Anemometers (5) – to measure wind velocity profile (e.g., cup type)</li> </ul>	<ul style="list-style-type: none"> <li>Mounted so that anemometer cups sit at 0.5 m, 1.0 m, 1.5 m, 2.5 m and 5.0 m above ground surface – height adjustable depending on surface roughness height; mounted on south side of tower</li> </ul>
<ul style="list-style-type: none"> <li>Sensit (1) – saltating particle counting instrument</li> </ul>	<ul style="list-style-type: none"> <li>Positioned in field upwind of the tower (determined by dominant erosive wind direction). Instrument should be maintained with base 2-3 mm above the soil surface to measure saltating particle impacts (and reduce chance of burial during transport events)</li> </ul>
<ul style="list-style-type: none"> <li>Data logger (1) and peripherals (power supply, solar panel, charge regulator, data storage device)</li> </ul>	<ul style="list-style-type: none"> <li>Mounted on mast so as not to obstruct anemometers: on north side of tower</li> </ul>
<ul style="list-style-type: none"> <li>Communications equipment, including digital cellular modem, antenna and mounting kits</li> </ul>	<ul style="list-style-type: none"> <li>Modem mounted inside data logger enclosure; antenna should be mounted to face nearest communications receiver</li> </ul>
<ul style="list-style-type: none"> <li>Tower hardware, including 10 m tower, crossarms with brackets, sensor mounts, data logger enclosure, base plate, guy wires and pegs, lightning rod</li> </ul>	<ul style="list-style-type: none"> <li>Crossarms to be mounted on southern side of tower, extending toward the south</li> </ul>

Appendix III provides a comprehensive list of the required instrumentation (sensors), hardware and communications equipment including approximate costs. Figure 4 and Figure 5 illustrate the meteorological tower setup for the Network sites. Positioning of the tower and peripheral instruments at the research sites is described in Part 6 of this manual.



Figure 4: Photograph of instrument mast on which are mounted the six anemometers (plus one wind vane at top), three air temperature sensors and relative humidity sensor (on right of tower), data logger enclosure, solar panel (may also be mounted on tower), rain gauge (at rear), Sensit (in ground, left of lowest anemometer), and communications antenna (facing direction of nearest cell phone tower).

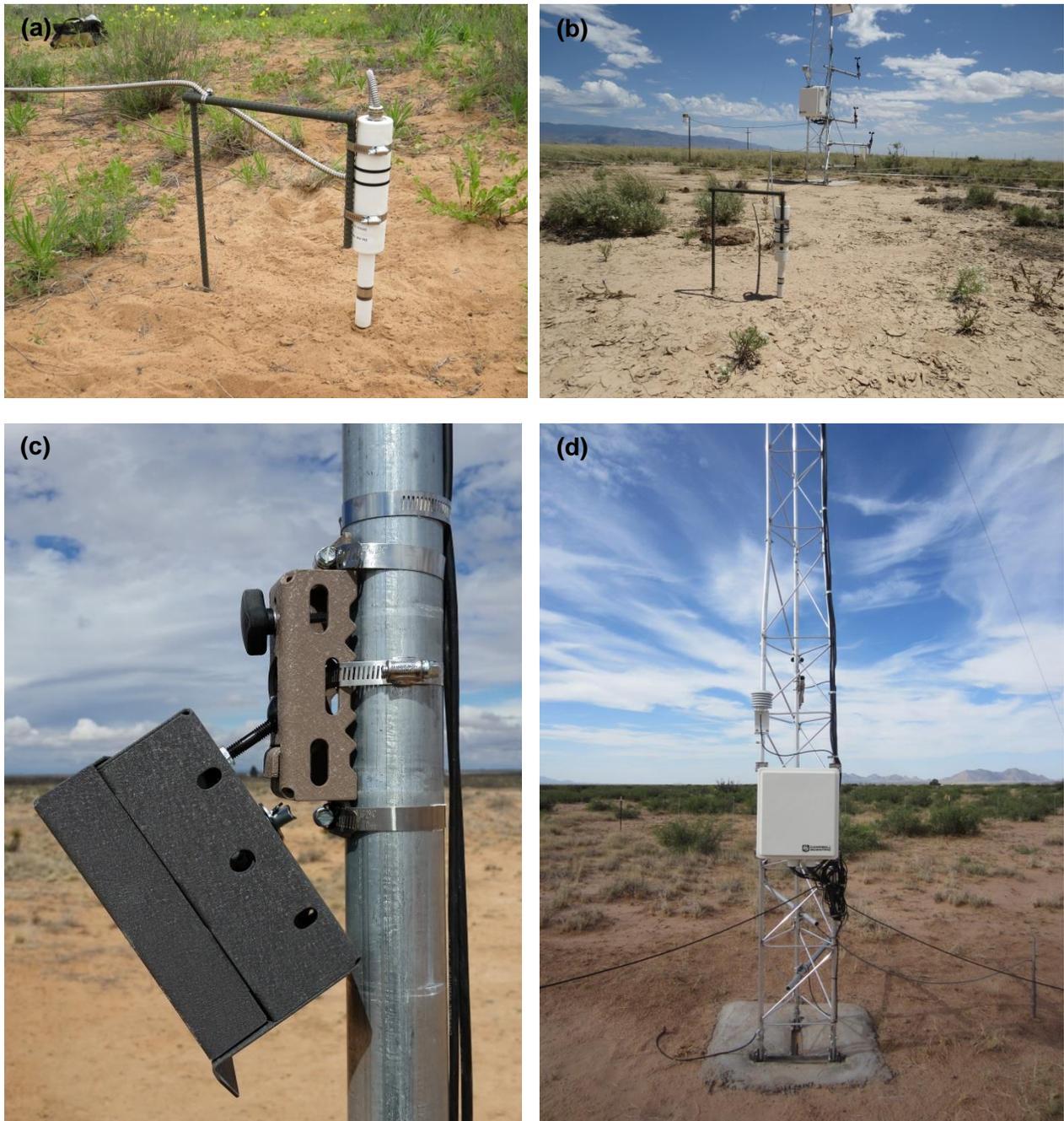


Figure 5: Photographs of meteorological tower components, including (a) close-up of the Sensit mounted so that the base of the sensor sits 2-3 mm above the soil surface; (b) Sensit, tipping bucket rain gauge mounted on a t-post (at rear), and base of the instrument tower; (c) time-lapse camera mounted the side of the instrument tower; and (d) close-up of the instrument tower base mounting plate, grounding wire, and data logger / communications enclosure. Note: sensor cables for the solar panel and rain gauge are run above ground to avoid damage from rodents. Sensor cables for the Sensit and lower anemometer are run through flexible aluminum conduit to the logger enclosure.

## 7.2 Time-lapse camera

A time-lapse camera should be used to monitor the site condition and provide a visual reference for changes in the soil surface and vegetation conditions.

- Cameras should be mounted on the meteorological tower such that the camera field of view enables the site condition to be monitored.
- Where practical cameras should be mounted facing north to avoid glare from the sun.
- Cameras should be programmed to take four pictures per day between 11am and 2pm to account for seasonal variability in solar noon.
- Photographs should be uploaded to the Data Submission Portal at <https://winderosionnetwork.org> at a minimum of 4 times per year.

## 7.3 Measurement frequency and reporting

Standardizing the sampling and data logging frequencies of the meteorological measurements is important for ensuring that derived parameter estimates needed for model development are consistent over time and comparable among research sites. Both sampling and data logging frequencies can have a significant effect on the estimation of variables and model calibration. This includes the aerodynamic roughness height ( $z_0$ ) and threshold shear velocity ( $u_{*t}$ ).

High-resolution measurements typically provide the best opportunity for understanding aeolian sediment transport processes and for calibrating and testing models. A trade-off of high-resolution data collection is that data storage and transmission costs can be large. However, these costs are small relative to the benefits of high frequency sampling and logging, which also allows for data to be aggregated to coarser temporal resolutions if needed. If coarse sampling and logging frequencies are used in the first instance, then high resolution process information cannot be retrieved, and valuable information may be lost.

Table 2 outlines the standardized meteorological data sampling and logging frequencies for the network.

**Table 2:** Meteorological sensors and standards for data sampling and logging frequencies

<b>Sensor (Logged parameters)</b>	<b>Sampling Frequency</b>	<b>Logging Frequency</b>
Anemometers (wind speed: average, maximum, standard deviation)	1 Hz	1 minute
Wind vane (wind direction)	1 Hz	1 minute
Temperature and Temp/RH (average)	1 Hz	1 minute
Rainfall (total*)	1 Hz	1 minute
Sensit (total saltation impacts)	1 Hz	1 minute
Sensit (total saltation seconds)	1 Hz	1 minute

\* Note: 1 minute logging frequency also allows intensity to be calculated.

All meteorological data will be output from the data loggers in standard format provided by the logger program, available on the Documents page at <https://winderosionnetwork.org> and Appendix V. This format should not be modified in any way prior to data transfer to the Network central database.

### 7.3.1 Meteorological sensor maintenance

Meteorological sensors, especially anemometers, require regular checking and maintenance for data quality assurance. In actively eroding landscapes dust can abrade anemometer bearings and cause them to fail, particularly for sensors mounted close to the ground. We recommend that anemometers are *checked and cleaned* every 6 months and *all bearings replaced and anemometers calibrated annually*. This straightforward procedure is described in the manufacturer's documentation for the sensors. Note: calibration of anemometers will require an update to the logger program for calibration coefficients.

- A site maintenance recording data sheet is available on the Documents page at <https://winderosionnetwork.org> and should be uploaded to the Data Submission Portal whenever maintenance is performed.

## 8. Aeolian sediment mass flux equipment and sampling

Measurements of the magnitude and frequency of aeolian horizontal (saltation) sediment mass flux (e.g.,  $\text{g cm}^{-1} \text{ month}^{-1}$ ) are required for the calibration and testing of wind erosion models. Sampling the saltation layer also provides a way for calculating the total (vertically integrated) horizontal sediment mass flux at a site.

Methods are available for directly measuring the suspended sediment (dust) flux, but we have not included these in the core methods at this time because: (1) measures of the saltation sediment mass flux are of most value for initial model development, calibration and testing, and (2) while numerous methods are available for measuring the suspended sediment flux, no set of instruments has emerged that are inexpensive (affordable to the network). An indicator of the dust flux can be obtained by conducting particle size analyses of the sediment trapped in horizontal transport. Approaches for these measurements are described in the Supplementary Methods (Section 2). Initially, direct measurements of the dust flux may be made at select sites on an event basis to develop a suitable dataset for model calibration and testing.

### 8.1 Sediment samplers for horizontal (saltation) sediment mass flux

*Modified Wilson and Cooke (MWAC)* samplers were selected as the standard for the following reasons: (1) efficiency at trapping sediment, (2) simplicity, and (3) ease of use and maintenance. A range of other sediment samplers is also available for measuring the horizontal sediment mass flux. Technical descriptions of the samplers and their efficiencies are provided in: Shao et al. (1993), Goossens and Offer (2000), Goossens et al. (2000) and Zobeck et al. (2003a) (see Supporting Literature). MWAC samplers were chosen over Big Spring Number Eight (BSNE) samplers because of their reliability in the field and lower cost.

### 8.1.1 Installation and maintenance of sediment samplers

- MWAC samplers are mounted on a mast with a wind vane that orients the sampler inlet to face the wind.
- A MWAC mast holds four (4) samplers mounted with brackets.
- Samplers should be mounted parallel to the ground at heights of 10 cm, 25 cm, 50 cm and 85 cm above the soil surface (measured from surface to center of inlet) to capture the decline in sediment mass transport with height above the surface.
- The MWAC masts (Figure 7) should be installed at cropland and rangeland sites according to the appropriate sampling design (Part 6.1 and Part 6.2).
- The location of individual MWAC masts should be determined using a random location generator in GIS software on an individual site basis and then identified in the field using a professional grade (<0.5 m accuracy) GPS.
- MWAC samplers at cropland sites that are temporarily removed for management treatments should always be returned to their original predetermined (random) locations.
- A template for labeling the MWAC samplers that will facilitate sample collection and processing is provided in Appendix VI.

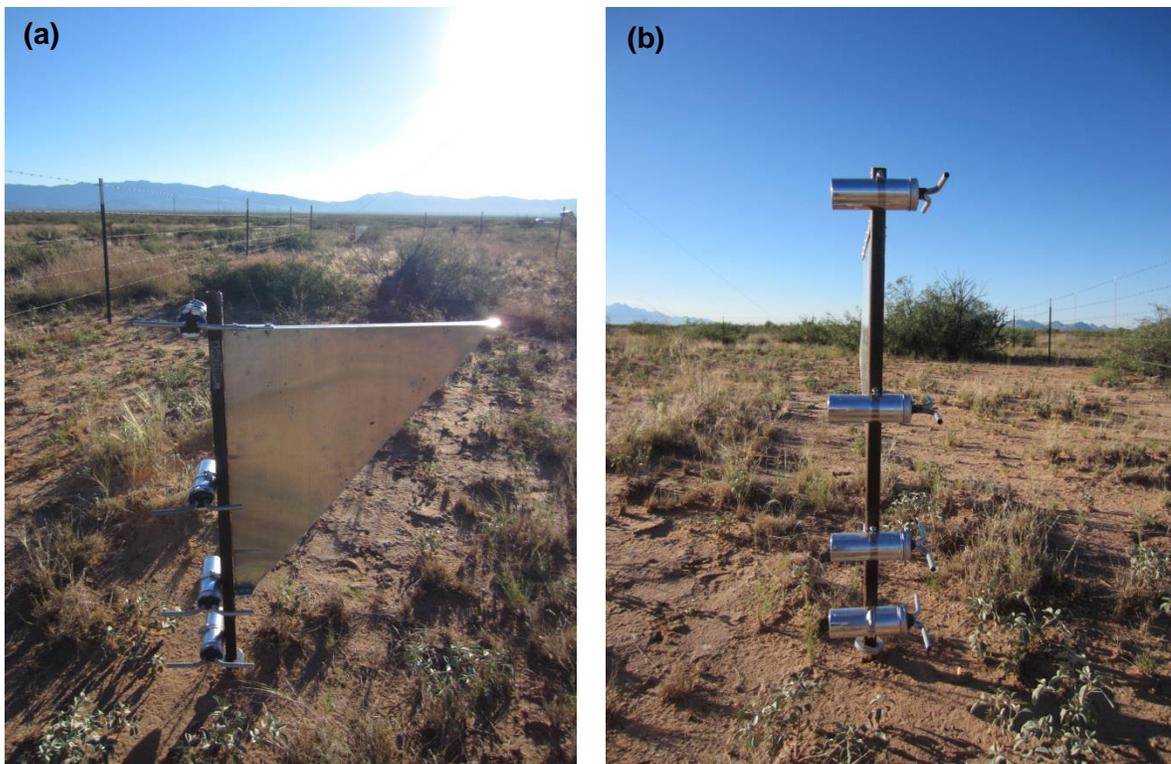


Figure 6: Mast with four MWAC samplers deployed on a wind vane showing: (a), side view and (b) front view. If necessary, samplers and fins should be painted non-reflective green or brown to reduce the public's attention.

