TOS PROTOCOL AND PROCEDURE: CDW – COARSE DOWNED WOOD

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See configuration management system for approval history.

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	01/28/2015	ECO-02135	• Initial release
B	02/02/2015	ECO-02673	• Migration to new protocol template, name change
C	02/29/2016	ECO-03584	• Updated volume factor values for 5 domains (Appendix E) • Additional guidance in chainsaw and fueling safety • Updated time estimates for SOP B (Section 6.4) • Added qualifying CDW characteristics to beginning of SOP B.1 • Changed **scientificName** to **taxonID** (**Table 9**); updated codes for \`unknown hardwood\` and \`unknown softwood\` • Updated Branch Bark Cover percent categories and guidance for remarks (SOP B.1, Step 8) • **Table 11** modified to focus less on evergreen tree characteristics; table re-structured to enable faster **decayClass** assessment • Added SOP B.2, devoted to tallying and measurement of forked CDW particles. • Added additional scenarios to **Table 12** • Updated sampling strategy priorities for SOP C.1 and C.2 • Added special instructions for SOP E - Data Entry • Created 2-page quick reference sheet for field usage (Appendix B) • Expanded limiting distances table (Appendix A - **Table 18**) • Expanded minimum round diameters table (Appendix A - **Table 19**) • Expanded Split CDW/Round Diameter Equivalents Table (Appendix A - **Table 20**)
D	03/09/2017	ECO-04422	• Updated text to account for data collection using a mobile application. • SOP B: Updated field names to be consistent with DPS ingest workbook.

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
			• SOP B.1: Updated 'Unknown Hardwood' and 'Unknown Softwood' codes, and added guidance for downed logs with Vegetation Structure tags. • SOP B.3 : Troubleshooting: Added slash pile guidance • Equipment and SOP C: Replaced electronic scale with tare-able spring scales, based on technician feedback. • Equipment and SOP C: Added Cant Hook and Log Stand to improve safety when cutting disks. • SOP C.1: Reorganized and added guidance for when bulk density sampling is considered complete. • SOP C.2: Changed \`diskID\` to an incrementing number that will enable easy per site tracking of total number of disks sampled. • SOP C.2: Diameter tape now used to record diameter of structurally sound disks with DBH ≥ 5 cm (was 10 cm). • Appendix B: Consolidated all diameter / distance tables into this appendix, eliminated old Appendix E. • Appendix D: Added transect length, F-values, for all sites to ensure repeatable, consistent tallying. • Appendix E: Newly added quarantine compliance appendix. • Appendix F: Added rank abundance of DSTs for targeted bulk density sampling completion.
E	7/26/2018	ECO-05680	• Section 2.4: Added definitions of bole, branch, fork, and twig. • Added Section 4.1 "Implementation Criteria": Suspend sampling when tally is zero, consider suspending sampling when fewer than 10 particles tallied. • Section 4.2: Added guidance to schedule CDW tally in different years in Distributed vs. Tower Plots, and to use a 5 y sampling interval instead of 3 y interval. • Section 6.1: Added 'pig-tail' stakes for tagging highly decayed logs. • SOP A.2: Added optional barcode workflow for tracking bulk density samples, speeding Fulcrum data entry. • SOPs B, C, D: Re-organized to integrate better with Fulcrum data collection steps. • SOP B.2: Re-organized dense vegetation guidance into Box 1. • SOP B.2: **decayClass** required for all tallied logs. • SOP B.4: New SOP with re-tally guidance.

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
			• SOP C.2: Added optional barcode workflow for tracking bulk density samples, speeding Fulcrum data entry. • SOP D.1: Changed dry criteria from ± 0.5 g or 0.5%, whichever is larger, to ± 0.5 g or 1%. • SOP D.1: Clarified that oven drying data only recorded for initial drying event. • SOP E.1: New section describing key parts of the digital data workflow.
F	06/17/2019	ECO-06149	• Section 4.2: Added scheduling information for synchronizing CDW in Distributed Plots with other TOS protocols. • SOP A: Added SOP A.2.1 to explicitly document preparation for implementing the barcode workflow. • SOP B.2: To avoid duplicates in database, updated **logID** strategy across forks in different size categories; added improved figures to illustrate. • SOP C.2: QA procedure now involves re-measurement of disk diameter, height, and fresh mass. • SOP C.2 and C.4: Improved **mappingMethod** = relative instructions to enable re-finding logs in bout2 bulk density sampling. • SOP C and SOP D: Clarified that QA should be performed in field and lab on same samples to enable full estimation of bulk density uncertainty. • Appendix F: Added Dogwood (D03 JERC) and Spongy Moth (D07 MLBS) quarantine information to **Table 26**. • Appendix G: Moved DST rank lists exclusively to SSL to enable dynamic update when required. Lists formerly were in both places.
G	02/01/2022	ECO-06738	• Updated to new template (NEON.DOC.050006 Rev K) • Section 2.4: New and updated definitions for central axis, fork, and particle. • Sections 3 and 4 and SOPs B and C and Appendix A: New workflow diagrams. • Section 4.3: Bulk Density Onset and Cessation guidance added. • Section 4.5: Sampling Timing Contingency introduction added • Section 4.6: New table with guidance on responding to delays. • SOP A.3: Guidance on calibrating spring scales added.

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
			• SOP A.4: Label guidance expanded and barcoding text updated to reflect that it is now required. • SOP B: Section on Spatially and Temporally Linked Protocols added. • SOP B.1: Clarified that sampling may occur outside of plot boundary and that problematic barriers may require transect to be reflected. • SOP B.2.1: Clarification about qualifying forks. • SOP B.2.3: Clarified that particle spanning multiple size classes requires multiple records. • New Post-Field Sampling Tasks SOP (SOP D) added. • SOP C and SOP D: Language regarding barcodes updated to reflect that it is not optional. • Appendix A.1: One page summary of procedures added. • Appendix B: Reminders added. • Appendix C: Site-specific sampling start and end dates updated for sites DSNY, JERC, OSBS, YELL, and SJER. • Appendix D: Site-specific volume factor and transect length updated for site YELL. • Appendix E: Equipment tables updated to add column about whether exact brand was required.
H	03/19/2026	ECO-07179	• Updated to new template (NEON.DOC.050006 Rev M) • Section 2.3: Definitions for D_{lim}, FWD, RD_E, and RD_{min} acronyms added. • Post-Field Sampling Tasks moved from a full SOP to SOP B.6. • SOP B.2 and Figure 2: Added pointID labels. • Section 4.1: Clarified that interannual schedule and plot priority matrix inform plot sampling order. • Section 4.6 Table 6: Added new sampling impractical reason "location vulnerable to planned sampling." • Section 5.2: Reiterated that chain saw should be checked for sharpness before going to the field. • Section A.4: Added new Table 8 regarding barcodes. • SOP B.2: Clarified in steps 8 - 10 that RDE is the preferred qualifying diameter and clarified guidance when RDE from app is not available. • SOP B.2 Table 9: Added **charExtent** and **charDepth** fields.

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
			• SOP B.2: Added new **Table 12** with specialized decay class criteria. • SOP B.2: Clarified that roads are not a transect boundary. • SOP B.3: Clarified use of RDE diameter in subsections B.3.1., B.3.2, and B.3.3. • SOP B.4: New "Charred CDW Logs" section. • SOP B.5 **Table 14**: Clarified that transect reflections are temporary and that roads are sampled the same as elsewhere. • SOP C.3: Added **logLength** to required log data. • SOP C.3: Referenced new fields **charExtent** and **charDepth** where appropriate and included new charred decayClasses in **Table 16**. • SOP C.3: Clarified to remove moss and to avoid shelf fungus at location where disk is cut. • SOP C.3: Clarified that the smallest possible spring scale should be used to weigh bulk density disks. • SOP C.5: Added new **Table 17** comparing Bout 1 and Bout 2 sampling, as well as new guidance on bout 2 sampling. • Appendix C **Table 21**: Updated site-specific dates for onset and cessation of sampling based on newer MODIS data and additional considerations. • Appendix D **Table 22**: Updated YELL volume factor and transect length, and LAJA sampling status. • Appendix F **Table 26** Quarantine Compliance: Updated a common name and added more scientific names.

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1 OVERVIEW

1.1 Background

Monitoring stocks of coarse downed wood (CDW) is important because CDW uniquely influences ecosystem function. In terms of ecosystem services, CDW provides habitat for wildlife, stabilizes soil, increases microenvironment heterogeneity, stores carbon (C) and nutrients over decades, and can enhance seedling germination for trees and other plants (Harmon and Sexton 1996). Because coarse downed wood logs can persist in the environment from decades to centuries, these logs have "afterlife" effects on ecosystem function of similar magnitude to those of live trees. Trees that die and fall to the ground as CDW decay and their carbon and nutrients are released to the soil. CDW therefore directly impacts soil conditions, which then indirectly impact a wide variety of organisms, from microbes to herbaceous plants to woody plants. In addition, knowledge about the quantity and size distribution of CDW logs at the landscape scale can be used to model the probability of fire occurrence and severity because CDW can be an important fuel source (Brown 1974, Affleck 2008). Accurately measuring the volume, frequency, and mass of CDW, and understanding the rate of decay of different taxonomic groups and size classes, therefore helps inform CDW contributions to ecosystem conditions.

There are two components of the sampling design that are required to accurately estimate CDW mass: volume estimation, and calculation of bulk density. There are numerous tally-based methods for estimating CDW volume that have been developed over the past 50 years. A historically common method, line intercept sampling (LIS; Warren and Olsen 1964), requires searching fixed-length transects for logs that intersect the transect. However, because the LIS method tallies CDW pieces with probability according to length and length correlates imperfectly with volume, the most voluminous CDW pieces may be underrepresented, resulting in increased uncertainty in CDW volume estimates compared to frequency and length estimates (Affleck 2010). Other recently developed methods sample CDW with probability proportional to volume, and are designed specifically to estimate log volume directly from simple tallies, with reduced uncertainty compared to LIS (e.g. Affleck 2008, Gove et al. 2013). The tally-method NEON employs, termed Line Intercept Distance Sampling (LIDS; Affleck 2008), tallies logs with probability proportional to volume and restricts the search for logs to a group of radial transects at each sampling point (Affleck 2008, 2010). By using transects, detection errors in brushy or complex terrain are minimized compared to other techniques that require searching for logs over large areas (Jordan et al. 2004). Importantly, and in contrast to LIS, the length of the transect is not fixed with the LIDS method. Instead, the length of the transect increases for large-volume logs, ensuring that a representative sample of large logs is tallied across multiple field sites (Affleck 2008).

To convert estimates of CDW volume to mass and/or carbon (C) density, it is necessary to measure the bulk density of downed wood in a manner that quantitatively accounts for the proportion of the CDW particle that is void volume (i.e., internal hollows that reduce bulk density compared to a solid particle). Wood bulk density is typically measured by cutting cross-sectional disks from a statistically sufficient population of CDW particles, then determining the mass and volume of the disk samples (Harmon and Sexton 1996).

There are two additional factors that must be addressed if log volume and density estimates are to be accurately converted to CDW mass or C density per unit area at the stand scale. The first is that CDW density tends to change predictably as log decay progresses, and the second is that density changes with decay class are often dependent on species (Harmon and Sexton 1996). That is, different species that appear to be in the same stage of decay may have very different wood bulk density values, due to differences in the proportion of heartwood to sapwood, as well as other species-specific wood properties. To capture variation in density throughout the course of log decay, NEON categorizes sampled CDW logs according to five standard decay classes defined by the U.S. Forest Service (Valentine et al. 2008). All CDW particles are also identified to taxon according to a NEON-standard taxonomic identification method (for plants, this method relies heavily on the taxonomic ID system developed by the USDA; http://plants.usda.gov).

1.2 Scope

This document provides a change-controlled version of Observatory protocols and procedures. Documentation of content changes (i.e., changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

1.2.1 NEON Science Requirements and Data Products

This protocol fulfills Observatory science requirements that reside in NEON's Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON's document repository, or upon request.

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products, and are documented in the NEON Scientific Data Products Catalog (RD[03]).

1.3 Acknowledgments

Selection of the standard operating procedures described in this protocol was informed by Affleck (2008, 2010), Gove et al. (2013), Harmon and Sexton (1996), and Keller et al. (2004). Dr. Mark Harmon provided invaluable feedback on all CDW quantification methods, and particularly for the bulk density sampling standard operating procedure.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science Data Quality Plan
AD[06]	NEON.DOC.000914	NEON Science Design for Plant Biomass and Productivity

2.2 Reference Documents

Reference documents contain information that supports or complements the current document. Examples include related protocols, datasheets, or general-information references.

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Data Products Catalog
RD[04]	NEON.DOC.001271	AOS/TOS Protocol and Procedure: DMP – Data Management
RD[05]	NEON.DOC.002121	Datasheets for TOS Protocol and Procedure: CDW – Coarse Downed Wood
RD[06]	NEON.DOC.003282	NEON Protocol and Procedure: SIM – Site Management and Disturbance Data Collection
RD[07]	NEON.DOC.005247	AOS/TOS Standard Operating Procedure: NEON Aquatic and Terrestrial Site Navigation
RD[08]	NEON.DOC.000987	TOS Protocol and Procedure: VST – Measurement of Vegetation Structure
RD[09]	NEON.DOC.001710	TOS Protocol and Procedure: LTR – Litterfall and Fine Woody Debris
RD[10]	NEON.DOC.001717	TOS Standard Operating Procedure: TruPulse Rangefinder Use and Calibration
RD[11]	NEON.DOC.000913	TOS Science Design for Spatial Sampling
RD[12]	Chainsaw Training	https://www.osha.gov/sites/default/files/publications/chainsaws.pdf, USFS S-212, and the MTDC Chain Saw and Crosscut documentation
RD[13]		Manual for Fulcrum Application: TOS Coarse Downed Wood [PROD] – All SOPs
RD[14]	NEON.DOC.014037	TOS Protocol and Procedure: HBP – Measurement of Herbaceous Biomass

2.3 Acronyms

Acronym	Definition
C	Carbon
CDW	Coarse Downed Wood
D_{lim}	Limiting Distance
DST	'Decay class x sizeCategory x taxonID' combination into which logs are sorted.
F	Volume Factor
FWD	Fine Woody Debris
LIDS	Line Intercept Distance Sampling
LIS	Line Intercept Sampling
PPE	Personal Protective Equipment
RD_E	Round Diameter Equivalent
RD_{min}	The minimum Round Diameter for a log to qualify for tallying at a given distance. RD_{min} (cm) = √(8 * M * F * D/Pi2), where M is the number of transect segments (3 for NEON sampling), and F is the volume factor (Affleck 2010).
VST	Vegetation Structure

2.4 Definitions

Bole: The trunk of a tree. A bole differs from a lateral branch in that it is a primary support structure for the individual and may support lateral branches.

Branch: Woody structures ≥ 2 cm diameter that emerge from boles at an angle > 45˚, or that emerge from other branches at any angle.

Central axis: The straight line that connects the two endpoints of a log (or the diameter class break point(s) if a log includes more than one diameter size class). For forked logs, the central axis is based on the longest fork.

Coarse downed wood (CDW): Any fallen log, and all its connected branches, with diameter ≥ 2 cm at the point where the CDW log intersects the LIDS transect. Qualifying CDW particles are referred to as 'logs' in this protocol for convenience. Qualifying logs also include standing dead that are > 45˚ off the vertical (Harmon and Sexton 1996, Affleck 2010).

Fork: A stem that is part of a multi-bole log; forks emerge from another bole at an angle < 45˚. Consider the whole length of the secondary fork and not just the basal portion when determining the angle relative to the main bole's central axis.

Fulcrum: Software platform used to create NEON electronic data entry applications.

Particle: A piece of coarse downed wood material, including but not limited to logs.

ServiceNow: Software platform used for problem/incident tracking and resolution.

Twig: Woody structures < 2 cm diameter that emerge from boles or other branches.

3 METHOD

The Standard Operating Procedures (SOPs) presented in this protocol describe tasks that, when taken together, allow estimation of CDW volume, length, frequency, mass, and projected cover at the stand scale. These SOPs are:

- **SOP A: Preparing for Sampling.** Preparatory steps for SOPs listed below, to be carried out prior to implementation.
- **SOP B: Field Sampling: Tallying and Measuring CDW.** Includes performing CDW volume tallies in the field using the LIDS technique, measuring logs for additional variables required to convert volume tallies to length, frequency, and projected cover estimates, identifying logs to taxon, and categorizing logs into decay class.
- **SOP C: Field Sampling: Bulk Density Sampling in the Field.** Includes field-sampling log cross-sectional disks and sub-sampling disks to generate samples for wood moisture calculations.
- **SOP D: Processing Bulk Density Samples in the Laboratory.** Steps to dry and weigh wood bulk density samples in the laboratory.

Qualifying CDW logs are divided into three different diameter size categories, as defined by Keller et al. (2004): 2–5 cm, 5–10 cm, and ≥ 10 cm. Furthermore, logs of all diameter must also be ≥ 1 m in length (Harmon and Sexton 1996). Dead trees that have not yet fallen to an angle > 45˚ from vertical (i.e., snags) are accounted for via the Vegetation Structure protocol (RD[08]), and logs that are suspended in the air > 2 m above the ground at the transect intersection point are ignored. Woody particles with diameter < 2 cm at the transect intersection point are considered Fine Woody Debris (FWD) and are not sampled as part of this Coarse Downed Wood protocol. Particles of FWD are sampled according to the Litterfall and Fine Woody Debris protocol (RD[09]).

Standard Operating Procedures (SOPs), in Section 7 of this document, provide detailed step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process samples, field technicians **must** follow the protocol and associated SOPs. Use NEON's problem reporting system to resolve any field issues associated with implementing this protocol.

The value of NEON data hinges on consistent implementation of this protocol across all NEON domains, for the life of the project. It is therefore essential that field personnel carry out this protocol as outlined in this document. If local conditions create uncertainty about carrying out these steps, it is critical that technicians document the problem and enter it in NEON's problem tracking system.

Quality assurance is performed on data collected via these procedures according to the NEON Science Data Quality Plan (AD[05]).

Specific overviews of SOP B, SOP C, and SOP D are provided below.

3.1 Overview of Tallying CDW (SOP B)

To implement SOP B, sampling locations (**Figure 1**) are established at the center of each Tower Plot, and also at the center of 20 Distributed Plots that are used for co-located diversity and percent cover, LAI, herbaceous biomass clip harvest, and vegetation structure measurements (RD[11]). Tower Plots are selected according to a spatially-balanced, random design, and Distributed Plots are selected according to a spatially-balanced, stratified random design, stratified by NLCD vegetation type (RD[11]).

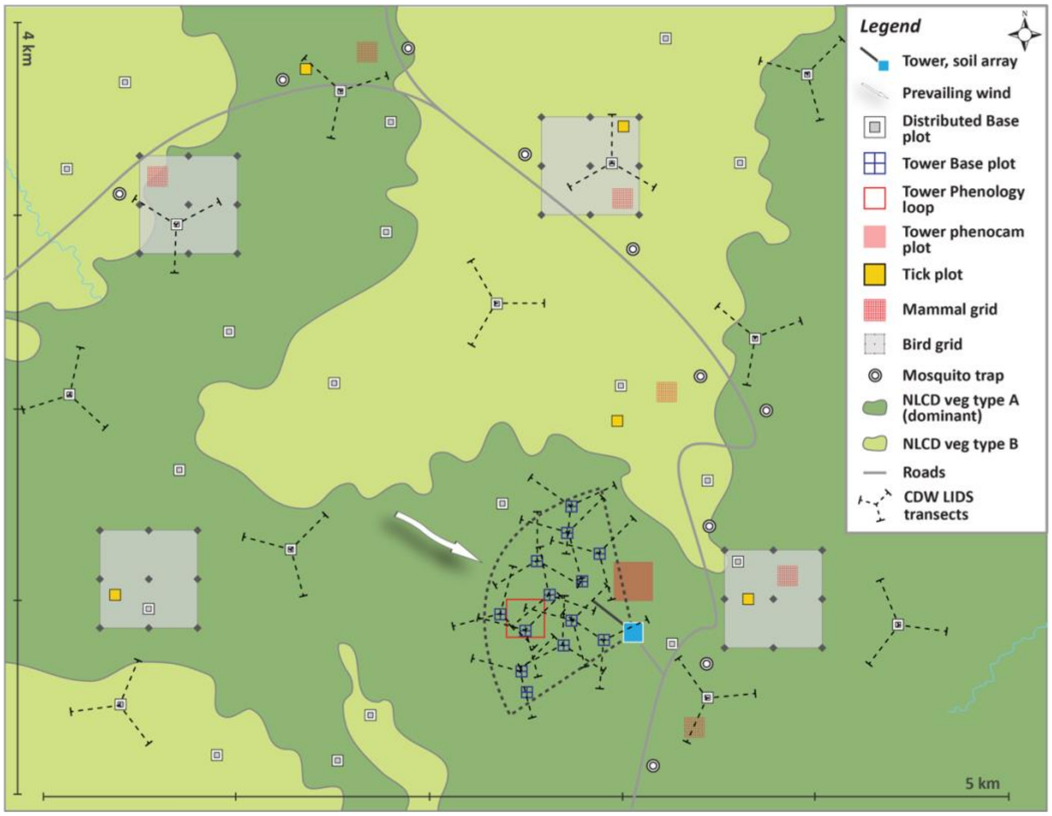

Figure 1. Three CDW transects per plot, represented with orange lines. Transects occur at both Tower and Distributed plots.

At each sampling location, three LIDS transects are established that radiate outward, with 120˚ separating each transect (**Figure 1**, **Figure 2**). The azimuthal orientation of each group of transects is chosen randomly for each of the sampling locations, to minimize effects of topography, directional blowdown, logging management, etc., on selection of CDW logs across all sampling locations. The per-plot random azimuths for LIDS transects are provided by Science and are built into the mobile data ingest application. LIDS azimuths are also available on the internal Sharepoint Sampling Support Library (SSL).

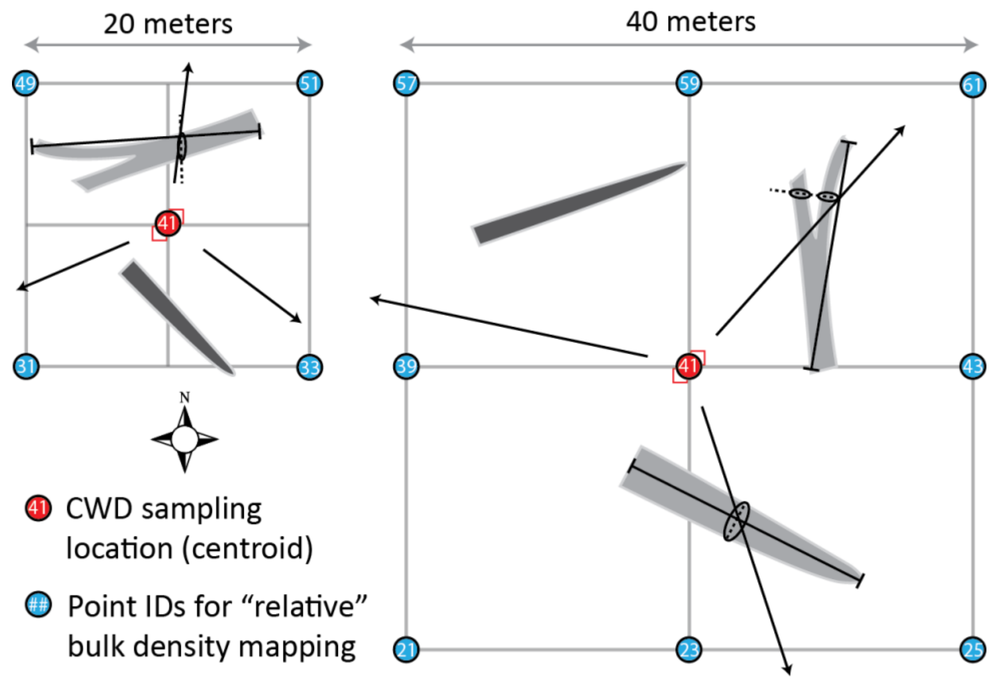

Figure 2. Illustration of three randomly oriented LIDS transects (solid black arrows) over a 20m x 20m plot (*left*), and a 40m x 40m plot (*right*). Transects start 3 m from the plot centroid (red circle at pointID 41). Light gray logs are those intersected by the CDW tally transects, and the black capped lines superimposed over these logs illustrate the log central axis. Short, dashed lines are perpendicular to the log central axis at the point where the log intersects the transect, and ovals represent diameters that are measured to determine whether a log is tallied. Darker gray logs do not intersect LIDS transects and are suitable for CDW bulk-density sampling. The blue pointIDs can be used for "Relative" mapping of logs sampled for bulk density (SOP C). Other pointIDs cannot be used for mapping as they are not associated with high-resolution GPS data.