### 8.1.2 Data collection and analysis

- Sediment samples are collected every 28 days, or at least *monthly*.
  - Samplers and masts/fins are removed from the field, and/or sample collection put on hold, at locations where snow covers the ground during the winter months.
  - A replacement set of sampler cans with a set of normal screw-cap lids can be swapped with the deployed sampler cans for quick sample collection in the field.
  - Sediment may be removed from the samplers by dry or wet collection methods.
  - A detailed description of both sample collection methods and data recording sheets are available on the Documents page at <https://winderosionnetwork.org>.
  - Sediment sample collection data sheets should be uploaded to the Data Submission Portal on the Network website at the end of every month.
  - Detailed instructions on how to build MWAC wind vane masts are provided in Appendix VII.
- MWAC sediment samples can be composited for archiving in order to reduce the total number of samples held in storage and to increase the retained sample size, which can be used for particle size analyses, nutrient analyses, etc.
  - Composite samples can be formed by grouping all samples at each of the respective heights (10 cm, 25 cm, 50 cm, 85 cm) collected at the first (A1, B1, C1,... I1), second (A2, B2, C2,... I2) and third (A3, B3, C3,... I3) MWAC masts (Figure 7).
  - This approach will reduce the 108 samples (27 masts each with 4 sampler heights) to 12 samples: Sample Group 1 (SG1) 10 cm, SG1 25 cm, SG1 50 cm, SG1 85 cm, Sample Group 2 (SG2) 10cm, SG2 25 cm, SG2 50 cm, SG2 85 cm, Sample Group 3 (SG3) 10 cm, SG3 25 cm, SG3 50 cm, SG3 85 cm.
  - Samples should be retained in clean plastic vials for later analysis.

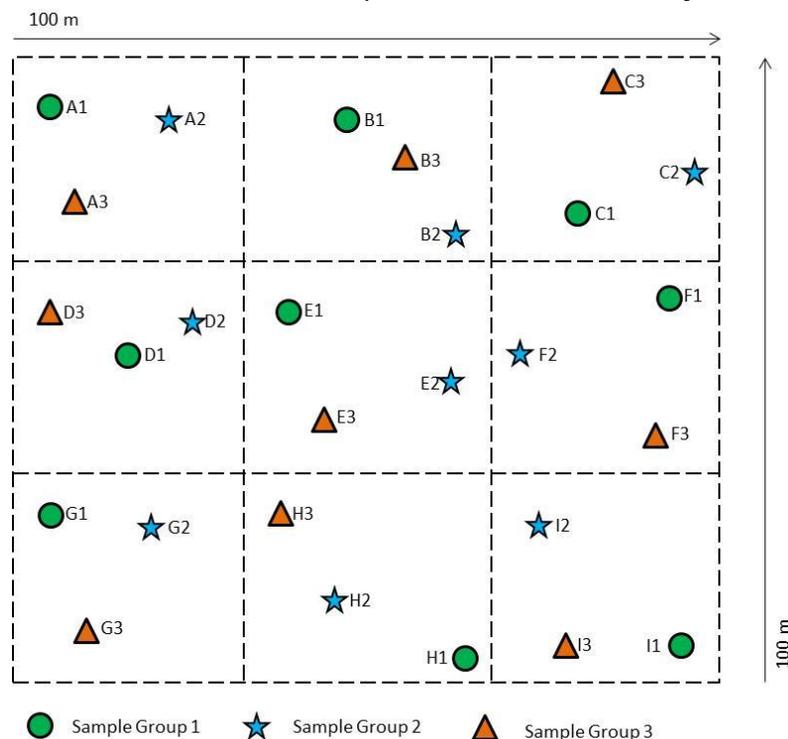


Figure 7. Illustration of how MWAC sediment samples can be composited after collection and weighing. Samples should be composited by height, such that 12 composited samples are produced.

## 9. Sampling land surface controls on wind erosion

Vegetation and soil surface characteristics control the susceptibility of land to wind erosion and its potential to erode and produce dust. Vegetation and soil surface conditions are *dynamic* and respond to climate variability and land management. Because wind erosion is sensitive to both of these conditions, a set of measurements describing vegetation and soil properties must be made in order to obtain reliable estimates of sediment flux. *For model development and calibration it is important that seasonal changes in vegetation height and cover are accounted for.* Small changes in vegetation cover, distribution, height and porosity can have large and non-linear effects on sediment transport and wind erosion.

### 9.1 Soil measurements

The susceptibility of soil to wind erosion (*erodibility*) is determined by the soil particle-size distribution (texture), organic matter content, moisture content, and soil structure, including the aggregate size distribution and presence of physical and biological crusts. These conditions are dynamic at the soil surface so repeated measures are required to understand temporal variations in erosion and the impacts of disturbance.

We have selected one method to describe the soil physical characteristics; the soil particle size distribution (PSD). Soil PSD provides a basis for understanding the dynamic soil properties and the threshold shear velocity ( $u_{*t}$ ) at which aeolian sediment transport is initiated at a site. The threshold shear velocity provides an integrative measure of the effects of soil properties and structural characteristics on wind erosion and can be derived from the meteorological tower data. Measurements of soil biological crust cover and rock cover are captured in the Line Point Intercept (LPI) method (Section 9.2.2). Methods for measuring other dynamic soil properties (e.g., aggregate size distribution and crusting) are described in the Supplementary Methods (Section II).

#### 9.1.1 Soil sampling

Soil samples should be collected for laboratory analysis of the soil particle size distribution.

- The soil sampling should follow a stratified-random sampling design on a 3 x 3 grid to ensure that the variance across the 1 ha site is captured (Figure 8).
- The strata (grid cells) all have the same area (~33 x 33 m) and in each stratum three locations should be selected by simple random sampling in three groups.
- Random locations should be discarded (samples not collected) if they fall within vegetation or have >50% litter cover.
- Three composite samples can be formed by grouping all samples selected in the first, second and third groups respectively (Figure 8).
- Collect 1 cm deep scoop samples (~250 g) from each random location within the cropland or rangeland site.

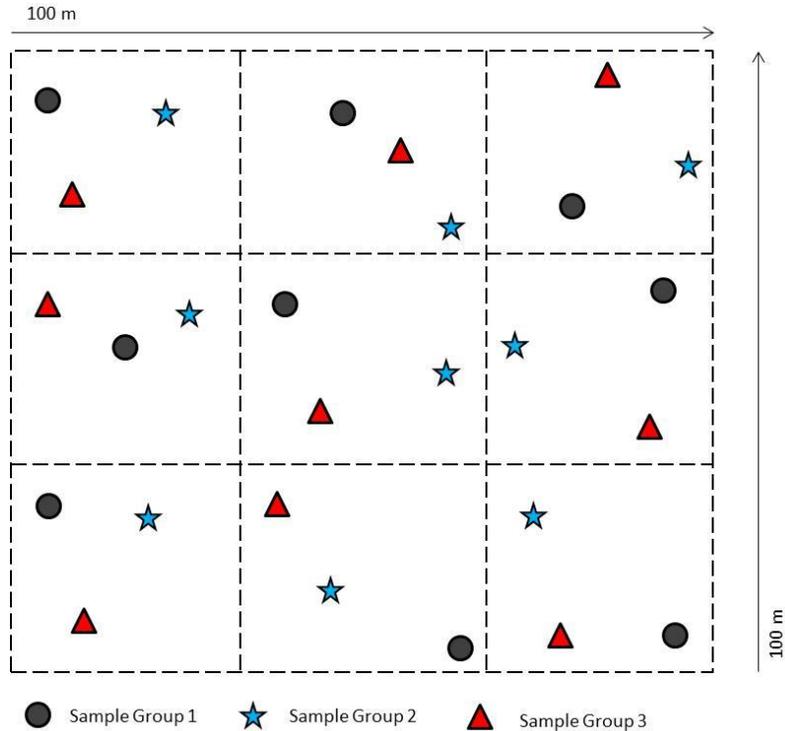


Figure 8: Soil sampling design for Network sites in both croplands and rangelands.

### 9.1.2 Sample storage and analysis

- Samples should be collected and stored in individually labelled bags and kept in a dry place before being sent to the USDA Jornada Experimental Range for analysis of the particle size distribution and other properties (e.g., mineralogy, organic matter and  $\text{CaCO}_3$ ) that influence the soil erodibility. These analyses will be conducted at a single location using standard equipment and methods to ensure results are comparable among the sites and suitable for input to models.
- Methods and results from the Jornada soil analyses will be provided to all sites.
- Sites are welcome to complete their own soil analyses in addition to those run by the Jornada. If separate analyses are to be run then additional soil samples should be collected or the samples split, using a sample splitter, before sending a portion (300 g from each sample group, Figure 7) to the Jornada for analysis.
- The recommended method for measuring the soil particle size distribution is the hydrometer method, described in: Klute, A. (Ed.) (1986) *Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods*. ASA and SSSA. SSSA Book Ser. 5. ISBN: 0-89118-811-8.
- *Please note* that estimates of soil erodibility (represented by  $u_t$ ) based on soil texture alone are approximate at best. The organization and cohesion of the soil primary particles (i.e., soil structure) has a dramatic effect on  $u_t$ . Actual erosion rates for recently disturbed, poorly structured, soil can be significantly larger than rates for well-structured soil of the same texture. Therefore, direct measurement of  $u_t$  (described in Part 7) is also necessary.

### 9.1.3 Measurement frequency

No standard has been established. Baseline soil measurements should always be completed at project initiation. Subsequent soil measurement frequency depends on other related project objectives, precision and accuracy requirements, and the amount of soil loss. Due to the preferential loss of fine particles under wind erosion, soil texture can change with time. The rate of change is slowed with tillage, where soil surface changes are diluted by mixing. Even in non-tilled systems, however, the short-term impact of soil texture changes on soil erosion are generally very small relative to the effects of changes in vegetation cover and structure, and soil surface disturbance. A single baseline measurement should be sufficient at most sites, but more frequent measurements may be required at sites undergoing significant (>5 cm) erosion/deposition.

## 9.2 Vegetation measurements

Vegetation and non-erodible roughness (e.g., rocks) protect the soil surface. They influence the erodible area of a landscape and the wind shear stress (energy) that can act to erode exposed soil surfaces. The *cover*, *distribution* and *height* of vegetation and other non-erodible roughness elements determine their effectiveness in reducing wind erosion. The methods for measuring these attributes are based on those used by the NRCS, BLM and other agencies for national rangeland monitoring, allowing data to be combined and compared at multiple spatial and temporal scales.

- The sampling methods (and instructional videos) for establishing transects, photo points, vegetation fractional cover, canopy height and canopy gap-size distribution are described in: Herrick et al. (2015) *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems, 2nd Edition* (<https://www.landscapetoolbox.org/manuals/monitoring-manual/>)
- Data recording sheets for LPI, height and canopy gap are available on the Documents page at <https://winderosionnetwork.org>.
- All data, including photo point images, and should be submitted through the Data Submission Portal at <https://winderosionnetwork.org> after every sampling effort.

### 9.2.1 Vegetation transect design

Transects should be used to measure the cover, distribution and height of vegetation and non-erodible roughness. The transect design should be based on the following methods:

- Vegetation sampling should be conducted on three (3) 100 m transects at both cropland and rangeland sites.
- The transects should follow bearings of 0°, 60° and 120°, intersecting at the center of the site (cropland sites; Figure 9) or at the meteorological tower (rangeland sites; Figure 10).
- Data points for LPI falling on the concrete tower base should be recorded as “PADD” on the data recording sheets in the Top, Soil Surface, and Height columns. The concrete start and end distances should be recorded as PADD start and PADD end on top of the Gap recording sheet.
- The transect design enables detailed directional estimates of the fractional vegetation cover, vegetation canopy gap-size distribution and canopy height to be acquired in an efficient way that can be related to the meteorological tower measurements of

aerodynamic roughness height ( $z_0$ ) and horizontal sediment mass flux from the MWAC samplers.

- It is acceptable and not an issue if a whole transect falls in a row interspace at cropland sites. This will provide information required for model development.
- Measurements along the transects will be treated as repeated measures. Where practical (e.g., rangeland sites), transect start and end points should be marked with rebar stakes to ensure that transect lines are in exactly the same place during each measurement. Markers on field boundaries may be used at cropland sites.
- The transect design and coverage also facilitates comparison of fractional vegetation cover with remotely sensed estimates. Such comparisons cannot be made reliably with vegetation measurement along a single line transect.

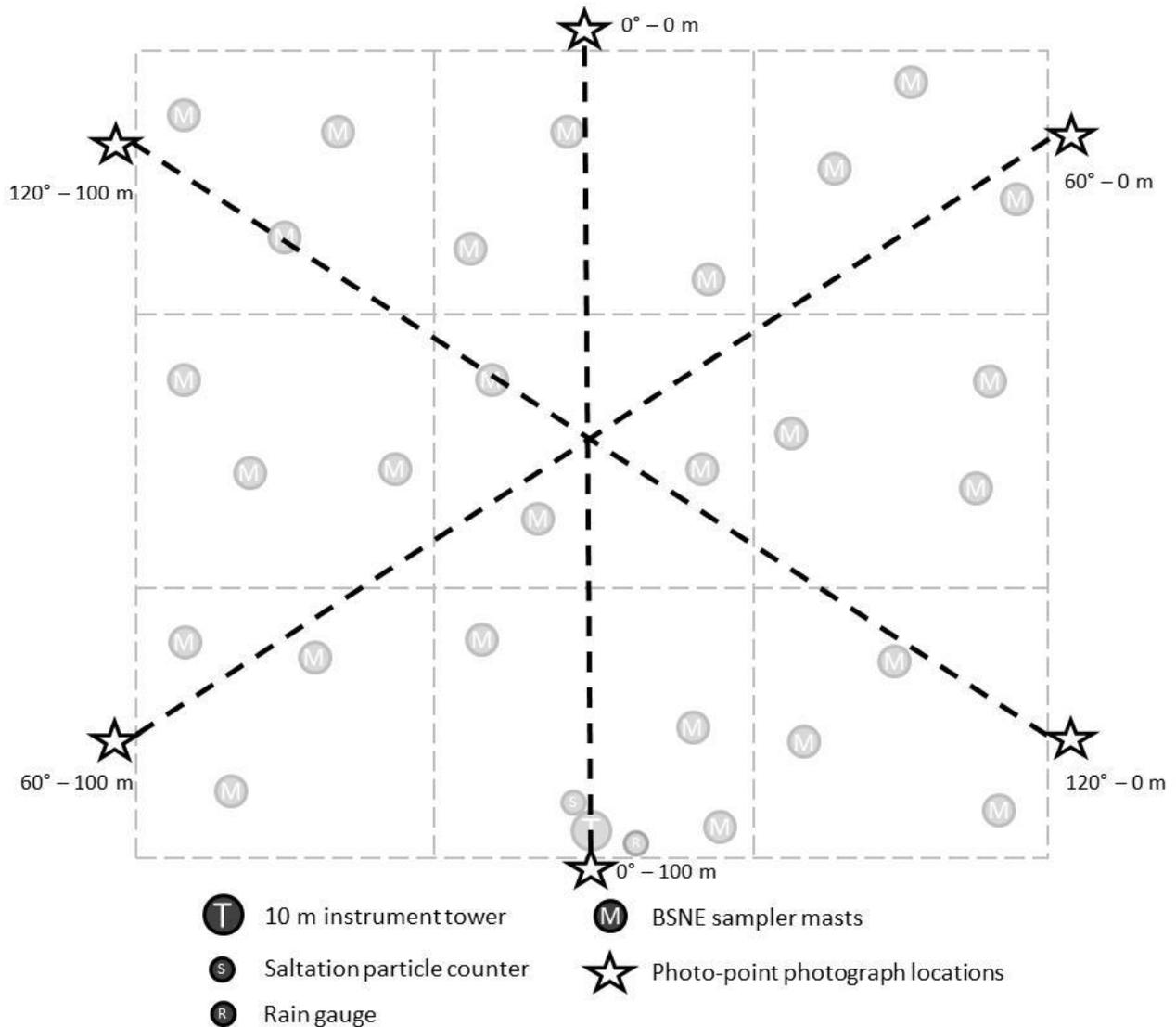


Figure 9: Illustration of the position of the vegetation transects for a cropland site. Note: this illustration is not drawn to scale.