Field staff search each of the 3 transects for qualifying CDW logs that intersect the transect, with the total transect distance searched being positively related to log diameter. In other words, the LIDS technique dictates that the search for larger logs occurs over longer transect distances to adequately sample relatively rare large logs that contribute disproportionately to total CDW volume. Limiting distances that correspond to various log cross-sectional areas are provided in **Table 18**, and the *CDW: Tally [PROD]* app provides an automated means to assess whether a log should be tallied after the user enters a log diameter, distance, and F-value. In the event the tablet should fail, **Table 18** may be used in the field as a reference to help determine whether specific logs should be tallied. Once it is determined that a log should be tallied, its cross-sectional area and length are measured, as well as the distance from the sampling location. In addition, each qualifying log is assigned to a decay class and is identified to the finest taxonomic resolution possible.

3.2 Overview of Bulk Density Field Sampling (SOP C)

SOP C details the field procedure for sampling CDW for bulk density (left side of **Figure 3**). Bulk density is sampled from three different diameter size categories (≥ 10 cm, 5-10 cm, and 2-5 cm), from logs that are not tallied in SOP B. A chainsaw, or less ideally a buck saw, is used to cut a narrow cross-sectional disk from each sampled log. The diameter and height of the disk are measured to enable calculating the volume of the disk, and the disk fresh mass is recorded in the field. For the two largest size categories, wedge-shaped pieces are sub-sampled from the disk, and these sub-samples are also weighed for fresh mass in the field. Subsamples are then transported back to the laboratory to calculate the disk's fresh mass to dry mass ratio. Disks sampled from the smallest size category are not sub-sampled and are transported to the laboratory in their entirety.

Cross-sectional disks cannot be cut from extremely decayed logs, and instead of removing a disk, a decayed section of log is simply scooped into a plastic bag and the negative space is measured for volume with calipers. The sampled material is then transported back to the laboratory, dried, and weighed as above.

3.3 Overview of Bulk Density Lab Processing (SOP D)

SOP D describes the procedure for measuring, drying, and weighing cross-sectional disks and wedges in the laboratory (right side of **Figure 3**). Knowledge of the wood sample dry mass allows calculation of bulk density (ρ) as:

$$\rho = \frac{disk\ dry\ mass\ (g)}{disk\ volume\ (cm^3)}$$

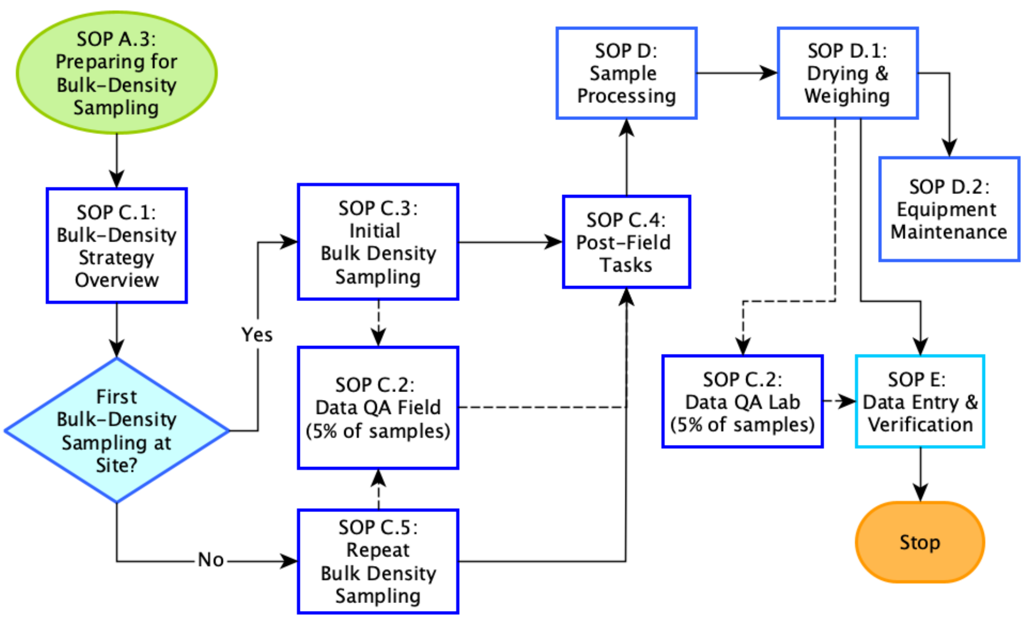

Figure 3. High level workflow diagram of Bulk-Density sampling.

For larger disks from which wedges were generated, the fresh-mass:dry-mass ratio is calculated for the wedge subsample, and this ratio, along with the fresh mass of the entire disk that was measured in the field, is used to determine the dry mass of the disk. Proper sample labeling, and tracking of sample data and metadata, is extremely important to enable this calculation.

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

Coarse Downed Wood sampling occurs every five years at sites where the protocol is implemented. To minimize labor spikes within a domain, implementation is staggered across sites so that not all sites are sampled the same year. In Tower Plots, SOP B is not synchronized with other protocols. However, in Distributed Plots, SOP B is synchronized in an 'on' year with two other TOS plant biomass protocols:

- TOS Protocol and Procedure: Measurement of Vegetation Structure (RD[08])
- TOS Protocol and Procedure: Measurement of Herbaceous Biomass (RD[14])

Scheduling of these three protocols is further coordinated with other TOS plant sampling protocols according to **Table 1**.

Table 1. Coordination of Coarse Downed Wood sampling with other TOS plant and soil sampling protocols through time. Years 1 through 7 are shown to illustrate the temporal grouping of protocols, and the pattern repeats beyond year 7. Grey cells indicate synchronized 'chemistry' and 'productivity' protocol groups; brown cells indicate protocols implemented annually in Tower Plots; orange cells are protocols implemented every 5 y in Tower Plots.

Protocol*	Interval (y)	Plot Type	Plot Number	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
BGB	5	tower	20 or 30†	X					X	
CFC	5	both	16-20	X					X	
LAI	5	distributed	20	X					X	
LTR-bgc	5	tower	20 or 30†	X					X	
NTR	5	both	10	X					X	
SLS-bgc	5	both	10	X					X	
SLS-mb	5	both	10	X					X	
CDW	***5***	***distributed***	***20***		***X***					***X***
HBP	5	distributed	20		X					X
VST	5	distributed	20		X					X
HBP	1	tower	5 to 30†	X	X	X	X	X	X	X
LAI	1	tower	3	X	X	X	X	X	X	X
LTR	1	tower	20 or 30†	X	X	X	X	X	X	X
VST	1	tower	5-10‡	X	X	X	X	X	X	X
CDW	***5***	***tower***	***20 or 30†***				***X***			
VST	5	tower	20 or 30†					X		

* Protocol codes and definitions: **BGB** = Belowground Biomass of fine root sampling; **CFC** = Canopy Foliar Chemistry sampling; **DIV** = Plant Diversity sampling; **LAI** = Leaf Area Index sampling; **LTR-bgc** = Litterfall biogeochemistry analysis; **NTR** = soil nitrogen mineralization incubation; **SLS-bgc** = Soil biogeochemistry analysis; **SLS-mb** = Soil microbial biomass analysis (PLFA); **CDW** = Coarse Downed Wood sampling; **HBP** = Herbaceous Biomass and Productivity sampling; **VST** = Vegetation Structure sampling; **LTR** = Litterfall sampling (no chemistry).

† The total number of Tower Plots sampled for Coarse Downed Wood varies by site; see Appendix D to determine which plot types are sampled per site.

‡ A spatially-balanced subset of Tower Plots is selected for annual VST sampling at sites with relatively fast woody growth increment. See RD[08] for VST fast/slow growth increment classification by site.

Scheduling Considerations

The frequency and timing of CDW sampling depends on the SOP being implemented (**Table 2**). Note that SOP B "Field Sampling: Tallying and Measuring CDW" may be carried out independently from the bulk density SOPs (SOP C and SOP D). Consult the interannual schedule and the plot priority matrix to inform plot sampling order for the bout.

CDW Tally (SOP B) must be completed at least once at each site before the bulk-density SOPs are implemented, as initial Tally data inform which logs are sampled for bulk density. The bulk density sampling SOPs must always be performed together, and these SOPs may be carried out over more than one year to enable collecting the desired sample size (Appendix G).

Table 2. Sampling frequency, sampling effort, and timing guidelines for Coarse Downed Wood procedures on a per-SOP basis.

SOP	Plot Type	Plot Number	Sampling Events	Yearly Interval	Remarks
SOP B: Field Sampling: Tallying and Measuring CDW	Distributed	20 max*	1X per sampling year	Every 5 y	• Sampling should ideally be completed before the start of the next sampling season. • SOP B should be completed at least once prior to implementing the bulk density SOPs.
	Tower	20-30†			
SOP C: Field Sampling: Bulk Density Sampling in the Field	Distributed	20 max*	Once within first 3 y of Operations; second time 5-6 y after first bout began	5-6 y	• Sampling occurs twice per site. • A given sampling event may occur over two consecutive years if needed.
	Tower	20-30†			
SOP D: Processing Bulk Density Samples in the Laboratory	Distributed	20 max*	Once within first 3 y of Operations; second time 5-6 y later	5-6 y	Sample processing in the laboratory should occur ASAP following field work.
	Tower	20-30†			

*CDW sampling occurs in the same subset of Distributed plots that are used for other plant biomass protocols; not all Distributed Plots will be sampled if CDW logs are absent from selected plots.

† The number of installed Tower plots vary by site; typically, forested sites that produce CDW support twenty 40m x 40m plots; however, some sites with CDW may have thirty 20m x 20m Tower plots.

4.2 Implementation Criteria

- If CDW tally has not been completed at a given site, an implementation decision is made via an analysis of VST data in consultation with Science. Implementation is based on the probability of detecting CDW logs ≥ 2 cm diameter.
- If less than 5 CDW logs were tallied at > 20% of the sampled plotIDs, request a smaller volume factor (F) for the site as described in the "Too few CDW particles" section of SOP B.5 (**Table 14** and **Figure 4**).
- If CDW tally has been implemented, the F-value cannot be reduced further, and:
    - Any of the following are true:
        - No logs were tallied in at least one plot OR
        - Transects at < 10% of plots intersect a log OR
        - < 10 logs were tallied across all Distributed Plots or all Tower Plots
    - Communicate with Science to determine whether sampling should be suspended indefinitely until a state-changing event affects site-level CDW abundance (e.g., fire, brush-hogging, species invasion, etc.). Zeros do have value at the continental scale, so sampling may continue if logs are infrequent but still present.
    - Do not implement or schedule CDW bulk density (SOP C, SOP D).
- If CDW tally has been suspended indefinitely at a site:
    - Do not implement or schedule CDW bulk density (SOP C, SOP D).
    - Keep CDW tally on the inter-annual schedule in the event a state-change occurs and sampling is required.
    - Science and Field Science teams must communicate in the year prior to scheduled sampling to assess site conditions and determine whether a state-change has occurred and CDW tally should be implemented.