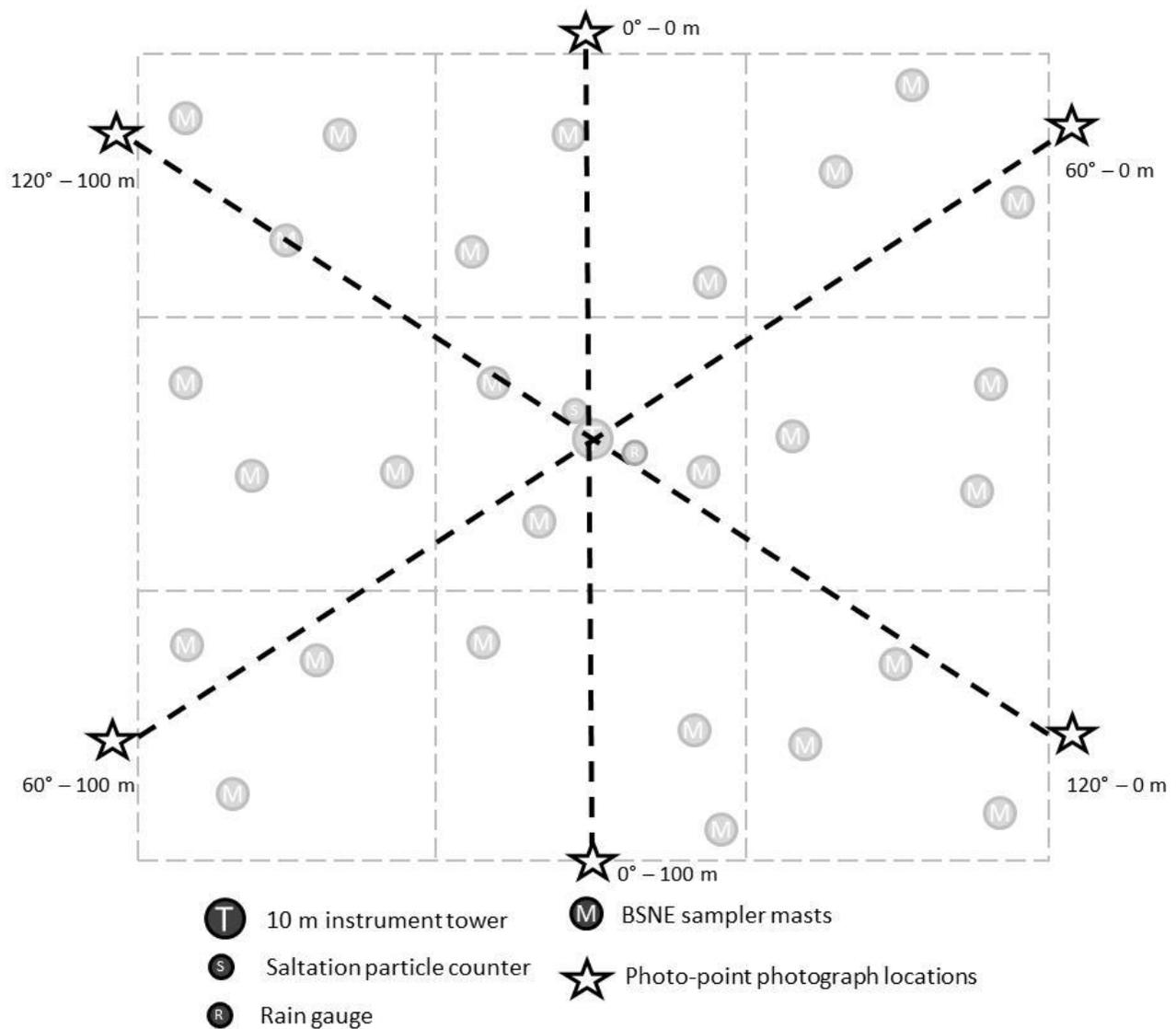


Figure 10: Illustration of the position of the vegetation transects for a rangeland site. Note: this illustration is not drawn to scale.

### 9.2.2 Photo points

Photographs should be taken along each transect from the transect start and end points (photos) with a label (i.e., whiteboard within the photo frame) to indicate the site ID, transect location, transect start or end, direction and date.

- Transect start and end points should be labelled (following the convention of “Transect direction ID – End of transect from which photo is taken, in meters”) as follows on the whiteboard: 0° – 0 m, 0° - 100 m, 60° - 0 m, 60° - 100 m, 120° - 0 m, and 120° - 100 m (Figures 9 and 10).
- For uniformly tall vegetation (e.g., cropland sites when vegetation is taller than 125 cm), photographs should be taken from 5 m back from the transect, with the camera positioned 30 cm above the height of the vegetation, angled so that the bottom of the

view finder is pointed at the end of the transect tape (even though the tape end may be obscured by vegetation). The whiteboard should be held at the top of the canopy in the center of the photo. Do not move or alter the vegetation structure when taking photos.

### *9.2.3 Vegetation cover: line-point intercept method*

Line-point intercept (LPI) provides data that can be used to calculate plant cover and composition indicators, including the percentage bare ground, foliar and basal cover by species and plant functional or structural groups.

- LPI measurements should be made at a sampling interval of 25 cm. This will ensure consistency in the measurements and ability to detect cover types at both cropland and rangeland sites.
- Vegetation types should be recorded using the USDA plant codes, which can be found at: <https://plants.sc.egov.usda.gov/java/>
- Specimens of unknown plants should be kept for later identification.
- The following soil surface codes should be used: rock fragment sizes: FG: 2-5mm, GR:>5-76mm, CB:76-250mm, ST:250-600mm; BR (bedrock), LC (lichen crust), CY (cyanobacteria crust), D (duff), AG (soil aggregates/clods, >2mm), LM (loose erodible soil, <2mm), PC (physically crusted soil), EL (embedded litter), M (moss).
- Note that AG, LM, and PC soil surface codes and DN/S (dung), AM (animal material, unattached) and HT (human trash) in the mid-layer codes are not specified in the Monitoring Manual, but should be used here.

### *9.2.4 Vegetation canopy height: cylinder height method*

Measurements of the vegetation canopy height should be made with the LPI measurements to describe the height of the plant community or crop. The aim of this approach is to be able to describe in detail the roughness characteristics of the site, providing a basis for the model to account for multiple roughness layers (i.e., trees, shrubs, grasses and oriented soil ridges).

- Canopy height should be recorded as the maximum height of any vegetation element (leaf or stem) located within a 15 cm radius every 2 m along the transects.
- If no vegetation is present then height is recorded as zero.

### *9.2.5 Vegetation spatial distribution (canopy gap-size distribution): canopy-gap intercept method*

Canopy gap measurements should be taken to determine the horizontal structure of the plant community, and therefore its distribution. While the canopy gap method was developed for rangelands, it provides a suitable estimate of the distribution of plants in croplands. Measuring canopy gap distribution along intersecting transects will ensure that along- and across-row canopy distributions are measured.

- In order to compare data with NRI and BLM records, canopy gaps are interrupted by any plant species, including annuals.
- Record the beginning and end of each gap between plant canopies longer than 5 cm.
- Canopy occurs any time 50% of any 3 cm segment of tape edge intercepts live or dead plant canopy, based on a vertical projection from canopy to ground.

- For croplands and rangeland sites with annual plants, gaps may be stopped by individual crop plants, annual grasses and forbs.
- For cropland sites the soil ridge height, spacing and orientation should be recorded at this time.
- This method is labor intensive, but will provide the information necessary to develop the wind erosion roughness model beyond the capabilities of currently available schemes.

### 9.2.6 Measurement frequency

Baseline vegetation measurements should always be conducted at project initiation. Subsequent vegetation measurement frequency depends on the temporal dynamics of vegetation cover and structure. In general the following protocol applies:

- For *croplands* a measurement frequency should be used that captures changes in biomass through the growing season and in response to management interventions (e.g., crop rotations, pre- and post-harvest, mulching, tillage). This should be determined on a site basis depending on crop type and its growth rate.
- For *rangelands* a measurement frequency should be used that captures seasonal changes in vegetation cover and structure (e.g., Figure 11).

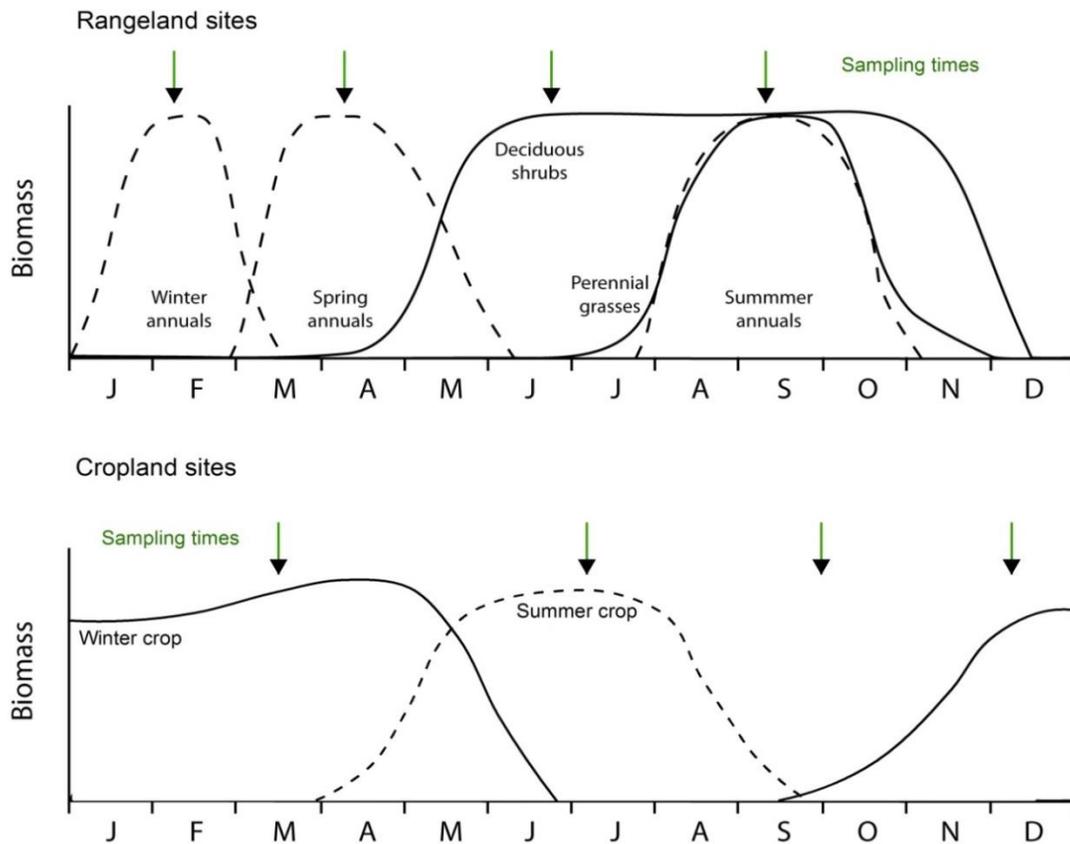


Figure 11: Idealized diagram showing example sampling times to measure seasonal variations in vegetation biomass that affect wind erosion, captured by fractional cover, canopy gap, and height methods. Note: sampling times will vary for each site depending on climate and management. Image courtesy of Dawn Browning, 2015 (personal communication).

- At locations with snow cover during winter months, vegetation sampling may be restricted to the spring, summer and fall to capture the changes in biomass. However, collecting data during the winter may be appropriate if sites are susceptible to wind erosion at that time.
- Note: for cropland sites LPI *should still be run* if fields are fallow or out of crop. It is important to know when and for how long the soil is bare or covered with residue.
- Vegetation sampling times can be flexible to account for inter-annual variability in biomass production and management.

## 10. Data reporting and storage protocol

It is important for the success of the Network that all data be stored in a standard format.

- Forms are available for all data collection on the Documents page at <https://winderosionnetwork.org>.
- All meteorological data will be transferred via cell network and uploaded directly to a central Network database in the format prescribed in the standardized data logger program (Appendix V).
- All vegetation data (LPI, height, canopy gap), vegetation transect photo points, site management records, site maintenance records, MWAC sediment sample data, and time-lapse camera photos should be uploaded to <https://winderosionnetwork.org> using the Data Submission Portal.
- The Database for Inventory, Monitoring and Assessment, DIMA) is available for free download at: <https://jornada.nmsu.edu/node/2754> and can be used for data management.

## 11. Summary of core methods

This document has described a set of methods for measuring factors controlling wind erosion and the direct measurement of horizontal sediment mass flux. Following the core methods will ensure that reliable data are obtained for the National Wind Erosion Research Network, and that this data has the greatest potential for multiple applications. These applications are:

- evaluating controls on wind erosion;
- evaluating wind erosion rates;
- calibration, testing and application of predictive models; and
- future development and testing of spatially explicit models and remote sensing applications

In some cases there may be opportunities to extend the core methods to collect either more detailed data or additional data on wind erosion controlling factors. The literature cited in this document provides descriptions of approaches that can be used to extend the core methods described here for wind erosion monitoring and assessment.

Table 3 lists those methods that *can* and *cannot* be modified, and the implications for the Network of doing so.

Table 3: Field methods described in this document that *can* and *cannot* by modified to suit individual site needs.

Method	What <i>can</i> be Modified	What <i>cannot</i> be Modified
Line-point intercept with plot-level inventory	<ul style="list-style-type: none"> <li>Additional information about species at all or subset of points (e.g., dead vs. live hit).</li> </ul>	<ul style="list-style-type: none"> <li>Number and length of transects (3 x 100 m transects)</li> <li>Number of points sampled along transects (sampling every 25 cm)</li> <li>Foliar vs. canopy cover (must use foliar)</li> <li>Definition of litter vs. standing dead (litter is detached; standing dead is included in foliar cover)</li> <li>Size threshold between soil and rock fragments (2mm)</li> </ul>
Vegetation height	<ul style="list-style-type: none"> <li>Nil</li> </ul>	<ul style="list-style-type: none"> <li>Radius of circle within which maximum height is determined (6" or 15 cm)</li> <li>Number, length and orientation of transects (3 x 100 m)</li> <li>Number of points sampled along transects (sampling every 2 m)</li> </ul>
Canopy gap measurement	<ul style="list-style-type: none"> <li>Nil</li> </ul>	<ul style="list-style-type: none"> <li>Number, length and orientation of transects (3 x 100 m)</li> <li>Minimum gap size (5 cm)</li> <li>Definition of canopy necessary to stop a gap (50% cover of any 3 cm segment)</li> <li>Inclusion of annual grasses and forbs</li> </ul>
Soil sample collection	<ul style="list-style-type: none"> <li>Sample locations within plot (should be randomly identified within GIS layer of site generated during site establishment)</li> <li>Additional soil sampling depths (&gt;1 cm)</li> </ul>	<ul style="list-style-type: none"> <li>Depth at which surface soil samples are collected (0-1 cm)</li> </ul> <p>Note: samples collected during site establishment, not every month.</p>

<b>Method</b>	<b>What <i>can</i> be Modified</b>	<b>What <i>cannot</i> be Modified</b>
Meteorological measurements	<ul style="list-style-type: none"> <li>• Lower anemometer heights</li> <li>• Distance of saltation particle sensor from 10 m mast (minimum of 3 m)</li> </ul>	<ul style="list-style-type: none"> <li>• Height of upper anemometers and wind vane (5 m and 10 m)</li> <li>• Data recorded and sampling and logging intervals</li> </ul>
Wind erosion threshold measurement	<ul style="list-style-type: none"> <li>• Nil</li> </ul>	<ul style="list-style-type: none"> <li>• Type of saltation particle sensor used</li> <li>• Data sampling and logging intervals</li> </ul>
Sediment mass flux samplers	<ul style="list-style-type: none"> <li>• Nil</li> </ul>	<ul style="list-style-type: none"> <li>• A minimum of four (4) samplers must be used on each vertical MWAC mast.</li> </ul>

## SECTION II – Supplementary methods

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### 12. Recommended approaches for additional data collection

This section provides a set of supplementary methods that can be used to obtain more information about wind erosion processes than with the core methods alone. The section also provides some suggestions for modifying the core methods to expand the utility of the data collected. In particular, these suggestions include the collection of additional measurements of dynamic soil surface properties. These soil measurements may be particularly useful for characterizing the erodibility of cropland sites.

#### 12.1 Site location and description

For rangeland sites, supplementary information acquired through Pedoderm and Pattern Class and Rangeland Health assessments can aid interpretation of wind erosion processes with respect to the site condition:

- The methods for Pedoderm and Pattern Class assessments are described in: Burkett et al. (2012) *A field Guide to Pedoderm and Pattern Classes Version 2.3* (<https://jornada.nmsu.edu/biblio/field-guide-pedoderm-and-pattern-classes-version-23>)
- The methods for making a Rangeland Health site assessment are described in: Pellant et al. (2005) *Interpreting Indicators of Rangeland Health* (<https://jornada.nmsu.edu/sites/jornada.nmsu.edu/files/IIRHv4.pdf>)

#### 12.2 Soil measurements for cropland sites

##### **Soil surface roughness**

Measures of the roughness of the soil surface can provide additional information for interpreting management and climate effects on soil erodibility ( $u_{*t}$ ) and the aerodynamic roughness ( $z_0$ ) of the soil surface as it affects the wind shear velocity ( $u_*$ ). Soil surface roughness measurements can be made at two scales. These are (1) the scale of soil ridges produced by tillage (oriented roughness), and (2) the scale of the soil aggregate / clod (random roughness).

- Oriented roughness produced by tillage (ridges created by tillage tools in the direction of tillage) can be described in terms of the ridge height, ridge spacing and ridge direction (Zobeck et al., 2003a).
- Oriented roughness measurements are included as part of the core methods in the site management records.
- Random roughness can be measured by pin meter, chain or laser profiler, and expressed as the standard deviation of height elevations along the soil surface (Zobeck et al., 2003a). Random roughness measurements do not include surface slope and oriented roughness effects.
- Random roughness can also be measured at cropland sites following tillage treatments.
- If collected, random roughness measures should be included in the site management record (Appendix II).

- If random roughness measurements are taken, this should be done at a minimum of 5 locations along each of the six 50 m vegetation transects.

### **Soil dry aggregate size distribution and erodible fraction**

Measurements of the soil dry-aggregate size distribution and erodible fraction may be useful at cropland sites for interpreting the soil erodibility ( $u_{*t}$ ) responses to tillage treatments, and at rangeland sites where crusted soils have been disturbed (e.g., by livestock trampling), but remain in an aggregated state.

- Methods for measuring the soil dry-aggregate size distribution (DASD) using rotary sieves or nested vibratory sieves are described in Zobeck et al. (2003a). We recommend the use of vibratory sieves as they are typically more accessible.
- The soil erodible fraction (EF) represents the fraction of soil aggregates at the soil surface that are smaller than 0.85 mm in size. These aggregates can be mobilized and transported by the wind.
- The soil EF can be measured by gently passing a known mass of surface soil (top 1 cm) through a 0.85 mm sieve. The mass fraction that passes through the sieve is the erodible fraction, which can be calculated as a percentage of the total sample mass.
- 10 soil samples collected from random locations within a site should be used to assess the DASD and EF. The average and standard deviation can be used to represent the EF.
- It is recommended that measures of the soil DASD and EF are made regularly (minimum of *monthly*) at cropland sites to measure the effect of management on the soil erodibility.
- A minimum of 5 locations should be sampled along each of the six 50 m vegetation transects.

### **Crust characteristics**

The presence of physical and biological soil crusts can affect the erodibility of soil by modifying the threshold shear velocity for soil mobilization by wind ( $u_{*t}$ ), and the supply of erodible sediment that can be transported by wind. Soil crusts form (physical) or grow (biological) in response to precipitation events and so are dynamic features of the soil surface that affect wind erosion. The effect of crust characteristics on wind erosion is still insufficiently understood to enable accurate representation in wind erosion models. However, knowledge of crust characteristics can assist in understanding soil erodibility dynamics and rates of wind erosion.

- The fractional cover of biological soil crusts will be measured as part of the Line Point Intercept method described in Part 9.2.2 of the Core Methods.
- The strength of physical and biological soil crusts can be measured with a pocket penetrometer to provide an indicator of the resistance of crusts to the abrasive action of saltating grains (through the force necessary to rupture the crust) (Zobeck et al., 2003a).
- Soil crust strength measurement with a penetrometer should be integrated into the Line Point Intercept measurements along the six 50 m transects at sites. A minimum of 5 crust strength measurements should be made per transect, and the average and standard deviation of the measurements should be used to report the crust strength and its variability.
- Details of the soil crust strength measurement are given in Zobeck et al. (2003a).

## 12.3 Sampling directional sediment flux

### *Sediment sampler design*

A mast consisting of fixed direction MWAC samplers can be used to provide more data on the dominant/less dominant directions in which sediment transport occurs at a site. Directional samplers consist of an array of eight MWAC samplers mounted with brackets to a frame, positioned toward the four cardinal directions and four intercardinal directions (N, NE, E, SE, S, SW, W and NW). The fixed samplers provide a measure of horizontal sediment mass flux at a single height from each direction (Figure 12). Multiple arrays of fixed samplers can be positioned around a site to estimate the sediment mass flux and net soil loss within a specific eroding area.



Figure 12: MWAC samplers deployed on a directional bracket to sample sediment flux from the four cardinal and four intercardinal directions (N, NE, E, SE, S, SW, W and NW).

Note: Sampler inlets must be horizontal to the ground, irrespective of whether the cans are positioned in an upright or horizontal way (as per Figure 6).

## 12.4 Sampling vertical (dust) emission flux

Measurements of the vertical (dust) emission flux ( $F$ ) are required to calibrate and test model performance in estimating dust emission. This mode of sediment transport differs from the horizontal (saltation) flux in that it represents the sediment carried in suspension by the wind. This fine sediment ( $<63 \mu\text{m}$ ) is typically enriched in soil nutrients and carbon, can travel long distances ( $>10^3 \text{ km}$ ), and impacts local site productivity, human health, climate and biogeochemical cycles (e.g., carbon cycle).

An approximation of the vertical dust flux can be obtained by measuring the particle size distribution of sediment flux trapped in MWAC samplers. However, like Big Spring Number Eight (BSNE) samples, MWACs are inefficient (<40%) at capturing sediment with diameter <10  $\mu\text{m}$ . This approach may therefore underestimate the fine dust flux.

Direct measurement of the fine (< 10  $\mu\text{m}$ ) dust emission flux can be carried out using isokinetic dust samplers. A range of instruments is available and the methods for deploying these are described in Zobeck et al. (2003a).

## 12.5 Sampling dust deposition flux

Measurements of the vertical (dust) deposition rates  $F_d$  are required with measurements of the vertical (dust) emission  $F$  to quantify the net vertical sediment mass flux. The dust deposition flux should be measured using the trap design of Reheis and Kihl (1995), detailed in Appendix X, and on the Documents page at <https://winderosionnetwork.org>.

- A minimum of three (3) deposition traps should be located at a Network site in order to estimate the variance in deposition rates across the site.
- The traps should be mounted at a height of 1.5 m (to base of pan) above the soil surface to avoid contributions from the horizontal (saltation) mass flux.
- The traps should be located randomly around the site, with locations determined using GIS and accurate (<25 cm) GPS for positioning in the field.
- Figure 13 illustrates the deployment of a cake pan type deposition trap.



Figure 13: Photograph of a dust deposition trap (e.g., Reheis and Kihl, 1995) deployed in the field.

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## APPENDIX I – Soil Field Texture Analysis

The following flow diagram outlines the process of determining soil texture in the field. Note that field texture analysis of soils is a first-order approximation of the true texture. Therefore training via multiple sources (e.g., in the field, calibration on laboratory-tested soils, and considerable practice) is required before proficiency in soil texturing may be achieved.

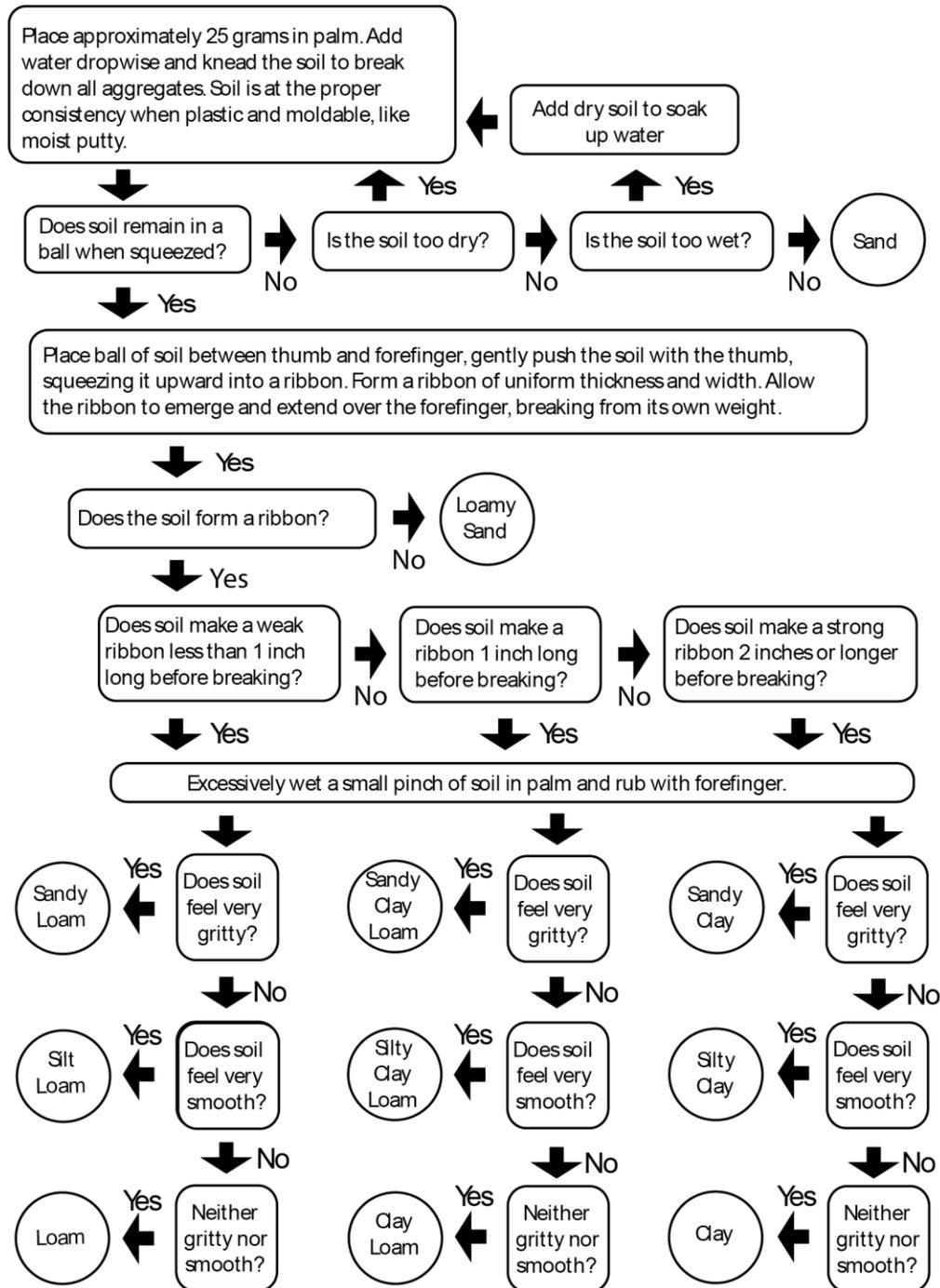


Figure A1. Flow chart for determining soil texture in the field by hand.

## APPENDIX II – Site Management Records

The following pages provide example reporting sheets for management information at rangeland and cropland Network sites. These sheets can be found on the Network website. Follow the format of the reports in all cases. Entries may be left blank if not appropriate.

Management Recording Sheets in pdf and MS Excel formats can be accessed on the Documents page at: <https://winderosionnetwork.org>.