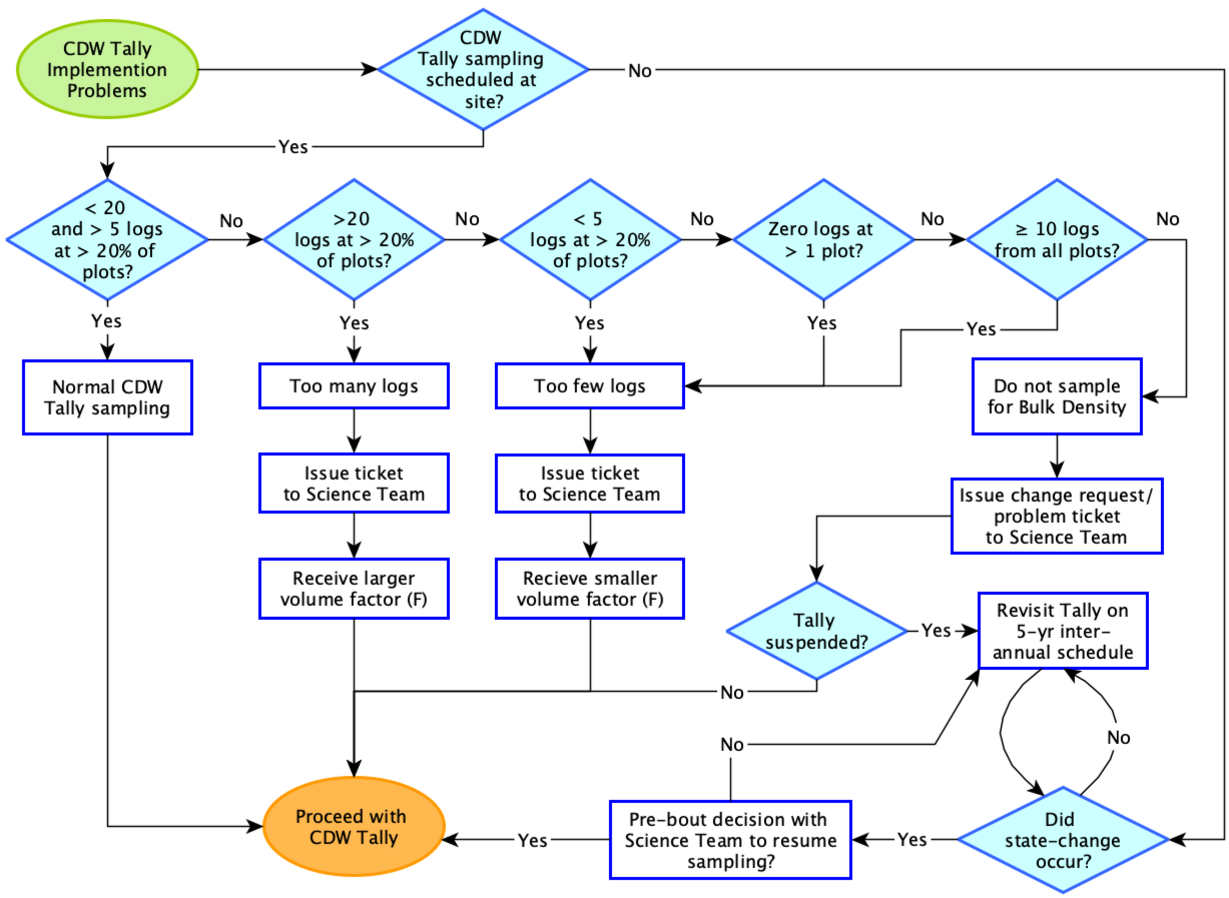

Figure 4. CDW Tally implementation problems workflow.

4.3 Criteria for Determining Onset and Cessation of Sampling

CDW Tally Onset and Cessation

Because CDW production may be maximal during periods of seasonal storm activity, CDW Tally (SOP B) sampling is typically timed to occur *after* the period of maximal expected storm activity for a given site.

- Refer to **Table 21** for sampling onset guidelines. Provided dates are guidelines only, and it is incumbent upon Field Science to select sampling onset dates that are appropriate for each site and consistent with periods of storm activity. Submit a Schedule Change Request if dates listed in **Table 21** are not feasible for your site(s).
- If there is not a seasonal pulse of CDW production and there is a dense understory that reduces visibility, then a schedule change request can be made to allow CDW Tally sampling during a leaf-off period.

- The temporal window in which CDW Tally must be completed is relatively long – it is only required that CDW field sampling be completed before the season of maximum storm activity resumes.

CDW Bulk Density Onset and Cessation

- CDW Bulk Density Bout 1 sampling (SOP C) should not occur until an initial bout of Tally sampling in both Tower and Distributed plots has been completed (SOP B). This is to ensure that a complete census is available to create a comprehensive DST rank abundance list.
    - Tip: Because CDW Tally in Distributed and Tower plots is staggered (**Table 1**), schedule the first implementation of SOP C the same year that SOP B is implemented at a site for the second time.

- Criteria for cessation of CDW Bulk Density (SOP C) sampling are detailed in SOP C.1. Briefly:
    - DSTs (Decay class x sizeCategory x taxonID combinations) that cumulatively make up at least 80% of the total tallies have been sampled.
    - Alternatively, the criterion immediately above has not been met, but all CDW plots have been searched within a 50 m radius of the plot centroid and the subset of DSTs on the list that were present have been sampled. Desired sample sizes may not be achievable for all DSTs.

4.4 Timing for Laboratory Processing and Analysis

Because wood samples will continue to decay after collection and before drying, particularly when very moist, it is important to place wood samples into the drying oven as soon as possible following collection.

- Ideally, place samples in the drying oven within 24 hours of collection in the field.
- If drying within 24 h is not feasible:
    - Keep samples in breathable sample bags in a dry place (e.g., muslin cloth bags or heavy duty kraft paper bags). Keeping samples in a breathable bag is important (as opposed to plastic) because air-drying at room temperature can begin before the sample is placed in the drying oven.
    - Place samples in the drying oven within 5 days of collection in the field.

Once wood samples are dry, they may be placed in temporary storage prior to weighing. There are no scientific limits on the time oven-dried samples may be placed in temporary storage prior to laboratory processing.

4.5 Sampling Timing Contingencies

Changes in sample timing on the order of hours to weeks have relatively little impact on the integrity of Coarse Downed Wood Tally (**Table 3**) and Bulk Density (**Table 4**) sampling compared to many other protocols. The key constraint on Coarse Downed Wood Tally sampling timing is that it should be completed before the onset of winter storms or other predictable events that would create fresh new coarse downed wood logs (e.g., hurricanes).

Table 3. Contingency decisions for Coarse Downed Wood field tally work (SOP B).

Delay/Situation	Action	Outcome for Data Products
Hours to days	If delay prevents completion of any of the three LIDS transects originating within a given **plotID**, record in the **remarks** field: 1. Document delay for the **plotID** in question. 2. Note distance along transect at which delay occurred. 3. Return to transect ASAP and continue sampling at distance recorded in the **remarks** field.	None anticipated
	If delay occurs between plots, resume CDW survey at next **plotID** ASAP.	None anticipated

Table 4. Contingency decisions for Coarse Downed Wood bulk density sample collection (SOP C).

Delay/Situation	Action	Outcome for Data Products
Hours to days	If delay prevents completion of bulk-density disk sampling: 1. Label cross-sectional disk, place any "wedges" into a labeled sample bag, and transport samples to an indoor work area. 2. Complete required disk measurements and record disk data. 3. Return to the field ASAP and continue sampling additional log cross-sectional disks.	None anticipated
	If delay occurs after sampling a log is complete but before the next log is begun, resume bulk density sampling ASAP.	None anticipated

4.6 Missed or Incomplete Sampling

Sampling according to the schedule is not always possible, and multiple factors may impede work in the field at one or more plots or sampling locations during a bout. For example:

- Logistics – e.g., insufficient staff or equipment
- Environment – e.g., deep snow, flooding, inclement weather, fire, smoke, or
- Management activities – e.g., controlled burns, pesticide application

Instances such as those listed above must be documented for scheduling, tracking long-term plot suitability, and informing end users of NEON data availability. Some types of missed sampling are due to events that should be recorded in the Site Management App; refer to the Site Management and Disturbance Protocol for more detail (RD[06]).

Missed or Incomplete Sampling Terms

Terms that inform Missed or Incomplete Sampling include:

- **Protocol Sampling Dates**: Bout-specific sampling dates (Appendix C).
- **Scheduled Sampling Dates**: Bout-specific sampling dates scheduled by Field Science and approved by Science. These dates coincide with or are a subset of the Protocol Sampling Dates.
- **Missed Sampling**: Incidence of *scheduled sampling* that did not occur. Missed Sampling is recorded at the same resolution as data that are ordinarily recorded.
- **Sampling Impractical**: The field name associated with a controlled list of values that is included in the data product to explain a Missed Sampling event – i.e., why sampling did not occur.
- **Rescheduled**: Missed Sampling is rescheduled for another time according to one of the scenarios documented in **Figure 5**, resulting in no change to the total number of sampling events per year.

The documentation that must accompany missed sampling depends on the timing, subsequent action, and the audience appropriate for numerous scenarios (**Figure 5**).

To Report Missed or Incomplete Sampling:

1. Missed or Incomplete Sampling that cannot be rescheduled within the Schedule sampling dates must be communicated to Science by a ServiceNow Incident.
    a. For Missed Sampling that is Rescheduled, there are some cases that require approval by Science and Operations (**Figure 5**).
    b. Consult **Table 5** below to determine required actions if scheduled activities are delayed or canceled. Guidance for this and other NEON protocols is summarized for ease of use in a table posted to a Field Science Sharepoint library. However, this protocol is the ultimate source of information should any discrepancy exist.

2. Create a Fulcrum record for each Missed Sampling event in the field that cannot be rescheduled. That is, if data are recorded in the field at the plot level, a record must be made for each plot missed.
    a. For Coarse Downed Wood Tally (SOP B), record each plot not sampled in each bout; it could be all plots or a subset of plots.
    b. For Coarse Downed Wood Bulk Density (SOP C and SOP D), documentation of Missed Sampling is not required since bulk density measurements are not linked to a specific narrow time period.
3. For each missed sampling record, the **Sampling Impractical** field must be populated in the mobile collection device (**Table 6**).
4. For rescheduled sampling events that occur outside of the defined Protocol Sampling Dates, a protocol-specific Flag may be recorded by Science (**Figure 5**).

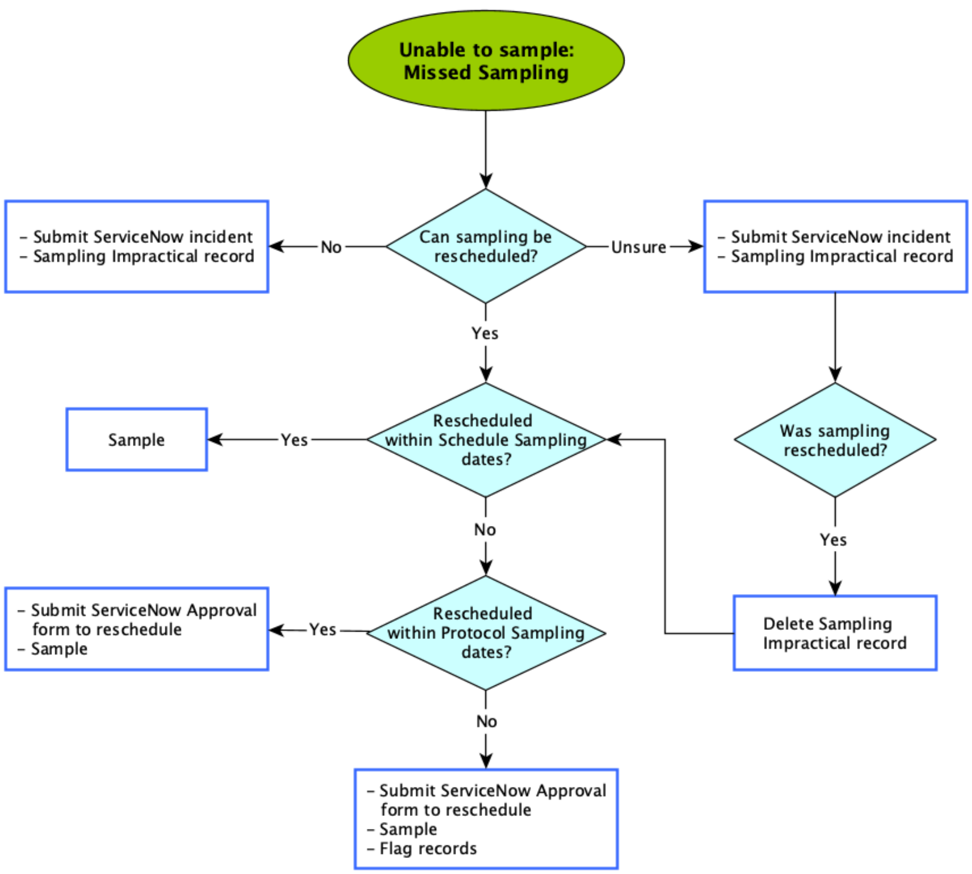

Figure 5. The documentation to account for a Missed Sampling event depends on the situation for each sampling unit not sampled per bout that is not sampled. Diamonds represent decision points and boxes describe the required action. Required actions may include a) Submitting a ServiceNow incident, b) creating a Sampling Impractical record, c) Science creating a data Flag, d) creating a Site Management record, or e) some combination of (a) – (d).

Table 5. Guidance for responding to delays and cancellations encountered during implementation of the Coarse Downed Wood protocol.