### Management record reporting structure for cropland sites

<b>NATIONAL WIND EROSION RESEARCH NETWORK</b>														
<b>CROPLAND SITE MANAGEMENT SURVEY</b>										Site: _____				
Historically, how was this field cropped or managed, and for how long (years): _____														
Historically, how long was this field grazed if at all (approx. number of years): _____														
List field improvements (e.g., watering points, fencing, wind breaks, etc.) and distances to tower which existed prior to tower installation: _____														
How often do you plant cash crops or cover crops (something other than your primary crop)? _____														
What crop(s)? _____														
Comments or details not mentioned above:														

**Table for recording management details – Record an entry for every activity or manipulation of this field.**

Date	Name(s)	Crop	Activity or Operation	Tillage	Soil Random Roughness (mm)	Soil Oriented Roughness			Irrigation		Herb / Pesticide (/ac)	Fertilizer (/ac)	Estimated Yield (lbs/ac)	Stocking Rate (if applicable)	Notes	
						Ridge Height (cm)	Ridge Spacing (cm)	Ridge Aspect (azimuth)	Method	Amount (cm/hr)						

**Management record reporting structure for rangeland sites**

<b>NATIONAL WIND EROSION RESEARCH NETWORK</b>									
<b>RANGELAND SITE MANAGEMENT SURVEY</b>					<b>Site:</b> _____				
Historically, how was this pasture managed, and for how long (years): _____									
Historically, how long was this pasture grazed if at all (approx. number of years): _____									
List pasture improvements (e.g., watering points, fencing, wind breaks, etc.) and distances to tower which existed prior to tower installment: _____									
Comments or details not mentioned above:									

**Table for recording management details -- Record an entry for every management action for this pasture.**

Date	Name(s)	Activity or Operation	Pasture Size	Stocking rate	Livestock species/breed	Duration (months)	Pasture Improvement	Estimated Yield at end of growing season (lbs/ac)	Notes

## APPENDIX III – Recommended Meteorological Equipment and Costs

Supplies include meteorological sensors, hardware and communications equipment used to collect data for the calibration and testing of a national wind erosion model. The orders include equipment that is specialized for the collection of the necessary data for this purpose. A complete description of the supplies, quantity and cost is as follows:

Item	Product Code	Unit Price*	Quantity	Total Cost*
Wind speed sensor 23ft cable	RM Young 03101-L	\$275.35	1	\$275.35
Wind speed sensor 17ft cable	RM Young 03101-L	\$272.65	1	\$272.65
Wind speed sensor 15ft cable	RM Young 03101-L	\$270.85	3	\$812.55
Wind speed/direction sensor 35ft cable	RM Young 03002-L	\$669.75	1	\$669.75
Temperature sensor 33ft cable	107-L	\$109.85	1	\$109.85
Temperature sensor 13ft cable	107-L	\$100.85	1	\$100.85
Temperature/RH sensor Rotronic HygroClip2 23 ft cable	HC2S3-L	\$458.39	1	\$458.39
Temperature/RH shield (6 plate)	41003-5A	\$120.00	2	\$240.00
Temperature/RH shield (10 plate)	41003-5	\$170.00	1	\$170.00
Rain gauge 20ft cable	TE525-L	\$364.00	1	\$364.00
Battery (12V, 24Ah)	BP24	\$145.00	1	\$145.00
Charge regulator	CH100-SW	\$190.00	1	\$190.00
Solar panel (20W)	SP20	\$290.00	1	\$290.00
CR1000 data logger	CR1000-XT-SW	\$1,682.05	1	\$1,682.05
Conversion module	LLAC4-SW	\$125.00	1	\$125.00
Compact flash module	CFM100	\$250.02	1	\$250.02
Compact flash memory card (-40-+85C)	CFMC2G	\$52.00	1	\$52.00
Enclosure	ENC16/18	\$390.00	1	\$390.00
4G LTE CAT1 cellular module for Verizon	CELL210	\$435.00	1	\$435.00
Null modem cable 9-pin male-male	18663	\$4.20	1	\$4.20
CS I/O to 9-pin RS-232 DCE Interface	SC932A	\$137.50	1	\$137.50
Antenna	800MHz YAGI Antenna	\$160.00	1	\$160.00
Surge suppressor kit		\$110.00	1	\$110.00
Cellular phone antenna	COAXNTN-L33	\$115.68	1	\$115.68

cable				
Antenna mounting kit	CM230	\$30.00	1	\$30.00
UT30 30ft Instrument tower	UT30	\$840.00	1	\$840.00
Tower mounting base	RFM18	\$140.00	1	\$140.00
Grounding kit	UTGND	\$56.00	1	\$56.00
Guy wire kit	UTGUY	\$190.00	1	\$190.00
4ft crossarms	CR204	\$84.00	6	\$504.00
DCE Interface	SC932A	\$95.00	1	\$95.00
Right-angle sensor mount	CM220	\$28.00	6	\$168.00
Loggernet software	Campbell Scientific	\$579.35	1	\$579.35
Sensit saltating particle sensor	Sensit HN14-LIN	\$1850.00	1	\$1850.00
Time lapse camera	Reconyx HC500	\$499.99	1	\$499.99
Camera enclosure	Hyperfire security enclosure	\$49.99	1	\$49.99
Camera mounting bracket	CAMLOCKbox	\$36.49	1	\$36.49
Memory card (4GB)		\$19.99	1	\$19.99
Camera lock	Master Lock 72-inch key padlock cable	\$16.98	1	\$16.98
Misc. tower hardware (e.g., hose clamps, cable ties, aluminum flexible conduit)	Various			~\$500.00

\* Prices approximate and subject to change.

Installation of the meteorological tower and hardware (base plate, guy wires, and pegs) follows instructions provided in the user manual by Campbell Scientific or other relevant supplier.

**Note A:** We recommend fabricating your own stakes to hold the tower guy wires. Each stake can be a 4.5 ft length of 0.5 inch steel rod or rebar with a large (e.g., 7/8 inch) washer welded to the top. Three stakes are required for one tower.

**Note B:** Less expensive solar panel and battery options are available and can be substituted for those listed here.

## APPENDIX IV – Meteorological Tower Sensor Wiring Instructions

---

The following table specifies wiring for the 10 m instrument tower with sensors as outlined in Part 7 of the Core Methods.

Sensor/Instrument	Wire Color	Attach to	Logger/Peripheral
LLAC4	12V	12V	CR1000
	D1	C1	CR1000
	D2	C2	CR1000
	D3	C3	CR1000
	D4	C4	CR1000
	G	G	CR1000
Wind Speed/Direction (03002), 10 m	Green	1H	CR1000
	White	Ground	CR1000
	Clear	Ground	CR1000
	Black	Ground	CR1000
	Red	P1	CR1000
	Blue	VX1	CR1000
Wind Speed (03101), 5 m	Clear	Ground	CR1000
	White	Ground	CR1000
	Black	P2	CR1000
Wind Speed (03101), 2.5 m	White	Ground	LLAC4
	Black	P1	LLAC4
	Clear	Ground	CR1000
Wind Speed (03101), 1.5 m	White	Ground	LLAC4
	Black	P2	LLAC4
	Clear	Ground	CR1000
Wind Speed (03101), 1 m	White	Ground	LLAC4
	Black	P3	LLAC4
	Clear	Ground	CR1000
Wind Speed (03101), 0.5 m	White	Ground	LLAC4
	Black	P4	LLAC4
	Clear	Ground	CR1000
Air Temp (T107), 10 m	Red	1L	CR1000
	Clear	Ground	CR1000
	Purple	Ground	CR1000
	Black	VX2	CR1000

Continued...

Sensor/Instrument	Wire Color	Attach to	Logger/Peripheral
Air Temp	Red	2H	CR1000
(T107), 2 m	Clear	Ground	CR1000
	Purple	Ground	CR1000
	Black	VX3	CR1000
Air Temp / RH	Green	12V	CR1000
(HC2S3), 4 m	Brown	2L	CR1000
	White	3H	CR1000
	Clear	Ground	CR1000
	Yellow	Ground	CR1000
	Gray	Ground	CR1000
Air Temp / RH	Yellow	4H	CR1000
(EE181), 4 m	Blue	4L	CR1000
	Red	12V	CR1000
	Clear	Ground	CR1000
	Black	Ground	CR1000
Rain Gauge			
(TE25WS), 1.5 m	White	5V	CR1000
	Black	C5	CR1000
	Clear	Ground	CR1000
Sensit	Red	12V	CR1000
(HN14-LIN), 0.05 m	White	C6	CR1000
	Black	Ground	CR1000
Solar Panel	Red	Charge	CH100-SW
	Black	Charge	CH100-SW
Raven XTV Modem	Red	12V	CR1000
	Black	Ground	CR1000

### Modem Account Activation

- Activate modem with Verizon Wireless with a machine to machine 250MB/month data plan
- Ensure a “Static” IP address is provided when account is activated

### Modem Setup/Configuration

- Refer to CELL210 4G LTE CAT1 Cellular Module for Verizon Manual.  
<https://s.campbellsci.com/documents/us/manuals/cell200-series-static-qdg.pdf>

### Software Required

- Ace Manager 3.3.0 [https://www.campbellsci.com/19\\_1\\_768](https://www.campbellsci.com/19_1_768)

- Campbell Scientific Loggernet
- Please provide Jornada with modem telephone number, modem address (e.g., [122.100.100.100:6785](https://122.100.100.100:6785)), IMEI, and serial number when complete.

## APPENDIX V – Meteorological Tower Data Logger Program

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This section provides the CR1000 data logger programs for the 10 m instrument tower with sensors as outlined in Part 7 of the Core Methods.

<https://winderosionnetwork.org>

\*\*\*\*\* PROGRAM (A) – Default Program for CR1000 \*\*\*\*\*

Note: This program is loaded as the default and named: default.CR1. The program will enable communications with the data logger should the main program fail.

Public SW12IsOn As Boolean 'this gives the user some feedback on the status of the SW12 port

BeginProg

Scan (1,Sec,3,0)

SW12(1)

SW12IsOn = status.sw12volts(1)

NextScan

EndProg

\*\*\*\*\* PROGRAM (B) – Sampling Program for CR1000 \*\*\*\*\*

'CR1000

'Created by Short Cut (2.9)

'////////// Declare Variables and Units //////////

Public BattV

Public PTemp\_C

Public WS4\_ms

Public WS3\_ms

Public WS2\_ms

Public WS1\_ms

Public WS6\_ms

Public WindDir

Public WS5\_ms

Public T107\_2m

Public T107\_9m

Public AirTC\_4m

Public RH\_4m  
Public Rain\_mm  
Public Sensit  
Public SenSec  
Public Flag As Boolean  
Public Switch12 As Boolean  
Public CellPower As Boolean

Dim BattMin = 11.5  
Dim BattMax = 12.0

Units BattV=Volts  
Units PTemp\_C=Deg C  
Units WS4\_ms=meters/second  
Units WS3\_ms=meters/second  
Units WS2\_ms=meters/second  
Units WS1\_ms=meters/second  
Units WS6\_ms=meters/second  
Units WindDir=degrees  
Units WS5\_ms=meters/second  
Units T107\_9m=Deg C  
Units T107\_2m=Deg C  
Units AirTC\_4m=Deg C  
Units RH\_4m=%  
Units Rain\_mm=mm  
Units Sensit=Counts/Hz

```
'////////// Define Data Tables //////////  
DataTable(Table1,True,-1)  
  DataInterval(0,60,Sec,10)  
  CardOut(0,-1)  
  Sample (1,Switch12,Boolean)  
  Average(1,Round(T107_9m,2),FP2,False): FieldNames("T107_9m")  
  Average(1,Round(AirTC_4m,2),FP2,False): FieldNames("AirTC_4.5m")  
  Average(1,Round(T107_2m,2),FP2,False): FieldNames("T107_2.5m")  
  Maximum(1,Round(RH_4m,2),FP2,False,False): FieldNames("RH4.5m")  
  Totalize(1,Rain_mm,FP2,False): FieldNames("Rain_mm_Tot")  
  WindVector (1,WS6_ms,WindDir,FP2,False,0,0,3):FieldNames("WindDir")  
  Maximum(1,Round(WS6_ms,2),FP2,False,False): FieldNames("WS6_ms_10mMax")  
  Maximum(1,Round(WS5_ms,2),FP2,False,False): FieldNames("WS5_ms_5mMax")  
  Maximum(1,Round(WS4_ms,2),FP2,False,False): FieldNames("WS4_ms_3.5mMax")  
  Maximum(1,Round(WS3_ms,2),FP2,False,False): FieldNames("WS3_ms_2mMax")  
  Maximum(1,Round(WS2_ms,2),FP2,False,False): FieldNames("WS2_ms_1mMax")  
  Maximum(1,Round(WS1_ms,2),FP2,False,False): FieldNames("WS1_ms_.05mMax")  
  StdDev(1,Round(WS2_ms,2),FP2,False): FieldNames("WS2_ms_StDev")  
  Average(1,Round(WS6_ms,2),FP2,False): FieldNames("WS6_ms_10mAvg")  
  Average(1,Round(WS5_ms,2),FP2,False): FieldNames("WS5_ms_5mAvg")  
  Average(1,Round(WS4_ms,2),FP2,False): FieldNames("WS4_ms_3.5mAvg")
```

```

Average(1,Round(WS3_ms,2),FP2,False): FieldNames("WS3_ms_2mAvg")
Average(1,Round(WS2_ms,2),FP2,False): FieldNames("WS2_ms_1mAvg")
Average(1,Round(WS1_ms,2),FP2,False): FieldNames("WS_ms_0.5mAvg")
Totalize(1,Sensit,FP2,False)
Sample(1,SenSec,FP2)
EndTable

```

```

DataTable(Table2,True,-1)
  DataInterval(0,1440,Min,10)
  Minimum(1,BattV,FP2,False,False)
EndTable

```

```

'//////////////////// Main Program //////////////////////

```

```

BeginProg
'Main Scan
CellPower=True
Scan(1,Sec,1,0)
'Default Datalogger Battery Voltage measurement 'BattV'
Battery(BattV)
'Default Wiring Panel Temperature measurement 'PTemp_C'
PanelTemp(PTemp_C,_60Hz)
'03101 Wind Speed Sensor measurement 'WS4_ms' on the LLAC4
PulseCount(WS4_ms,1,11,0,1,0.75,0.2)
If WS4_ms<0.21 Then WS4_ms=0
'03101 Wind Speed Sensor measurement 'WS3_ms' on the LLAC4
PulseCount(WS3_ms,1,12,0,1,0.75,0.2)
If WS3_ms<0.21 Then WS3_ms=0
'03101 Wind Speed Sensor measurement 'WS2_ms' on the LLAC4
PulseCount(WS2_ms,1,13,0,1,0.75,0.2)
If WS2_ms<0.21 Then WS2_ms=0
'03101 Wind Speed Sensor measurement 'WS1_ms' on the LLAC4
PulseCount(WS1_ms,1,14,0,1,0.75,0.2)
If WS1_ms<0.21 Then WS1_ms=0
'03002 Wind Speed & Direction Sensor measurements 'WS6_ms' and 'WindDir'
PulseCount(WS6_ms,1,1,1,1,0.75,0.2)
If WS6_ms<0.21 Then WS6_ms=0
BrHalf(WindDir,1,mV2500,1,1,1,2500,True,0,_60Hz,352,0)
If WindDir>=360 Then WindDir=0
'03101 Wind Speed Sensor measurement 'WS5_ms'
PulseCount(WS5_ms,1,2,1,1,0.75,0.2)
If WS5_ms<0.21 Then WS5_ms=0
'107 Temperature Probe measurement 'T107_C8'
Therm107(T107_9m,1,2,1,0,_60Hz,1,0)
'107 Temperature Probe measurement 'T107_C1'
Therm107(T107_2m,1,3,1,0,_60Hz,1,0)
'HC2S3 (constant power) Temperature & Relative Humidity Sensor measurements 'AirTC4' and 'RH4'
VoltSe(AirTC_4m,1,mV2500,4,0,0,_60Hz,0.1,-40)
VoltSe(RH_4m,1,mV2500,5,0,0,_60Hz,0.1,0)

```

```

If RH_4m>100 AND RH_4m<103 Then RH_4m=100
'TE525/TE525WS Rain Gauge measurement 'Rain_mm'
PulseCount(Rain_mm,1,15,2,0,0.254,0)

'Pulse measurement for Sensit
PulseCount(Sensit,1,16,0,0,1,0)
If Sensit>0 Then SenSec+=1

'Modem 12V Failsafe Instruction (will keep modem off if power drops below 11.5V and allow to turn
on above 12V)
If BattV < BattMin Then
  CellPower = False
Else
  If BattV > BattMax Then CellPower = True

'Modem Power instructions (power on @:50min of hour, power off @:10min of hour)

If CellPower =True AND TimeIntoInterval (50,60,Min) Then PortSet (9,1)
If Flag=false Then
  If TimeIntoInterval (10,60,Min) Then PortSet (9,0)
  Endif
Endif
Switch12 = status.sw12volts(1)

' Scott's Idea
' If BattV< BattMin Then CellPower=False
' If BattV> BattMax Then CellPower=True
' If TimeIntoInterval(50,60,Min)OR CellPower=True OR Flag=True Then PortSet(9,1)
' If TimeIntoInterval(10,60,Min) OR CellPower=False OR Flag=False Then PortSet(9,0)
' End If
' Switch12 = status.sw12volts(1)

'Call Data Tables and Store Data
CallTable(Table1)
CallTable(Table2)
If IfTime(0,60,sec) Then SenSec=0
NextScan
EndProg

```

## APPENDIX VI – MWAC Naming Protocol

This section provides details on naming / labeling MWAC sampler masts for ease of sample collection and data processing.

- Each MWAC mast is named according to the cell in which it is located.
- Cells are named A through I (Figure A2)
- MWAC masts are named A1, A2, A3, etc. through I3.
- Sampler cans mounted on masts are named according to the mast on which they are located, plus their height. For example, for mast “A1” samplers are labeled: A1\_85, A1\_50, A1\_25, and A1\_10. These represent the 85cm, 50cm, 25cm, and 10cm samplers, respectively.

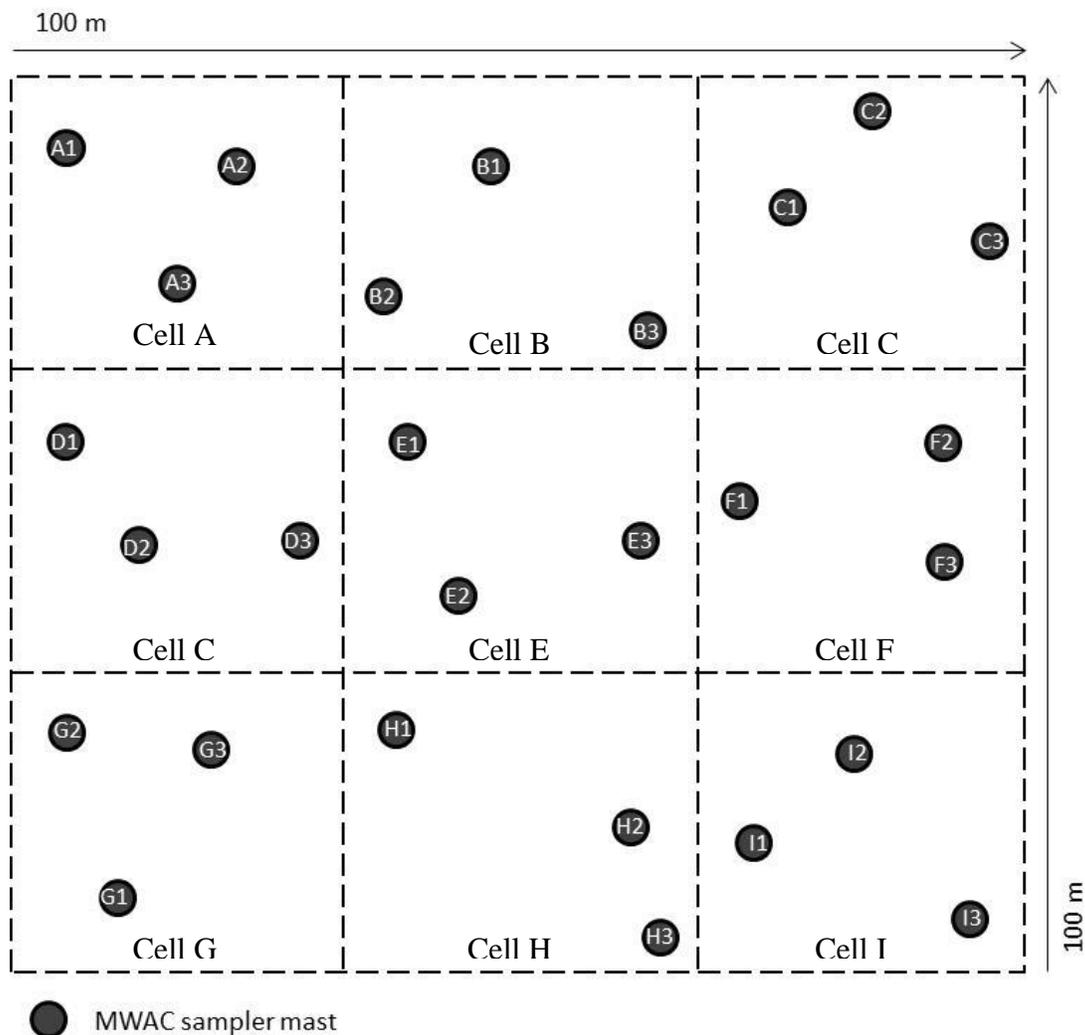


Figure A2. Naming system for MWAC sampler masts at Network sites. Note: This is an example. MWAC sampler locations are determined randomly within each cell, and will be different at each location.

## APPENDIX VII – Time-lapse Camera Setup

---

This section provides support for setting up the Reconyx time-lapse camera. It is most important that users read the manual carefully before use.

- Battery Requirements – 12 rechargeable batteries (Provided w/ charger)
- SD Card Provided – 4GB (10,000 images)

Note: The camera can withstand temperatures from 0° - 120°F

After following instructions in the camera's manual for initial setup, add site name to the auto-stamp for photograph ID purposes:

### ADVANCED SETTINGS

#### TRIGGER

1. Motion Sensor – **OFF**
2. Finished - **OK**

#### TIME LAPSE (*Note: one hour increments*)

1. AM Period – **ON**
2. Start AM Period – **10:00AM**
3. End AM Period – **12:00PM**
4. PM Period – **ON**
5. Start PM Period – **12:00PM**
6. End PM Period – **3:00PM**
7. Picture Interval – **30 MIN**
8. Finished - **OK**

**RESOLUTION** – Set image size to **1080p** (*1080p is ideal for wide screen monitors*)

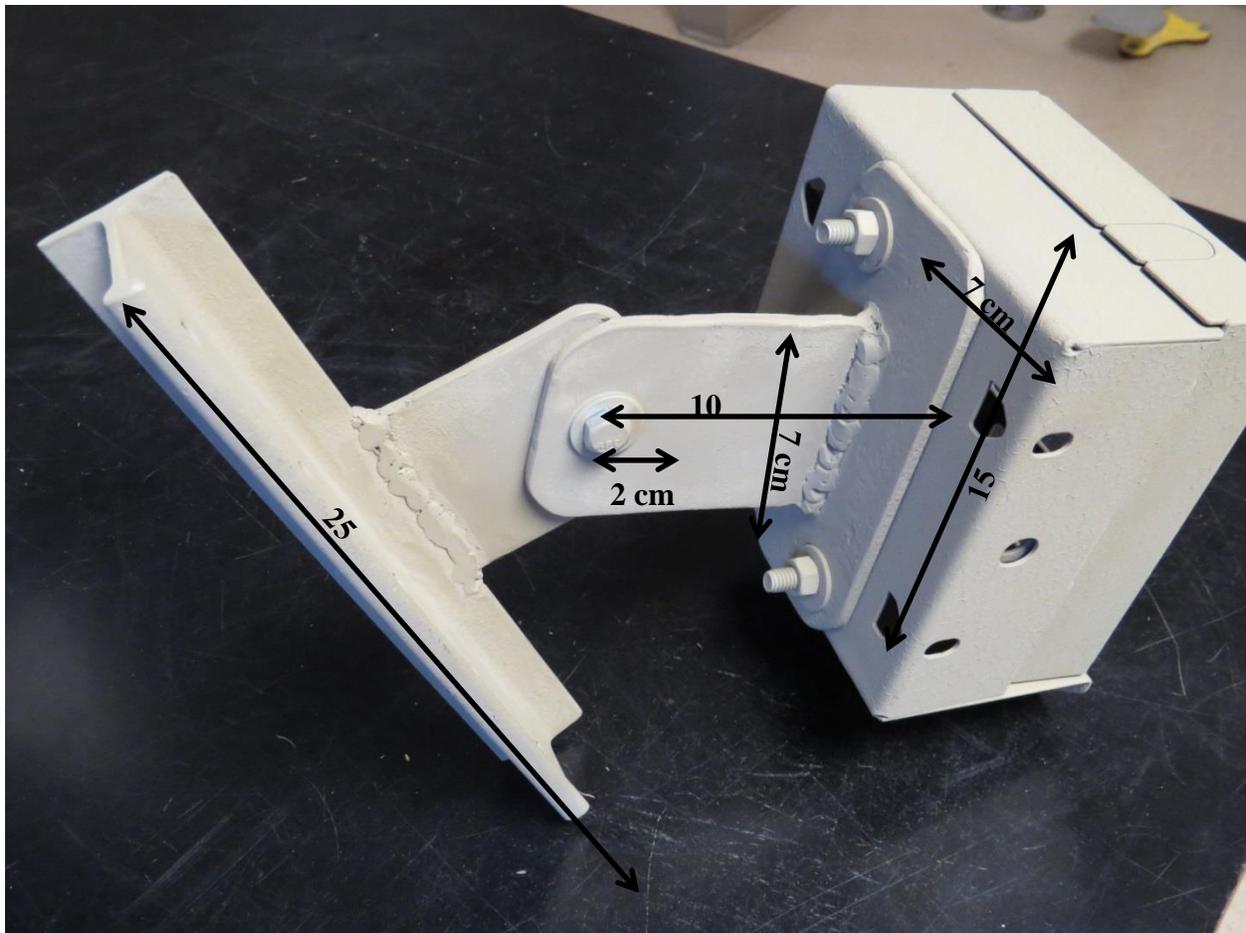
### Camera Attachment to Mast

Cameras are attached to the meteorological mast so photographs provide an overall perspective on site condition. It is not expected that photographs include the whole site, but provide a qualitative indicator of site condition that can be used as a visual reference for interpreting changes in soil surface and vegetation conditions.

Photographs below show a mounted camera. Note that the camera angle is adjustable up and down and to either side. To adjust the angle of the camera, loosen the nut on the bolt holding the 2 articulating plates together, and then retighten at the desired angle turn the black knob on the mount, thus loosening the ball and allowing you to move the camera around the mount.



Figure A3. Photograph showing time-lapse camera mounted to mast with ball-arm for adjusting camera enclosure, in which the camera is contained.



### Photo Tracking

It is recommended that a record be kept of all camera servicing. The image below provides an example of how servicing can be tracked.



## APPENDIX VIII – MWAC Mast Construction Guide

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This section provides details on the construction of masts designed to hold Modified Wilson and Cooke (MWAC) sediment samplers. The original MWAC wind vane design can also be adopted at the discretion of individual sites. However, the recommended mast/sampler combination enables for the fin height to be adjusted (by using a taller mast) so masts can be located close to vegetation while still being able to rotate freely. This ability to be located close to vegetation is essential for sampling the spatial variance in sediment transport at the Network sites. Samplers should not be moved away from vegetation as this will significantly bias the sampling.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. The tools are not patented. None of the authors receive any compensation from manufacturers.

**Caution:** Fabrication of the sampler masts, like any shop fabrication project, can result in injury. If you are not comfortable with the required procedures and standard safety protocols, find someone who is.

### Materials needed for construction of one MWAC sampler mast\*

- 1" steel square tube – 32 ½" length (x1) [ensure wall thickness is suitable to allow tubing to freely rotate around ½" conduit.]
- 1" steel strap – cut into 1/2" lengths (x4)
- 1" steel strap – 5 ½" length (x1) – or 4 x steel right angle/brackets
- 1" steel strap – 3 ½" length (x1) – or 4 x steel right angle/brackets
- ½" aluminum angle – 22" length (x1)
- ½" aluminum angle – 2" length (x1)
- 24" by 24" sheet aluminum, 0.036" thick
- Bolts with washers and nuts (1/4" x ¾" hex bolts, ¼" nuts and ¼" lock washers (x4 each)
- 2 ½ - 3 ½" steel hose clamps (x4)
- 1/8" diameter x ¼" grip rivets (x7)
- *Bench saw (to cut steel strap and sheet aluminum)*
- *Welding materials*
- *Measuring tape*
- *Drill with bits to suit rivets and bolts*
- *Rivet gun*
- *Vice grips*

\* Multiply materials by 27 for construction of 27 MWAC masts.

Note: The length of the square tubing should be adjusted in order to adjust the fin height where increased height is needed so that the fin can freely rotate 360° next to vegetation.

### Sampler mast construction

***It is recommended that the full instruction guide be read prior to commencing the MWAC construction.***

***If you have any questions please contact Nicholas Webb (nwebb@nmsu.edu).***

*Assemble jig and prepare mast components*

1. A jig is useful for holding the mast pieces in place for welding.
2. The jig is built from a piece of 2" x 4" x 1/4" aluminum or steel angle into which slots to accept the 1" pieces of 1/2" x 1/8" strap retainers that hold the hose clamps are cut.
3. It is also necessary to grind out some recesses for the drive gear on the hose clamps so that they sit flat when you weld the retainers over them.
4. The piece of angle is welded to a piece of 1/8" aluminum or steel plate to which the guides for the 34 1/4" pieces of 1" x 1" x 1/8" square tube and fin supports are welded. These can be seen in the picture below (Figure A5). The plate is supported by some pieces of aluminum or steel square tube on the back so that the jig sits level. Clamp the pieces in place using small vice grips with wide throats.



Figure A5. View of jig for welding retainers for hose clamps and fin to mast. Note: Figure A6 shows mast with fittings positioned in jig.

5. Detail of the slots to hold the sampler mounts in place are shown in Figure A6. They will place the sampler inlets at 10, 25, 50, and 85 cm above the ground when the post and support are so installed in the ground. The pictures are for the 85 cm and 50 cm sampler clamps. You will also see the guides and supports for the top of the tube and the upper fin support in Figure A5 as well as the gouge for the clamp gear.