Activity Name	Days Delayed from Schedule	Delay Action	Cancellation Action
Tallying and Measuring CDW in the Field	< 1 season	Resume sampling when possible	If not able to complete during first season then submit a Schedule Change Request to determine whether completing in a second season is possible.
Bulk Density Sampling in the Field	> 1 season after start of sampling	Resume sampling during second season	Not applicable (complete sampling within two sampling seasons)
Processing Bulk Density Samples in the Laboratory	> 1 day after collection in the field; Not room in drying oven	Make sure samples are in breathable bags (not plastic) so they can begin to air-dry	Not applicable (once samples have been collected they need to be oven-dried and processed)

Table 6. Protocol-specific Sampling Impractical reasons entered in the Fulcrum application. If more than one is applicable, choose the dominant reason sampling was missed.

Sampling Impractical reason	Description
Other	Sampling location inaccessible due to other ecological reason described in the remarks
Location flooded	Standing or flowing water too deep to complete sampling
Logistical	Site or plot access compromised, staffing issues, errors (e.g., equipment not available in the field)
Management	Management activities such as controlled burn, pesticide applications, etc.
Extreme weather	Events (e.g., thunderstorms, hurricanes) that compromise safety and access
Location vulnerable to planned sampling	Location vulnerable to excessive technician impacts during planned sampling

4.7 Estimated Time

The time required to implement a protocol will vary depending on several factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided in **Table 7** is an estimate based on completion of a task by a skilled two-person team (i.e., not the time it takes at the beginning of the field season). Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, a problem ticket should be submitted. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 7. Estimated staff and labor hours required for implementation of the Coarse Downed Wood protocol.

SOP	Estimated time	Suggested staff	Total person hours
SOP A.2: Preparing for CDW field tally	0.5 h	1	0.5 h
SOP 0: Preparing for CDW field bulk density	2 h[1]	1	2 h
SOP A.5: Preparing for CDW laboratory processing	0.5 h	1	0.5 h
SOP B: CDW field tally	1 h – 1.5 h per plot (sparse) 2 h – 8 h per plot (dense)[2]	2	2 h – 3 h per plot (sparse) 4 h – 16 h per plot (dense)
SOP C: CDW bulk density field	2 h – 16 h per plot[3]	2	4 h – 32 h per plot
SOP D: CDW bulk density lab	1 – 3 min per sample	1	1 h – 15 h[4]

[1] Includes estimated time for chainsaw maintenance.

[2] Dense vegetation contributes to longer sampling times by impeding accurate placement of transect tapes and/or walking a transect.

[3] Wide range in estimated time due to variation in tree species richness across sites, variation in vegetation density.

[4] Expected sample number varies between 60 – 300 by site. Time estimate includes handling, drying, weighing, and recording data for each wood sample.

5 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices.

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the EHS Safety Policy and Program Manual (AD[01]) and Operations Field Safety and Security Plan (AD[02]). Additional safety issues associated with this field procedure are outlined below. If an employee witnesses any unsafe conditions or uncontrolled hazards that present an imminent danger, they should immediately take action to stop work and report such conditions to their manager. Employees must also report all workplace injuries, illnesses, incidents, or releases to the environment as soon as possible, regardless of the severity.

5.1 Safety: Tallying and Measuring CDW in the Field (SOP B)

5.1.1 Measuring Distances with the Laser Rangefinder

A laser rangefinder/hypsometer/compass instrument may be used to determine transect distances and measure log lengths. Safety considerations for this instrument include:

- Avoid staring directly at the laser beam for prolonged periods. The rangefinder is classified as eye-safe to Class 1 limits, which means that virtually no hazard is associated with directly viewing the laser output under normal conditions. However, as with any laser device, reasonable precautions should be taken in its operation. It is recommended that you avoid staring into the transmit aperture while firing the laser.

- Never attempt to view the sun through the scope. Looking at the sun through the scope may permanently damage the eyes.

5.1.2 Measuring Log Length

When measuring logLength, or any other log attribute, it is recommended that personnel avoid standing, climbing, or working on logs, regardless of how high off the ground the log may be. Log surfaces may be slippery, resulting in a fall hazard, or logs may roll, introducing additional crushing risks. In addition, standing on logs can impact sample quality and measurements.

5.2 Safety: Bulk Density Sampling in the Field (SOP C)

Chainsaw Safety

SOP C requires that field staff cut cross-sectional disks from downed logs to generate bulk density data. The most efficient way to collect cross-sectional disks from downed logs is with a chainsaw, although a hand-powered buck saw is a less ideal option that can be employed should regulations or logistics prevent the use of a chainsaw. Should a chainsaw be chosen to complete the sampling task, there are multiple safety regulations provided in RD[12]. To ensure safe operation of the chainsaw, NEON staff are required to complete USFS S-212 training (or equivalent) prior to operating a chainsaw. Training must be completed at least every 3 years. In addition to following the safety regulations and training cited above, bring a first aid kit to the plot, use hand signals if verbal communication is impaired by the sound of the saw, and be aware of the plot coordinates in the event an emergency needs to be reported. An emergency response plan should be prepared in advance, and all staff should be aware of the plan.

Personal Protective Equipment Requirements

- Personal Protective Equipment (PPE) for the head (hard hat), ears (ear protection), eyes (safety glasses), face (e.g., shield), hands (gloves), feet (e.g., boots), and legs (chainsaw chaps) must be worn when operating the saw to prevent or lessen the severity of injuries to workers (see RD[12]).
- PPE must be inspected prior to use to ensure it is in serviceable condition.
- Do not wear loose-fitting clothing.

Before Taking the Saw to the Field

- Verify that the saw's chain is sharp. If the chain is not sharp, then sharpen the chain according to the manufacturer's instructions.

Before Starting the Saw

- Clear the area of obstacles that might interfere with cutting the log. Clear away dirt, debris, small tree limbs, and rocks from the saw's path.
- Look for nails, spikes, or other metal in the log before cutting.
- Check controls, chain tension, and all bolts and handles to ensure they are functioning properly and adjusted according to the manufacturer's instructions.
- Make sure the lubrication (bar oil) reservoir is full.
- Start the saw on the ground or on another firm support. **Drop starting is never allowed**.
- Start the saw at least 10 feet from the fueling area, with the chain's brake engaged.

While Running the Saw

- Assure a solid, flat surface for foot placement, prior to operating the chainsaw.
- Safety is paramount when operating the saw:
    - Preserve chain sharpness; operating a dull saw leads to fatigue.
    - To preserve sharpness, cut less decayed classes first, as more decayed logs will require passing the saw into the duff / topsoil layer.
    - When cutting into the duff / topsoil layer, always use care and be ready for kickbacks.
    - If necessary and feasible, move the log to be cut so the chain avoids contact with soil or rocks.
- Keep hands on the handles and maintain secure footing while operating the chainsaw.
- Be careful that the log or branches will not bind against the saw. Watch for branches under tension, they may move suddenly when cut.
- Do not cut directly overhead or above shoulder height.
- Shut off the saw or release throttle prior to retreating.
- Shut off the saw or engage the chain brake whenever the saw is carried more than 3 steps, or across hazardous terrain.
- Be prepared for kickback; saws must be equipped with a mechanism that reduces kickback danger (chain brakes, low kickback chains, guide bars, etc.)
    - Do not saw with the tip. If equipped, keep tip guard in place.

Fueling the Saw

Due to EPA requirements for non-venting fuel containers/systems, all fuel containers and gasoline powered saws manufactured after 2010 can become pressurized during normal use, and in some cases, can create fuel ‘geysers’ when fuel containers are opened. Such fuel geysers have been known to catch fire, and multiple severe burn injuries have been reported when this occurs. When re-fueling a gasoline powered chainsaw, pay attention to the following:

- Let the saw cool before opening the fuel cap. Never add fuel to a running or hot saw.
- Cover the cap with a rag while slowly opening any tank. This will slowly relieve any internal pressure and prevent fine mists of any escaping fuel from finding an ignition source.
- Check the fuel container for the following requirements:
    - Must be metal or plastic.
    - Must not exceed a 5-gallon capacity.

  - Must be approved by the Underwriters Laboratory (UL), Factory Mutual (FM), the Department of Transportation (DOT), or other nationally recognized testing laboratory.
  - Type 2 gas cans meet all the above requirements.
- Dispense fuel at least 10 feet from any ignition source.
  - Refuel over a gasoline spill mat / tarp, so small spills can evaporate before entering soil.
  - No smoking during fueling.
  - Fueling should ideally occur on the road or nearest approach to the plots.
  - Fueling should never take place within a designated NEON plot.
- Use a funnel or flexible hose when dispensing fuel into the saw.

6 PERSONNEL

6.1 Training Requirements

All technicians must complete protocol-specific training as required in the Field Operations Job Instruction Training Plan (AD[04]). Additional protocol-specific required skills and safety training are described here.

For the field component of this protocol, staff must be trained in navigating to points in the field with a GPS and manual methods.

As per OSHA recommendations, training requirements for chain saw use may include:

- Specific work procedures, practices, and requirements of the work site, including the recognition, prevention, and control of general safety and health hazards.
- Requirements of the OSHA Logging standard or equivalent, Bloodborne Pathogens standard, First Aid, and CPR training.
- How to safely perform work tasks, including the specific hazards associated with each task, and the measures and work practices which will be used to control those hazards.
- How to safely use, operate, and maintain tools which the employee will be required to utilize in completing the assigned tasks.

In addition, for both the field and laboratory work, training must emphasize the importance of consistent, detailed labeling of all samples. ***Improper or inconsistent labeling is the most common and problematic error associated with this work!***

6.2 Specialized Skills

When performing field tallies and measurement of CDW logs (SOP B), and when sampling CDW for bulk density (SOP C), the lead plant technician must possess the demonstrated ability to identify most relatively undecayed logs to species based on bark and branch characteristics. Ideally, the lead technician will also be able to identify most relatively decayed logs to either genus or family.

7 STANDARD OPERATING PROCEDURES

SOP Overview

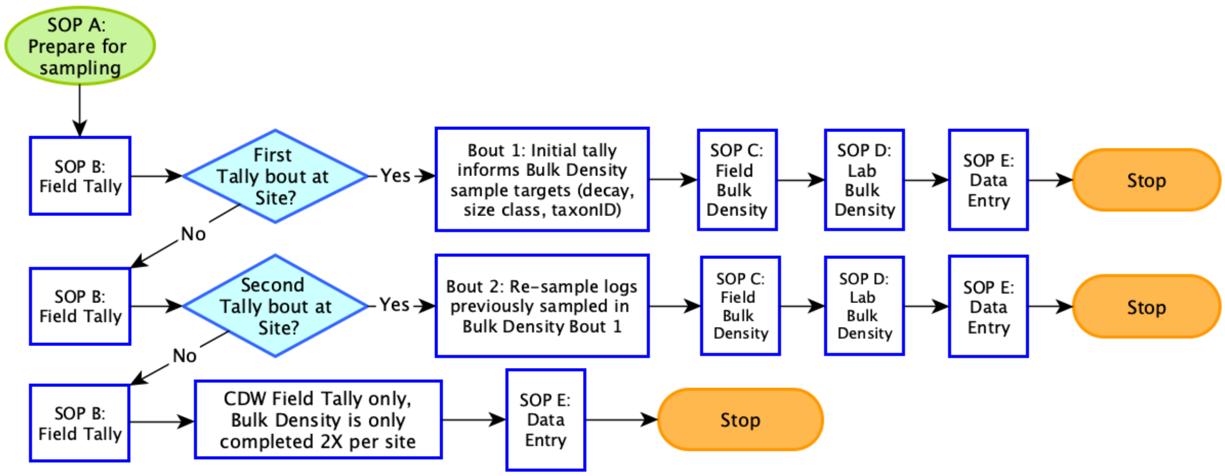

Figure 6. High-level workflow diagram illustrating major components and decision points within the Coarse Downed Wood protocol.

- **SOP A: Preparing for Sampling** (**Figure 6**).
- **SOP B: Field Sampling: Tallying and Measuring CDW.** (**Figure 6**, **Figure 9**). Find logs that intersect the transects and determine whether they qualify for tallying.
- **SOP C: Field Sampling: Bulk Density Sampling in the Field.** Collect disk samples of coarse downed wood logs away from transects, targeting the most abundant decay, size, and taxon (DST) combinations (**Figure 6**, **Figure 19**).
- **SOP D: Processing Bulk Density Samples in the Laboratory.** Weigh samples of known volume in the laboratory and generate bulk density data. Combined with CDW volume, bulk density data may be used to estimate CDW mass (**Figure 6**, **Figure 20**).
- **SOP E: Data Entry and Verification.** Guidelines and requirements for successful data entry and use of QC Checklist. This SOP is NOT a substitute for AOS/TOS Protocol and Procedure: Data Management (RD[04]). Staff must read RD[04] (**Figure 6**).

SOP A Preparing for Sampling

A.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged and synced at the beginning of each field day, whenever possible.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices at all times.

A.2 Preparing for Tallying and Measuring CDW in the Field (SOP B)

1. Plan and save sampling routes for field teams using standard site navigation procedures (RD[07]). Route planning enhances sampling efficiency and helps avoid accidental foot traffic within NEON plots.
2. Charge GPS and load target plot locations.
3. Check/set correct compass declination. Note that declination changes with time and should be looked up annually per site: http://www.ngdc.noaa.gov/geomag-web/
4. Prepare laser rangefinder according to guidelines in RD[10].
5. Charge and sync mobile data collection tablets.
6. Print (on all-weather paper) CDW "Field Tally Datasheets" and site-specific LIDS angle list.
7. Note the site-specific volume factor (F) for CDW sampling provided by Science (Appendix D, **Table 22**). The volume factor (F) is analogous to plot size, and along with the diameter of CDW present at a site, determines the sampling effort required at a given site. A single volume factor should be used across a site, do not use multiple values. The per site determination of F is in accordance with these general guidelines:
    a. Large F when CDW is plentiful and of relatively large diameter.
    b. Small F when CDW is sparse and of relatively small diameter.
8. Consult **Table 22** or Science for the appropriate LIDS transect length.
    a. For first-time sampling, Science determines transect length via analysis of Vegetation Structure data.
    b. Transect lengths may subsequently be revised after analysis of first-year CDW tally data.
9. If performing a re-tally (i.e., SOP B.7), prepare a list of logIDs and associated data from the most recent bout to aid in identifying logs that were likely tagged but for which tags cannot be found.

A.3 Preparing for Bulk-Density Sampling in the Field (SOP C)

1. Plan and save sampling routes for field teams using standard site navigation procedures (RD[07]). Route planning enhances sampling efficiency and helps avoid accidental foot traffic within NEON plots.
2. Charge GPS and load target plot locations.
3. Check/set correct compass declination. Note that declination changes with time and should be looked up annually per site: http://www.ngdc.noaa.gov/geomag-web/
4. Prepare chainsaw, when chainsaw use is permitted.
    a. Inspect chain and sharpen if necessary
    b. Inspect chain tension and adjust if necessary
    c. Prepare 2-cycle fuel in gallon fuel container
    d. Fill fuel and bar oil reservoirs (see Safety Section 5.2).
5. Cut waterproof “Rite-in-the-Rain” paper into 8 equally sized pieces per sheet for bulk density sample labels and attach a Type I barcode.
6. Mark unique **bagNumbers** on muslin bags with permanent ink (if no pre-marked bags exist). The same bags may be re-used for subsequent disk collections. Make sure that enough muslin bags are available well in advance since paper bags will rip with wet, heavy samples.
7. Charge and sync mobile data collection tablets.
8. Print CDW “Field Density Datasheets” and LIDS angle list.
9. Consult Appendix G for per site ranked lists of the most abundant ‘decayClass x sizeCategory x taxonID’ (DST) combinations at your site (based on analysis of SOP B data from both Tower and Distributed plots). Make sure to prioritize sampling the most abundant DSTs if time/resources are limiting.
10. Prepare drying oven:
    a. Clear sufficient space for wood bulk-density samples.
    b. Set temperature to 105 °C.
11. Print Drying Datasheets.
12. Calibrate spring scales.
    a. Before each bout and for each spring scale:
        i. Weigh a bag plus weight (any object is ok) to the nearest 0.1 g on a laboratory balance and record this as the reference weight (weight should be around the mid-point of scale’s range).

ii. Clip bag plus weight to spring scale and turn the knob at the top of the spring scale until the weight registered on the spring scale matches the reference weight.

b. Each year and for each spring scale calibrated in previous step:

i. Test that the spring has not become deformed over time.

ii. Record weights at approximately 25% and 75% of the scale's capacity.

iii. Discard any calibrated spring scale that registers a weight that deviates from the low-range or high-range reference weight by > 5% (e.g., outside of range 76-84 g for 80 g reference for a 100 g scale).

c. With heavy use (many heavy samples), re-calibrating multiple times per bout is prudent.

13. Optionally, if potentially qualifying logs are opportunistically noticed during field work for other protocols, record notes on how to relocate those logs on a tracking sheet (outside of data collection app).

A.4 Labels and Identifiers

Each log sampled in the field for tally or bulk density is assigned a **sampleID** that incorporates an **eventID**, **plotID**, and **logID** (SOP B and SOP C). In SOP C each subsample in the form of a disk that is collected from a selected log (two disks per log if log is ≥ 5 m long) is assigned a **subsampleID** that concatenates the **sampleID** and **diskID** (**Figure 7**).

For bulk density sampling, proper labeling of samples is critical while tracking samples through laboratory processing steps. Samples are labeled with human-readable information at all steps to improve and aid sample organization, and barcodes are used for most sample types to speed data entry and reduce transcription errors and typos. SOP C and SOP D create and process physical samples, so for these SOPs prepare labels using pre-cut pieces of 'Rite-in-the-Rain' type all-weather paper and affix a Type I barcode (**Figure 8**). The label's **collectDate**, **plotID**, **logID**, **diskID**, and **subsampledID** (**Figure 7**) can be populated with a permanent marker in SOP C.

EXAMPLE SUBSAMPLE IDS:

Log with one disk:

CDW.2022.OSBS007.7871.1

Log with 2 disks:

CDW.2022.JERC001.8898.1

CDW.2022.JERC001.8898.2

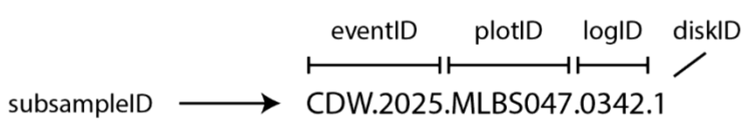

Figure 7. Annotated subsampleID structure.

About Barcode Uses and Placement

Figure 8. An example of a Type I barcode. These large-size, field-tolerant barcodes have a prefix of 'A' followed by 11 numbers.

Barcodes are required for Coarse Downed Wood bulk density disk samples (or subsamples).

- Barcodes speed entry of data into the *CDW: Lab Bulk Density [PROD]* app if barcodes are first recorded in the *CDW: Field Bulk Density [PROD]* app. Adhesive barcode labels should be applied to dry, room temperature sample labels (prepared in SOP A.3 step 5 above) in advance of their use in the field. Barcodes should be applied at least 30 minutes prior to use but may be applied at the start of the season.
- Barcode labels should be Type I for SOP C and SOP D (**Figure 8**). Note that a barcode label is applied *in addition to* labeling the disk sample or subsample with human-readable information (hand-written or printed).

Barcodes are scanned into the mobile application when the disk or disk subsample is placed into the bag; only one barcode may be associated with a particular sample.

Many protocols use a mix of human intelligible labels and barcodes in their workflow. For CDW sampling, barcodes are useful for minimizing transcription errors and tracking samples from the field to the domain support facility.

Best practice for barcode application and maintaining proper adherence to sample labels:

- All barcodes need to be applied to dry pieces of paper for 30 mins before use. Type I (prefix A, plus 11 numbers) are for all field samples.

- Prepare sample tag by affixing one Type I adhesive barcode label to each piece of paper destined to be placed in bag that is to be used to contain each sample. Adhesive barcode labels should be applied to dry, room temperature pieces of paper in advance of their use in the field (at least 30 minutes prior but may be applied at the start of the season).

- Barcode labels must be associated with a unique sample, and each barcode must be mapped to one sample in the database. Barcodes are unique, but are not initially associated with a particular sample, so you are encouraged to adhere barcode labels to needed slips of paper in advance.

- Do not reuse barcodes. If a barcode is associated with multiple samples the Parser will reject the records associated with the duplicate barcodes.

About Barcode Uses and Placement

This protocol generates disk subsamples of logs, and these disks are weighed in the field and again after being dried. The workflow of drying subsamples in the drying oven precludes reliably attaching barcodes to the bags used in drying, and so they are instead placed inside the bag. Although it is always acceptable to use barcodes, in some cases barcodes are absolutely required. **Table 8** provides a quick reference to the types of samples this protocol generates that require barcodes. The rule of thumb is that the primary field sample will ALWAYS need a barcode due to its importance in generating future samples.

Table 8. Barcode requirements for sample types generated by the CDW – Coarse Downed Wood protocol.

Sample Type	Description	Example Identifier	Fulcrum App	Container Type	Barcode Used	Barcode Required ?	Barcode Qty
Logs in the field	*Logs tallied in the field but not collected.*	*NEON.CDW. D10.00120 (NEON.CDW.domainID. logID*	*CDW: Tally*	*None*	*None*	*Not required*	*None*
Logs in the field	*Log sampleID is for log left in field; only subsample is collected*	*CDW.2025.MLBS012. 0362 (CDW.year.plotID.logID)*	*CDW: Field Bulk Density*	*None*	*None*	*Not required*	*None*
Field samples	*SubsampleIDs are for disks cut from logs in field*	*CDW.2025.MLBS012. 0362.1 (CDW.year.plotID. logID.diskID)*	*CDW: Field Bulk Density*	*Drying bag (barcode is on piece of paper in bag)*	*Type I*	***Always Required***	*1 per disk; variable (depends on number of DSTs)*

A.5 Preparing for Laboratory Processing of Bulk Density Samples (SOP D)

1. Print lab drying datasheets that are used to track when samples have finished drying (linked via the TOS Sampling Support Library).
2. Check lab electronic scale accuracy with 100 g standard weight.

SOP B Field Sampling: Tallying and Measuring CDW

Qualifying CDW logs have the following characteristics:

- Diameter ≥ 2 cm AND length ≥ 1 m, with central axis that intersects the transect (**Figure 2**). Woody particles < 2 cm diameter are ignored for this protocol. These particles are considered Fine Woody Debris and are sampled via the Litterfall protocol (RD[09]).
- Suspended logs should *not* be tallied if:
  - The angle from the ground exceeds 45˚ *or*
  - The log is ≥ 2 m above the ground where it intersects the transect, *or*
  - It is unsafe to measure the log.
- Is *not* a dead stem attached to a living plant.
- Is *not* a decumbent but living stem.

Goals

- Tally and measure qualifying CDW logs (**Figure 9**) along 3 transects per plot in all Tower Plots and a subset of twenty Distributed Plots (list provided by Science).
  - Tally allows estimation of CDW volume, a critical metric for calculating CDW mass and carbon stocks.
  - Measurement of CDW logs allows estimation of frequency, length and other variables important for assessing ecosystem function.
- Identify qualifying CDW logs and assign to decay class, size category, and **taxonID**.
  - These three variables are very important to accurately convert volume estimates to mass and carbon stock estimates.
- Enter data into the ***CDW: Tally [PROD]*** mobile application. See the Coarse Downed Wood Fulcrum Manual (RD[13]) for data entry details.

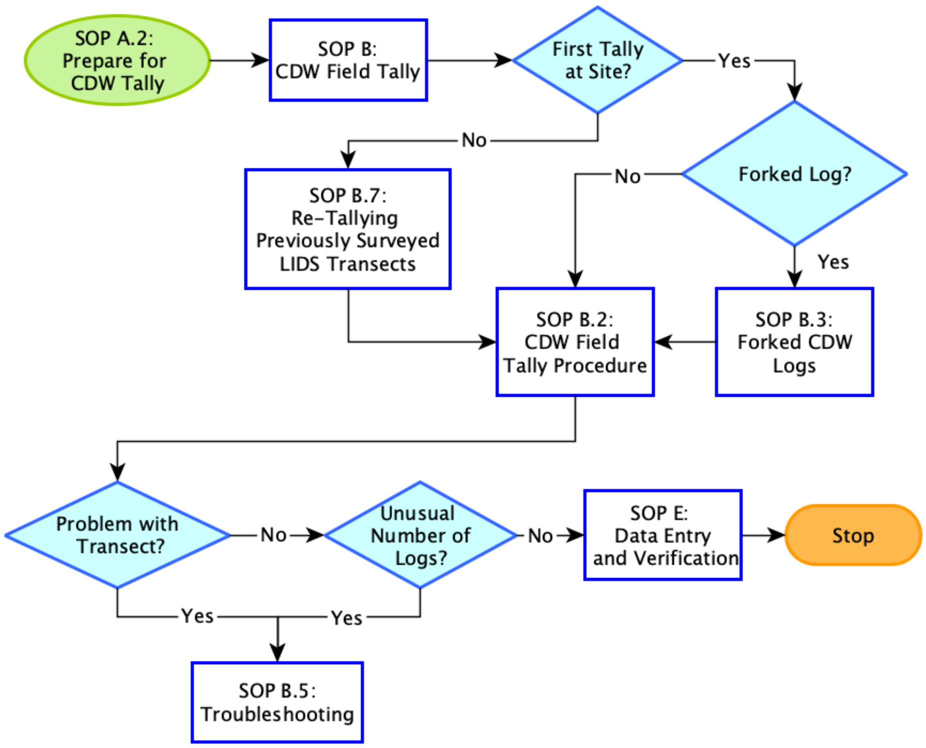

Figure 9. High-level workflow diagram for the CDW Tally Procedure.