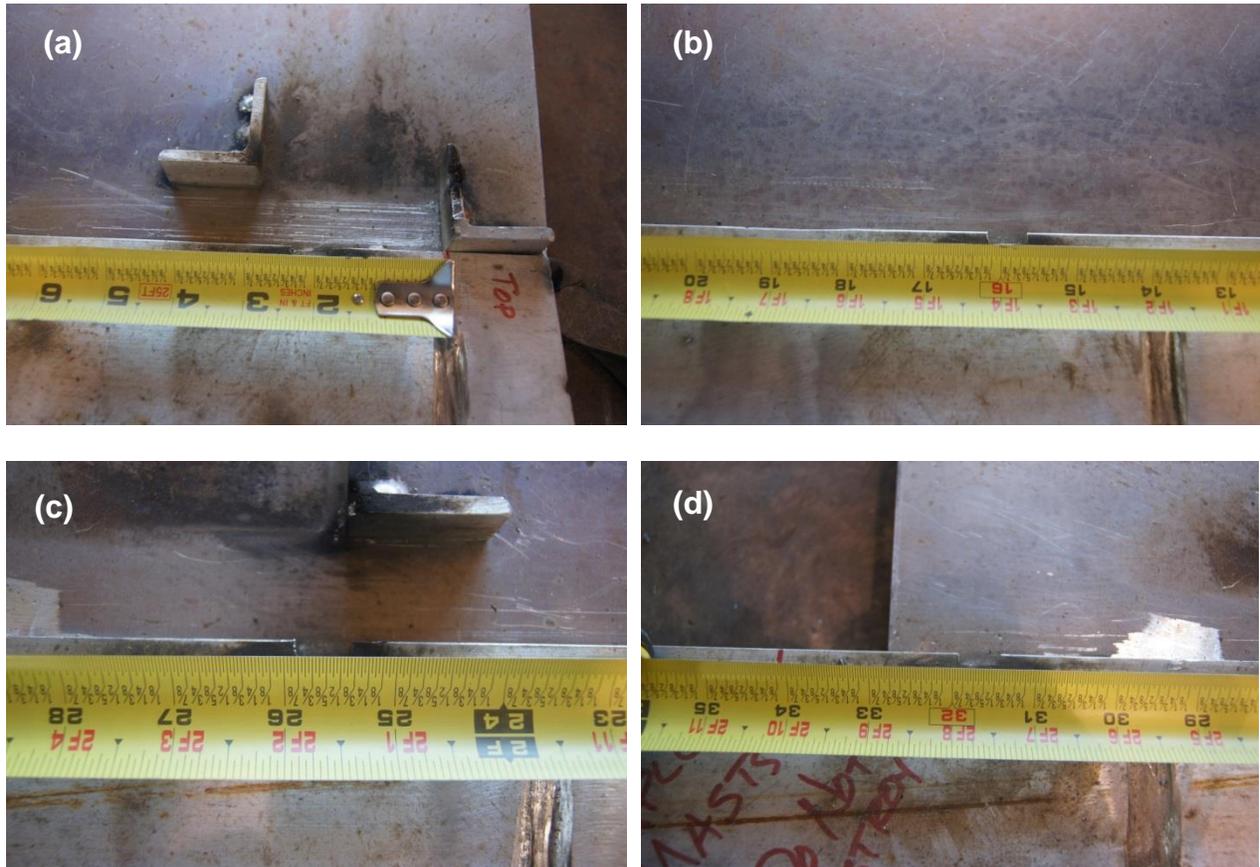


Figure A6. Detail of retainer cuts to place sampler mounts at 10, 25, 50 and 85 cm above the ground.

6. The two fin supports are made by bending the 5 ½" and 3 ½" lengths of steel strap into right-angles (Figure A7). Alternatively, right-angles with holes drilled can be purchased from a hardware store.
7. Drill two holes in each support so that the 22" length and 2 ½" length aluminum angles can be attached.
8. The fin is later secured between the aluminum angle piece and the top and bottom supports.
9. The following pictures (Figure A7) show the upper fin support and lower fin support respectively.



Figure A7. Upper (a) and lower (b) fin supports with holes drilled to attach the top and bottom aluminum right angles and fin.

#### *Assemble mast*

10. Place all parts on the jig and line up for welding (Figure A8). Be sure to position the hose clamps such that they can be tightened to hold the sampler cans.



Figure A8. MWAC components positioned in jig (a), including square mast, top (long) and bottom (short) right-angles to attach fin, four hose clamps for cans, and retainers to secure hose clamps. Detail of the 85 cm clamp and retainer (1" strap cut to 1/2" length) and top fin support are shown in part (b).

11. The following pictures (Figure A9) show the 50 cm and the 10 cm and 25 cm part placement details, respectively.

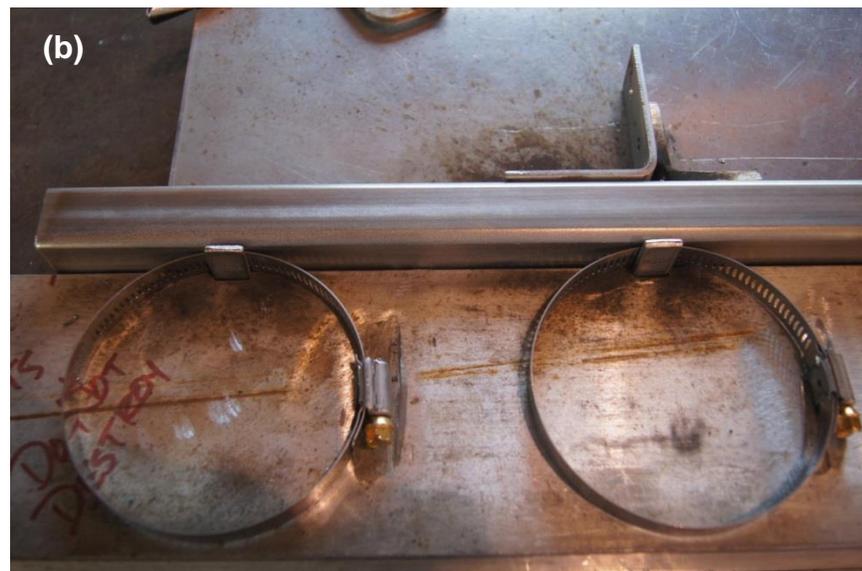


Figure A9. Detail of the mid (50 cm) (a) and lower (25 cm and 10 cm) hose clamps positioned on jig with retainers ready for welding (b).

12. Weld the top and bottom right-angles and MWAC mounting brackets to the square tubing.
13. Be careful not to weld the side of the fin supports with holes to the square mast.
14. When welded and cleaned up, the mast will look like that shown in Figure A10, with the mast top to the right of the picture.



Figure A10. Welded MWAC mast (a) and close-up of the top welded hose clamp and fin support (b).

15. Details of the 50 cm and the 10 and 25 cm levels respectively are shown in Figure A11.

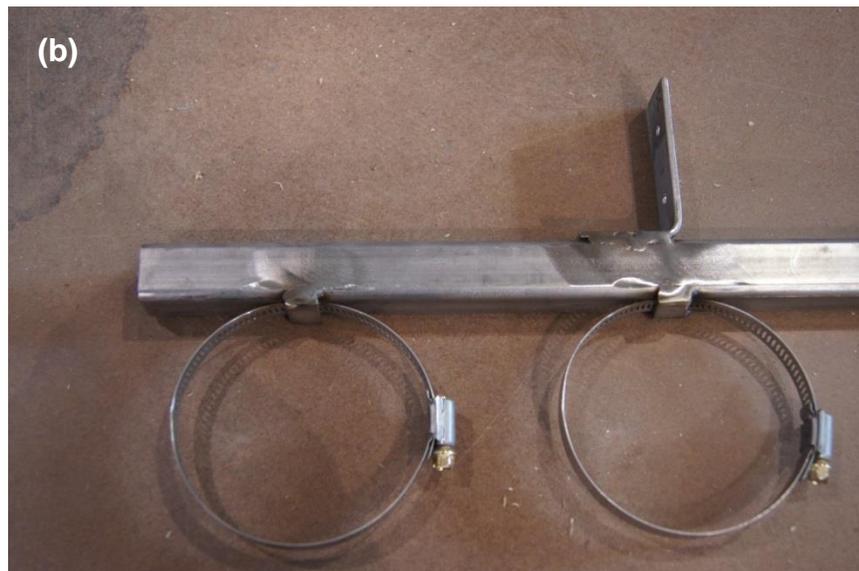


Figure A11. Detail of the mid (50 cm) (a) and lower (25 cm and 10 cm) welded hose clamps and fin support (b).

16. The measurement details of the supports for the fin supports on the welding jig are shown in Figure A12. All the measurements are from the top of the 1" X 1" square tube.



Figure A12. Detail of the position of the upper (a) and lower (b) fin supports with measuring tape. Both measurements are shown from the top of the mast (in inches).

17. Once the fin supports are welded in place, the aluminum angles and fin can be attached.
18. Two holes should be drilled in each of the top and bottom aluminum angles to attach to the fin supports. The aluminum angles can then be bolted to the supports.

*Prepare mast fin and attach to mast*

19. Cut the 24" x 24" sheet aluminum into an offset diagonal pattern like that shown in Figure A13. The 2" flat section of the fin will attach to the bottom aluminum angle on the mast, while the long (22") top section will attach to the top (22") aluminum right angle on the mast.

20. Note: one 24" x 24" sheet will make two mast fins.

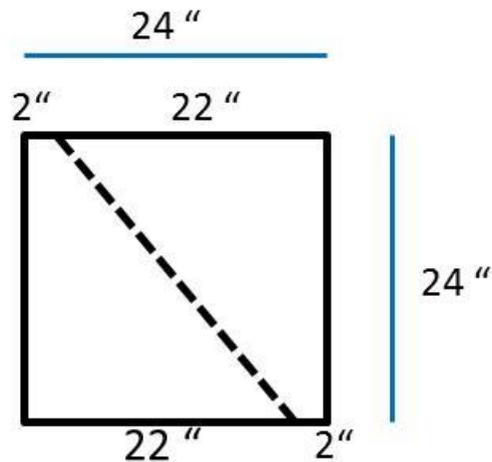


Figure A13. Diagram showing dimensions of the MWAC fin to be cut from sheet aluminum. Note offset of cut (along dotted line) so that the 2" bottom of the fin can be joined to the bottom fin support angle on mast.

21. Break  $\frac{1}{4}$ " on the diagonal of the fin and fold flat. This will add strength to the fin and reduce the chance of injury by cutting (Figure A14).

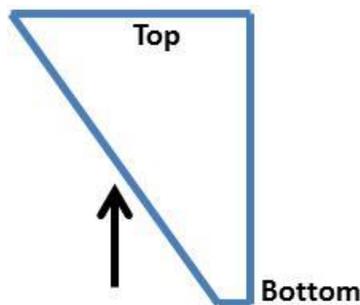


Figure A14. Diagram of MWAC fin cut from sheet aluminum. A fold should be made along the diagonal to improve fin strength.

22. Clamp the fin to the inside of the top and bottom right angles attached to the fin supports on the mast.
23. Carefully drill five holes through the fin and top right angle and two holes through the fin and bottom right angle. The size of the holes should be appropriate to the size of the rivets being used.
24. Rivet the fin to the top (22") and bottom (2") aluminum right angles (Figure A15).
25. Align fin assembly in top and bottom angle on mast and hold with vice grips or clamps. Using holes in top and bottom angles, carefully drill through aluminum and fin assembly.
26. Attach fin assembly to mast with hex bolts, nuts and lock washers. The mast is now complete.



Figure A15. Detail of the MWAC fin top riveted to the aluminum angle and top fin support (A and B), and the bottom aluminum angle and fin support (C). Also visible are the bolts holding the top and bottom fin supports to the aluminum angles (step 19).

## APPENDIX IX – MWAC Sampler Construction Guide

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This section provides details on the construction of masts designed to hold Modified Wilson and Cooke (MWAC) sediment samplers. The original MWAC wind vane design can also be adopted at the discretion of individual sites. However, the recommended mast/sampler combination enables for the fin height to be adjusted (by using a taller mast) so that masts can be located

### Materials needed for construction of 27 MWAC samplers

- 3" diameter, 6" height, 21.7 oz. aluminum screw-top can with lid (x 27)
- $\frac{3}{4}$ " internal diameter,  $\frac{5}{16}$ " total diameter rubber grommets (x 54)
- $\frac{3}{4}$ " outer diameter, 0.68" internal diameter, 0.035" wall thickness, 6061 T6 round aluminum tubing in 5ft length (x 11) – cut into 12" and 10" lengths (27 of each)
- Two-part epoxy (e.g., PC.7)
- White gloss exterior paint
- *Step drill bit sizing up to 1 inch*
- *Drill*
- *Paint brushes for epoxy and paint application*
- *Pipe cutter*
- *Pipe bender – suitable for  $\frac{3}{4}$ " pipe*
- *Deburring tool*
- *Tape measure and marker pen*

### Assembly

1. Drill two  $\sim\frac{3}{4}$  inch holes in each lid. The holes must align through the center of the lid, leaving sufficient room to insert a rubber grommet into each hole (Figure A16-A).
2. Insert one rubber grommet into each hole in each lid (Figure A16-B).
3. Using a pipe cutter, cut the round aluminum tubing into one 12 inch length (inlet) and one 10 inch length (outlet) per sampler, and use the de-burring tool to remove any metal burrs so that the inlet and outlet tubes have smooth internal surfaces while maintaining integrity of tube diameter.
4. Using a pipe bender, bend each section of aluminum tubing to a right angle with the apex of the bend at the same distance from one end of the tubes.
5. Insert one right angle tube into each hole in the lids. Be careful not to push the rubber grommets through the holes. The grommets should provide some resistance, holding the tubes in place. Align the tubes so that they point forwards/backwards and will sit parallel with the ground when mounted on the masts. The longer tube will be the inlet tube for the sampler (Figure A16-C).
6. Apply two-part epoxy to the join around the lids, the grommets and the metal tubing to fasten securely (apply to both the inside and outside of the lids). Be careful to do this in a well-ventilated space. Be careful not to get epoxy on the thread of the lid and lid gasket.
7. Screw lids onto the cans and leave for 24hrs, or until the epoxy is fully hardened.
8. An option is to paint lids white with exterior paint to help protect from UV deterioration in the field (Figure A16-D).

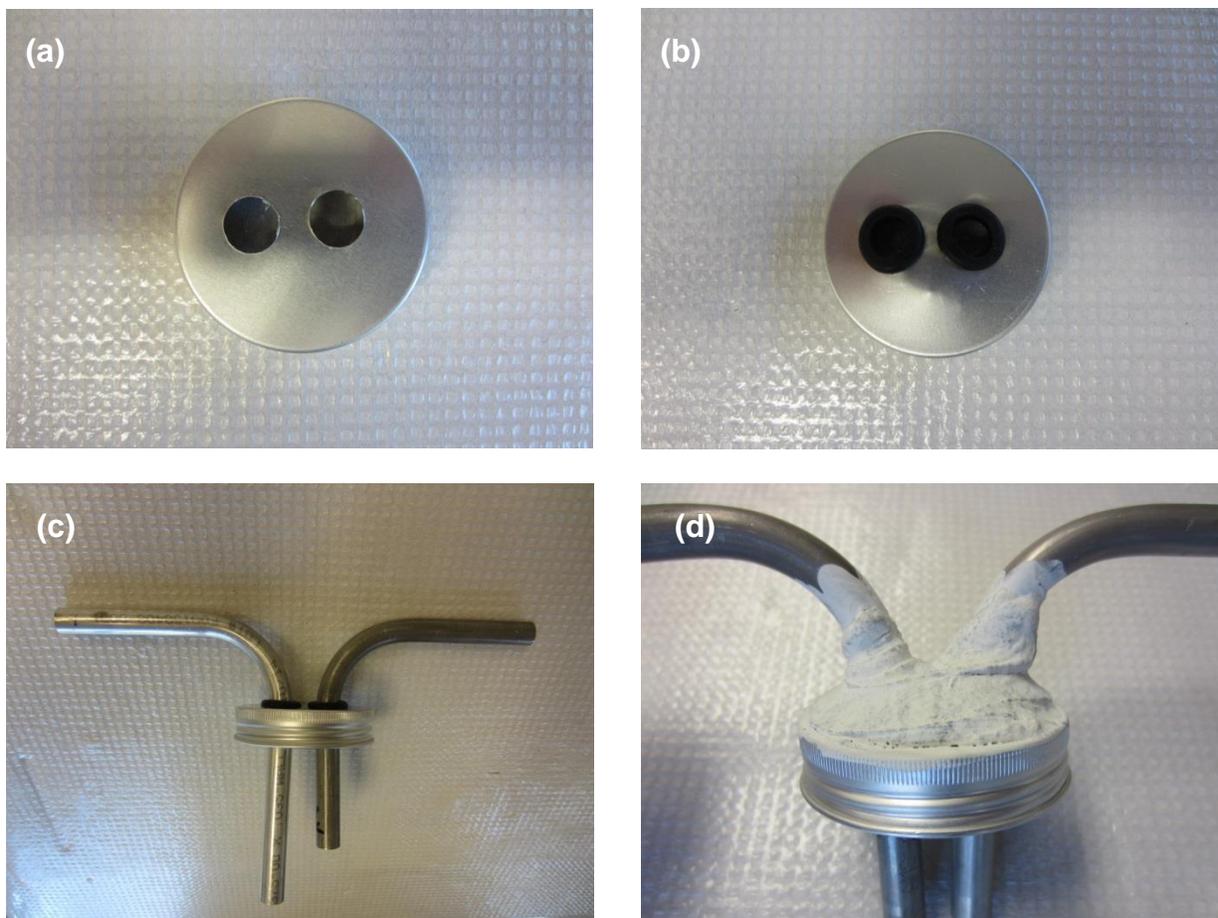


Figure A16. Detail of holes drilled in lid (A), the two rubber grommets fitted to the lid holes (B), with aluminum inlet and outlet tubes for rotating MWAC sampler masts (note inlet tube to left is longer than outlet tube) (C), and epoxy applied to cover base of tubes and grommets, securing the tubes in place (D).