B.1 Spatially and Temporally Linked Protocols

Vegetation Structure

The Coarse Downed Wood protocol and the Vegetation Structure protocol (RD[08]) are spatially co-located, and one of the important reasons why Coarse Downed Wood transects start 3 m from the plot centroid is to help avoid trampling vegetation at the plot centroid that is via the Vegetation Structure protocol. Furthermore, dead trees that have not yet fallen to an angle > 45˚ from vertical (i.e., snags) are accounted for via the Vegetation Structure protocol and should not be sampled in the Coarse Downed Wood protocol. Temporally, in Distributed plots Coarse Downed Wood and Vegetation Structure are sampled the same year in the five-year coordinated schedule (**Table 1**), but these protocols do not require within-season coordination.

Herbaceous Biomass

The Herbaceous Biomass and Coarse Downed Wood protocols do not require within-season coordination.

Coarse Downed Wood

Internally within this protocol, both Tower and Distributed plots should have been sampled for CDW Tally (SOP B) before proceeding to Bulk Density Bout 1 sampling (SOP C).

B.2 CDW Tally Procedure

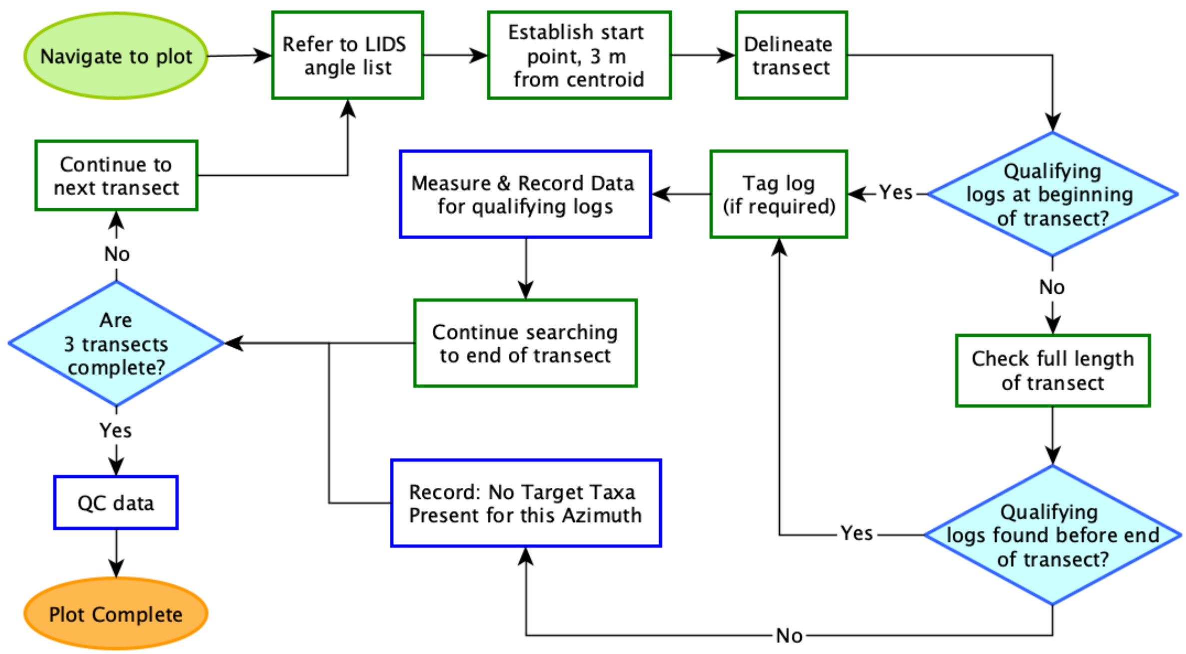

Figure 10. Summary of plot-level workflow for the CDW Tally procedure.

Procedure steps:

1. Navigate to the plot to be sampled (using the GPS if necessary) and locate the plot centroid. Avoid trampling the nested subplots that flank the centroid (**Figure 2**, pointID 41).
2. Create a parent-level record in the *CDW: Tally [PROD]* Fulcrum app for the **plotID**.
3. Assess the target plot for CDW potential:
   a. Use the “LIDS Angle List” to determine the azimuth relative to true north for the first LIDS transect. If the digital app is unavailable, azimuths for 3 LIDS transects per plot are provided by Science in the site-specific LIDS Azimuth Lists.
   b. While standing at the plot centroid (**Figure 2**), sight along the desired azimuth using a declination-corrected mirror-site compass or a calibrated TruPulse 360 rangefinder. ***!!!Note***: Be careful that metal items (inside or outside a backpack, or a backpack’s own metal frame, or earrings, bracelets, glasses frames, etc.) do not interfere with establishing an accurate bearing.

THE 3 METER GAP IS IMPORTANT TO:

- Minimize trampling around the centroid where Vegetation Structure measurements also occur, and
- Reduce the chance that CDW logs close to the centroid will be tallied on > 1 transect (if log is still tallied on > 1 transect then see **Table 14**).

i. Select an object in the middle distance (e.g., a unique looking tree, rock, or other feature) and use this object as a 'sight guide' for transect establishment along the desired azimuth.

c. For transects along which there is NO chance you will encounter qualifying CDW (e.g. transects that cross only grassland vegetation):

i. Create a child-level record in the *CDW: Tally [PROD]* Fulcrum app for the **plotID**,

ii. Record **lidsAzimuth** and **targetTaxaPresent** = 'No'.

iii. Save the child record.

d. If all three transects have NO chance of intersecting CDW:

i. Save the plot-level parent record.

ii. Proceed to the next **plotID** and continue sampling.

4. For all transects that may intersect CDW, use the sight guide from step 3.b to establish the origin and direction of the LIDS transect relative to the plot centroid.

a. Measure exactly 3 meters from the plot centroid toward the selected 'sight guide,' and anchor the end of the meter tape to the ground with a chaining pin. This point is the origin of the LIDS transect (**Figure 2**).

5. Create a child-level record in the *CDW: Tally [PROD]* app.

a. Record **lidsAzimuth** and **targetTaxaPresent** = 'Yes'.

6. Walk toward the sight guide and begin extending the transect to the maximum transect length (see **Table 22** for site-specific transect lengths).

- Place a chaining pin, pin flag, or temporary flagging every 10 m to accurately mark the transect, especially in a plot with dense vegetation.
- In extremely dense understory, it will be very difficult to navigate and to keep the tape straight. Do your best, and accept the fact that minor transect deviations are unavoidable.
- When line of sight is limited to several meters or less and severely limits accurately extending a tape along the transect, consider the strategies below.

STRATEGIES TO EXTEND LIDS TRANSECTS IN DENSE UNDERSTORY VEGETATION

- Mark points along the transect for future reference (if allowed by site host).
  - Mark logs or branches that indicate the beginning of the transect with marking that cannot be mistaken for CDW tags.
  - Establish a marker at the end of the transect.
- Work in shorter transect segments, rather than trying to establish the entire transect from beginning to end.
  - Walk the tape along the transect until you come to an obstruction.
  - Use a highly visible marker to indicate the end of a transect segment.
  - Markers can be kept in place to indicate intermediate points along the transect (if allowed by site host).
- Extend the transect from the origin using a calibrated compass and/or rangefinders.
  - Carefully maintain the **lidsAzimuth** and track the distance from the origin if a transect is paced out without the aid of meter tape.
- Triangulate around impenetrable obstacles (e.g., slash piles, "vine hell", *Rubus* thickets, etc.).
  - Re-align with the transect line and bearing as soon as possible.
  - Record the distance at which triangulation began and ended in the **remarks.**

7. Survey the transect for potentially qualifying CDW logs with diameter ≥ 2 cm AND length ≥ 1 m with central axes that intersect the transect (**Figure 2** and **Figure 11**).
   a. Assess qualifying diameter and length with respect to the point at which the central axis of the CDW log intersects the transect (**Figure 11**).
      - Since only logs < 2 m from the ground and < 45 deg angle with the ground at the point of intersection are considered CDW, only the portion of the log that meets those criteria should be measured and used to determine whether the log is long enough to qualify.
      - In **Figure 11**, the length of the central axis is measured from diameter 'breakpoints' because bulk density is calculated separately for different size categories, and thus length measurements must be assignable to these same diameter size categories:
        - 2 cm ≤ diameter < 5 cm
        - 5 cm ≤ diameter < 10 cm
        - diameter ≥ 10 cm

- **logMaxDiameter** is measured perpendicular to where the transect crosses the central axis of the log; if the log is bent, the measurement location will NOT be where the transect crosses the log itself (**Figure 11**).
- **logMinDiameter** is also measured for logs that are elliptical in shape (e.g., highly decomposed logs that have begun to collapse under their own weight).

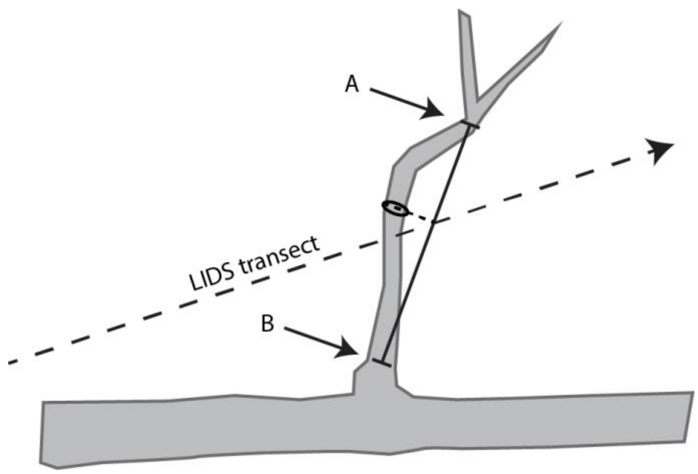

Figure 11. A LIDS transect (dashed line) intersecting a CDW log that is tallied within the 5-10 cm diameter size class. The intersected CDW log is attached to a larger log ≥ 10 cm diameter, but the transect does not intersect the larger size class so the larger size class is not tallied. Further along the branch from arrow A, the diameter is < 5 cm, and closer to the main bole from arrow B the diameter is ≥ 10 cm; the central axis (black line) is delineated along the portion of the log that is ≥ 5 cm diameter and < 10 cm diameter. Diameter is measured perpendicular to the central axis as shown by the oval in the figure. Diameter is *not* measured perpendicular to where the log intersects the transect, and diameter is *not* measured parallel with the transect where it intersects the log.

8. At a given distance along the transect, a log's cross-sectional area, combined with the volume factor, determines whether the log will be tallied. Diameter is an easy-to-measure proxy for cross-sectional area. Conceptually, the volume factor is inversely related to the CDW sampling area; the higher the volume factor, the shorter the transect and the less area searched for qualifying logs.
   a. If the auto-calculated round diameter equivalent (RD_E) is available in the *CDW: Tally [PROD]* app, use that RD_E to determine whether a log diameter qualifies.
   b. If the auto-calculated round diameter equivalent (RD_E) is NOT available in the *CDW: Tally [PROD]* app, use the following guidance to determine whether a log diameter qualifies.

EXAMPLES:

Example 1: Assuming a volume factor of F=8, CDW logs with D < 13.9 cm are NOT tallied if you have already walked 10 m along the transect.

Example 2: Assuming a volume factor of F=8, do NOT tally pieces of CDW with D < 10 cm if you have already walked 5.14 m along the transect.

i. For unforked round logs, **logMaxDiameter** is identical to RD_E and so **logMaxDiameter** can simply be used to determine whether a log diameter qualifies.

ii. For logs that are elliptical in shape, fall back on **logMaxDiameter** to determine whether a log diameter qualifies. Extraneous logs can be removed later based on the auto-calculated RD_E derived from **logMinDiameter** and **logMaxDiameter**.

iii. For forked logs, consult **Table 20** in Appendix A.3 to determine the RD_E, using conservative **logMaxDiameter** if the forks are elliptical. If unsure, tally and measure the log – extraneous logs can be removed later based on the auto-calculated RD_E derived from **logMinDiameter** and **logMaxDiameter** for each of the forks.