### Installing MWAC samplers in the field

Materials required to install one\* MWAC sampler mast in the field include:

- Assembled MWAC mast with four samplers
- 6 ft length of ½" steel conduit (x1)
- 7/8" internal diameter large washers (x2)
- ½" conduit coupling, cut in half
- *Pipe cutter*
- *Mallet*
- *Tape measure*

\* Multiply parts by 27 for installation of 27 MWAC masts in the field.

1. Slide conduit coupling onto ½” conduit and fasten halfway between ends. The large lip on the coupling should facing upwards to provide a rest for the washers.
2. Using a mallet, bang the ½” conduit into the ground so that the coupling sits just above the soil surface (~1 inch).
3. If top of conduit deforms use pipe cutter to remove top inch so that the MWAC mast will slide over the conduit.
4. Slide two washers onto the conduit so that they sit on the coupling.
5. Slide the MWAC mast onto the conduit so that it sits on the washers and can rotate freely in the wind.
6. Place samplers in the hose clamps and tighten, ensuring that the cans and inlet tubes sit parallel with the ground, and face forward (i.e., 12” tube to the front) (Figure A17).
7. Measure the heights of the MWAC sampler inlet tubes. The lowest inlet should sit 10 cm above the soil surface. If too high then adjust coupling height.
8. If correct heights cannot be established, the lower 1 inch of the mast square tubing may be cut off to enable more precise height positioning and to avoid washers sitting in the soil.



Figure A17. MWAC mast with four samplers installed in the field.

## APPENDIX X – Dust Deposition Trap Design

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This section provides details on the construction of Dust Deposition Traps (DDTs) following the design of Reheis and Kihl (1995). A minimum of three (3) deposition traps are to be deployed at each Network site in order to estimate the variance in dust deposition rates across the site.

### Materials needed for construction of 3 Dust Deposition Traps (DDT)

- 10" diameter angel food cake pan
- 1000 grams of 10mm lead-free glass beads/marbles (x 3)
- 5" x 5" square steel plate, 14 gauge (x 3)
- 3/4" x 2' steel pipe, threaded on one end (x 3)
- 3/4" x 5-1/2" threaded pipe nipple (x 3)
- 3/4" nut and washer (x 3 each)
- 3/4" steel pipe cap (x 3)
- #8, 3 1/2" steel smooth shank common nail (x 3)
- 40" x 36" perforated aluminum sheet (20ga, 0.250-inch round holes)
- 1" x 1/2" right-angle brackets (x 18)
- 8-32 x 1/2" flathead screws (x 36)
- 8-32 washers (x 72)
- 8-32 hex nuts (x 36)
- 1 can metal spray paint, camouflage color
- 6' T-post (x 3)
- T-post pounder
- 1-1/16" to 2" hose clamps (x 9)
- Welding materials
- Tin snips
- Chop saw
- Grinder or metal file

### Dust Deposition Trap Assembly

1. Construction of the mounting assembly (Figure A18)
  - a. Weld steel pipe in the center on the bottom of square steel plate, ensuring that the square plate is level (horizontal with the ground) when pipe is mounted vertically.
  - b. Cut 1/4" off the pipe nipple (some thread will remain at the cut end) and weld the cut end to the center on top of square steel plate.
  - c. Paint the assembly to prevent rust.



Figure A 18. Photograph of mounting arm assembly with welded steel plate.

2. Construction of the marble basket (Figure A19)
  - a. Construct a donut-type template with outside diameter of 8-3/4" and an inner hole diameter of 2-5/8" (Figure A19a).
    - i. Cut a 9"x 9" Square of perforated aluminum.
    - ii. Using the template, cut circle out of perforated aluminum (Figure A19b)
  - b. Cut a 1-1/2" x 30" rectangular strip of perforated aluminum.
  - c. Attach the aluminum strip to the donut with right-angle brackets, screws, washers, and nuts (Figure A19c).

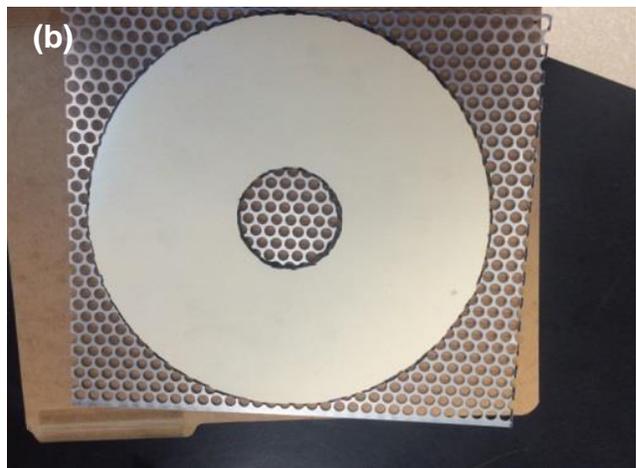
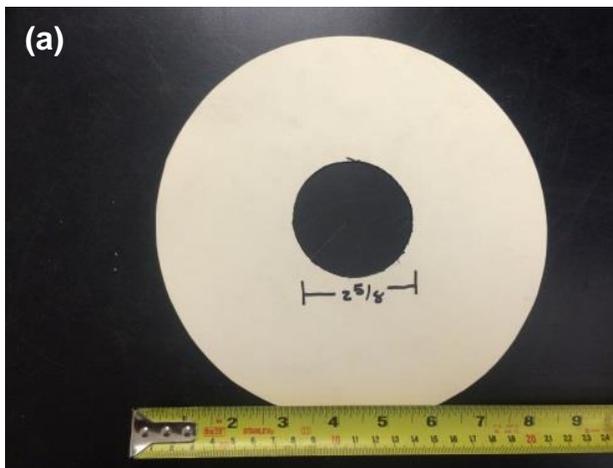


Figure A19 - continued over page.

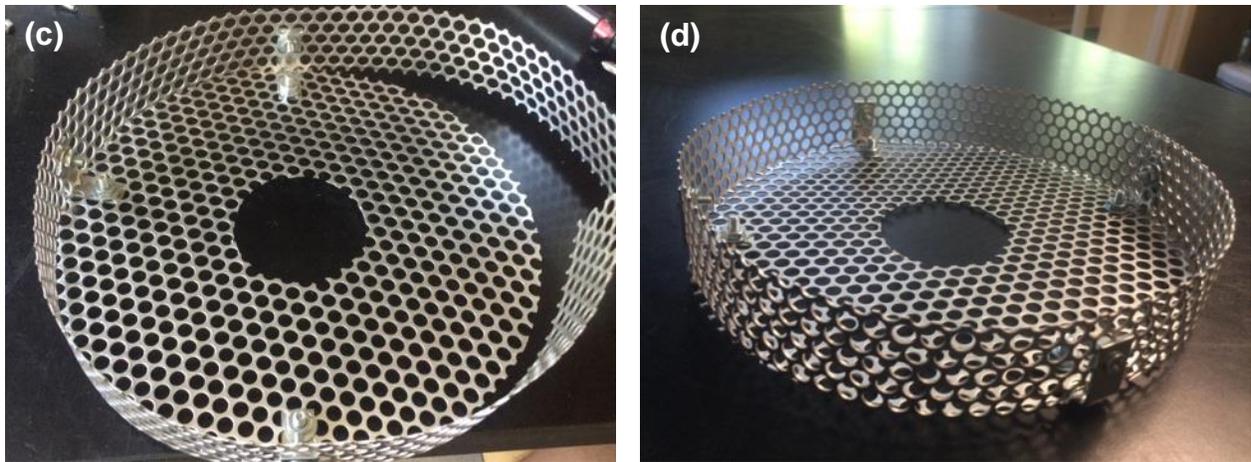


Figure A19. Illustration of the construction steps required to build the metal basket for holding marbles.

3. Construction of the bird defense.

a. Weld fluted nails to the steel pipe cap. Paint to prevent rust (Figure A20a).

b. Rim Tubing:

- i. Cut 31" tubing lengthwise from end to end and place on cake pan.
- ii. Designate and mark nail positions on tubing so that nails will extend vertically from pan rim.
- iii. Remove tubing from pan and insert nails 1-1/2" galvanized nails, spacing them approximately 1" apart (depending on tube thickness, pre-drilling may be required) (Figure A20b)

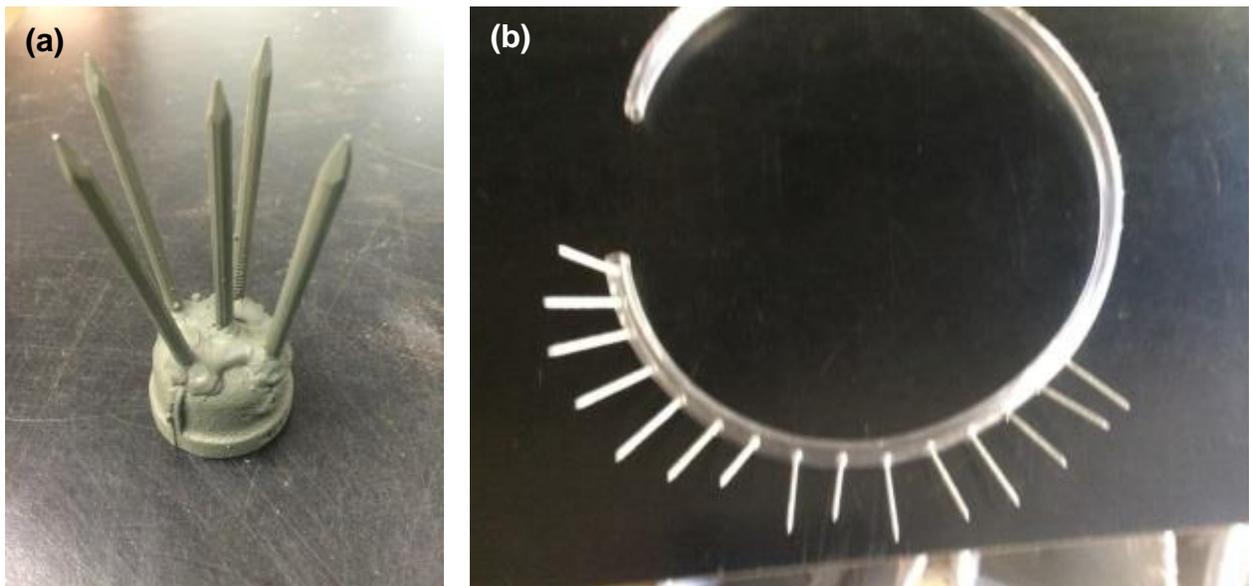


Figure A20. (a) Steel pipe cap with welded nails. (b) Nails inserted into tubing. Note, nails should go all the way around the tubing for completed product.

## Travel Lid Construction

1. Cut dowel rod into 4-1/2" lengths (x 3).
2. Using a 9/16" Countersink drill bit, drill a 1/2" deep hole in one end of the dowel, and 1/4" hole in the other end of the dowel.
3. Drill a hole in the center countersink hole lengthwise using a 23/64" drill bit through the entire dowel.
4. Drill a hole in center of durable plastic plate using a 23/64" drill bit.
5. Insert 4.5" hex bolt into 1/2" countersink hole and attach nut on opposite side and tighten.
6. Insert dowel assembly into center of cake pan. Place plastic plate upside down on top of cake pan aligning center hole with hex bolt of dowel.
7. Secure plastic plate with wing nut.
8. Cover with bouffant cap for storage and transportation of dust deposition traps to/from site.

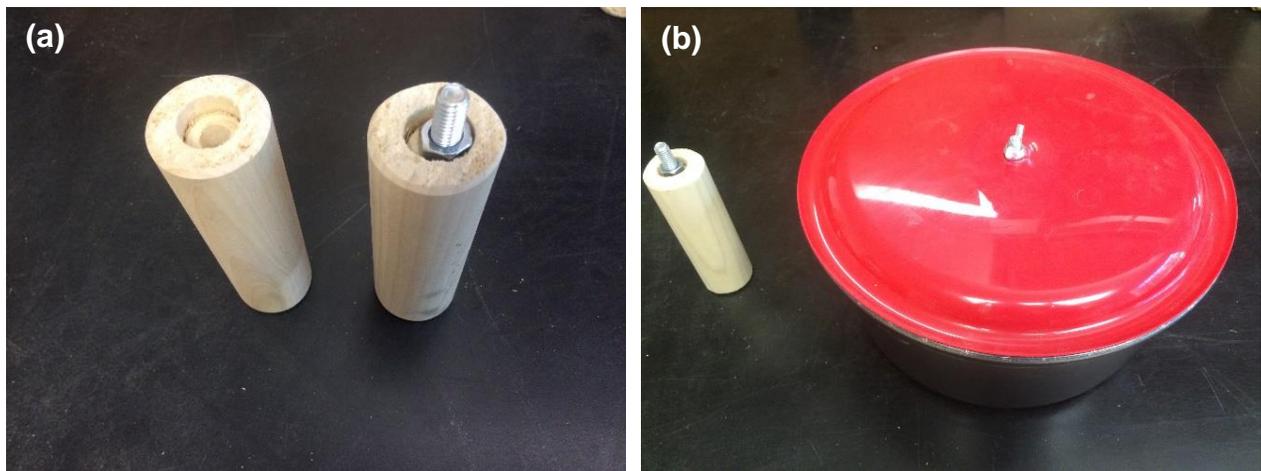


Figure A21. Dowel section for securing travel lid (a) and travel lid mounted on trap.

## Field Installation

1. Place glass beads in marble basket ensuring a 2-3 marble depth is consistent (Figure A22).



Figure A22. Dust deposition trap mounted in the field.

2. The traps should be mounted at a height of 1.5 m (to base of pan) above the soil surface to avoid contributions from the horizontal (saltation) mass flux.
3. The traps should be located randomly around the site, with locations determined using GIS and accurate (<25 cm) GPS for positioning in the field.
4. Attach the mount assembly to a T-Post using the 3 hose clamps.
5. Fasten the deposition trap (cake pan with marbles in basket) to mount assembly using  $\frac{3}{4}$ " washers and a nut. Screw on pipe cap with nails and attach tubing with nails to the rim of the cake pan (Figure A23).



Figure A23. Dust deposition trap mounted in the field.