9. When a potentially qualifying CDW log intersects the transect, use log length data from step (7), the appropriate diameter from step (8), the volumeFactor (F) of the transect, and the distance along the transect to determine whether the log qualifies for tally and measurement:
    a. Use the mobile *CDW: Tally [PROD]* application's auto-calculated Minimum Round Diameter (RD_{min})to determine whether the diameter of the log qualifies for tally.
    b. If the tablet or the mobile *CDW: Tally [PROD]* application fails, use either **Table 18** or **Table 19** in **Appendix A** to determine whether a log should be tallied.
        i. The tablet is more accurate for this task, so use **Appendix A** only in the event of tablet failure. If you are unsure, tally the log; corrections to the data can be made during data QC checks if appropriate **remarks** are recorded.
10. Additional considerations:
    a. Forked CDW logs are tallied according to SOP B.3.
    b. Logs charred by fire are recorded using additional criteria in SOP B.4 and **Table 12**.
    c. See SOP B.5 'Troubleshooting' for other common issues and their resolution (e.g., irregular logs, slash piles, too few or too many logs, etc.)
11. For a qualifying log, create a child-level record in the *CDW: Tally [PROD]* app, and:
    a. Enter the **lidsAzimuth** and record **targetTaxaPresent** = 'Yes'.
    b. Enter the **logDistance** and **logMaxDiameter** (**Table 9**).
    c. Record the **logID**:
        i. For logs ≥ 10 cm diameter, search for pre-existing tags if CDW tally has previously been implemented and record the **logID**. Using data from a previous bout (prepared in **SOP A.2**) and a metal detector may help in the search for pre-existing tags.
        ii. For untagged logs ≥ 10 cm diameter:

a) If not already tagged, mark with a numbered, **red** (for visibility) aluminum tag and record the **logID**.

b) Place the tag in a visible location near the intersecting point. Exceptions are if the wood is highly decayed at the intersect point; in this instance, use a pig-tail stake and place the tag where it is likely to stay in the log.

c) For CDW logs with multiple qualifying branches, place the tag on the first branch that qualifies along the transect.

iii. For logs ≥ 10 cm diameter previously tagged for VST:

a) Add a red tag to the log; the number on the red tag is the logID (use a new number, not the existing **vstTagID**).

b) Leave the VST tag and record in the **vstTagID** field.

iv. For logs < 10 cm diameter:

a) **logID** = 'LXX', where 'XX' is sequentially assigned in the field, starting over at '01' at each new plot. Always use the 'L' prefix for these logs to enable separation from tagged logs in the NEON database.

b) (If applicable) Record the **vstTagID**.

d. Record remaining required log attributes listed in **Table 9**.

Table 9. Log attributes recorded during CDW LIDS tallies.

Field	Recorded Data	Method
logDistance*	Horizontal distance from transect intersect point to transect origin; nearest 0.1 m	TruPulse 360 (**HD** mode) or transect tape
logMaxDiameter	• Maximum diameter of the log perpendicular to the log central axis at the point where the transect intersects the central axis (**Figure 11**); nearest 0.5 cm. • For roughly circular logs, this is the only diameter measurement required. • For elliptical logs, this is the major axis of the ellipse.	Calipers
logMinorDiameter	For elliptical logs (often highly decomposed), this is the minor axis of the ellipse; nearest 0.5 cm.	For highly decomposed logs, push a chaining pin or the non-jaw end of the calipers into the wood until soil is reached. Measure and record this depth.
logLength (see **Figure 11**)	Length of the log central axis; nearest 0.1 m.	Meter tape or TruPulse 360 (**SD** mode)
taxonID	Species, genus, family or unknown, in that order. It is preferable to assign a family and use an identification qualifier code (idQ = CF or AF) than to use the unknown codes. For true unknowns you still must choose either: • 'unknown hardwood' (code: '2Plant-H'), or • 'unknown softwood' (code: '2Plant-S') • If the log is very highly decayed, and distinguishing between hardwood and softwood is impossible, choose whichever is most likely based on the live trees in the plot, and the taxonIDs of other nearby downed logs that are less decayed. • Do NOT use 'unknown plant' (code: '2Plant')	• Visual inspection of remaining leaves, bark, surrounding live species, and other nearby downed logs; use field guide when helpful. • A digital photo that can be shared with an experienced botanist may also be helpful in assigning a **taxonID.**
Identification Qualifier (idQ)	If there is any uncertainty about the taxonID then this should be clearly indicated using one of the codes in **Table 10**.	Visual inspection
decayClass	Record for all qualifying logs. See **Table 11** for **decayClass** categories and descriptions. If the degree of decay is highly variable, then this can be noted in the **remarks**, but in the **decayClass** field record the single average **decayClass** that best characterizes the log as a whole.	Visual inspection
charExtent and charDepth	If a log has been charred by a fire then record using guidance in **SOP B.4**. Otherwise these fields default to none.	Visual inspection

* In extremely brushy conditions in which line of sight is obscured beyond a few meters, use the TruPulse with the brush filter in "FLt" mode, and establish waypoints along the transect at known distances from the transect origin. Measure distances from waypoints as needed.

Table 10. Identification qualifier codes (idQ) to designate unknown species, or those species with uncertain identification in the field.

idQ Code	identificationQualifier	Description
CS	cf. species	Roughly equals but "not sure" about the species
AS	aff. Species	"Similar to, but is not" the species
CG	cf. genus	Roughly equals but "not sure" about the genus
AG	aff. Genus	"Similar to, but is not" the genus
CF	cf. family	Roughly equals but "not sure" about the family
AF	aff. Family	"Similar to, but is not" the family

Table 11. Standard decay classes for CDW logs, modified from classes defined by Sollins *et al*. (1987) and Harmon *et al*. (2008).

decay Class	Shape	Bark	Wood Texture	Twigs	Branches
1	Sound, freshly fallen, round.	Intact, fresh.	Intact, no rot.	Large and small diameter twigs present. Leaves/ needles may be present.	Present. Branches have most or all of their bark.
2	Sound, round.	Intact or partly missing; log has begun to lose bark.	Intact, sapwood partly soft.	Larger diameter twigs may be present.	Branches are present but have lost some bark.
3	Heartwood sound, log supports its own weight. Still round.	Trace, log has little to no bark.	Sapwood can be pulled apart by hand or is absent.	Absent.	Branches mostly absent; remaining are stubs with little bark; branch stubs are held firmly by heartwood and cannot be wiggled by hand.
4	Log does not support its own weight, but maintains shape; can be kicked apart, but breaking with hands is difficult	Absent.	Heartwood rotten, and may be made up of soft, small, blocky pieces; a chaining pin can be pushed easily into the log.	Absent.	Mostly stubs; intact branches absent. Branch stubs can be wiggled by hand.
5	No structural integrity: log does not retain shape, can be manually broken; majority of log still above litter layer.	Absent.	Soft, powdery when dry.	Absent.	Absent.

Table 12. Specialized decay class criteria for use with tree fern logs at the D20 PUUM site, or for logs extensively charred by fire (e.g., at JERC, OSBS, and SOAP sites).

decay Class	Specialized Criteria
6	For tree ferns (*Cibotium* genus) at site PUUM the standard criteria aren't meaningful, so for that genus only use the single combined decay Class of "6".
Extensive char - sound	A chaining pin cannot be pushed into the charred log with moderate manual pressure. It is not possible to manually break apart the log.
Extensive char - moderate	A chaining pin can be partially pushed into the wood with moderate manual pressure, and the charred log still supports its own weight.
Extensive char - advanced	A chaining pin can be pushed all the way into the log or all the way through the log (for smaller diameter logs) with moderate manual pressure. The charred log does not support its own weight, and it is possible to manually break apart the log.

12. Record the **tagStatus**; choose one of the following:
    a. **ok**; tag is new, or existing tag present and value is consistent with previously entered value.
    b. **replaced**; log was tagged previously (> 90% probability) and tag is presently missing. It is known with > 90% probability what the previous tagID value was. A new tag with the previous tagID value has been attached.
    c. **notRequired**; log does not require a tag if <10 cm diameter.
13. Assess and record log decay characteristics. ***Note:*** The **decayClass** is required for all logs; decay characteristics in this step are required for logs ≥ 10 cm diameter and may also be recorded for logs < 10 cm diameter.
    - **leavesPresent** (or needles): 'Y' or 'N'
    - **twigsPresent**: 'Y' or 'N'. Twigs are defined as < 2 cm diameter woody structures attached to the main log to be tallied or attached to other branches emerging from the main log.
    - **branchesPresent**: 'Y' or 'N'. Branches are defined as ≥ 2 cm diameter woody structures attached to the main log to be tallied.
    - **branchBarkCover**: The % cover of bark on any branches; assign from the following categories: <5%, 5-10%, 11-25%, 26-50%, 51-75%, 76-95%, >95%.
    - **logBarkCover**: The % cover of bark on the main log to be tallied. Use the same % cover categories as above. Use the same % cover categories as above.

- **logHandBreakable**: 'Y' or 'N'. Pieces of the log (not bark) can be broken apart by hand; focus on whether relatively large pieces can be removed using a full-handed grip rather than whether it is possible to break off small pieces with a prying finger or fingernail.
- **logHoldsShape**: 'Y' or 'N'. The log holds its original shape and does not slump or conform to the shape of the substrate upon which it lies. Breaks or indentations due to the impact of falling do not count.
- **remarks**: Log-specific remarks, primarily for use by Field Ecologists during re-sampling, always be brief.

14. Save the child-level **logID** record.
15. Continue tallying logs that intersect the transect until the transect limit for the site is reached (see **Appendix D** for site-specific transect lengths).
    a. ***Note regarding transect reflection***: CDW logs selected for tally sampling may lie outside the plot boundary (**Figure 2**). If a problematic boundary or barrier (as explained in **Table 14**) is encountered before the full transect length has been sampled, then reflect the transect back in the direction of the transect origin using the guidance in the "transect intersects boundary" section of **Table 14**. Roads are not considered a boundary.
16. Repeat steps (4) – (14) for any remaining transects.
17. Save the parent-level **plotID** record.
18. Proceed to the next plot and continue CDW tally (**Figure 10**).

B.3 Forked CDW Logs

When a transect intersects a forked CDW log, it is necessary to use the summed cross-sectional area (round diameter equivalent; RD_E) of qualifying forks to determine whether the log should be tallied.

- The auto-calculated 'round diameter equivalent' field (RD_E) in the *CDW: Tally [PROD]* app combines the diameter of each fork into a single round diameter equivalent (RD_E).
- Additional required data for elliptical forked particles are listed in **Table 13**.

There are multiple scenarios that are possible with forked CDW. Each requires a unique strategy to ensure that logs are tallied consistently.

Table 13. Data required to determine whether elliptical forked CDW particles qualify for tally.

Field	Recorded Data	Method
ForkMax Diameter	• Maximum diameter of fork at the measurement point specified by the protocol. Recorded as `bForkMaxDiameter`, `cForkMaxDiameter`, etc. to account for multiple forks. • This is the only diameter necessary for roughly circular forks.	Calipers
ForkMinor Diameter	For elliptical forks, this is the minor axis of the ellipse, measured at the point specified by the protocol. Recorded as `bForkMinorDiameter`, `cForkMinorDiameter`, etc. to account for multiple forks.	Calipers, or for highly decomposed logs, push a chaining pin or the non-jaw end of the calipers into the wood until soil is reached.

B.3.1 Transect intersects single fork only or intersects log below fork

1. For a forked CDW log, the decision to tally (or not) is based on the round diameter equivalent (RD_E) at the single point at which the central axis of the log intersects the transect.
   - The RD_E is measured perpendicular to the log's central axis at the point where the transect intersects the log's central axis. Use the auto-calculated RD_E field in the *CDW: Tally [PROD]* app to determine whether the log should be tallied.
   - The length of the central axis is measured for the longest fork. Note that if the transect does not intersect the central axis, the log is not tallied (**Figure 12A**). Conversely, if a transect intersects the central axis, then measurements are made of that central axis and also any additional forks intersected by a line perpendicular to the central axis, even if the additional fork is < 1m long or is not intersected by the LIDS transect (**Figure 12B**).
   - Consider the entire log when measuring log-level attributes – ***while paying attention to any diameter class breakpoints***.

2. Record one **logID** for the tallied log and utilize the same tag placement guidance as for logs without a fork.

3. Record required diameter(s) and log-level attributes as specified in (**Table 9**).

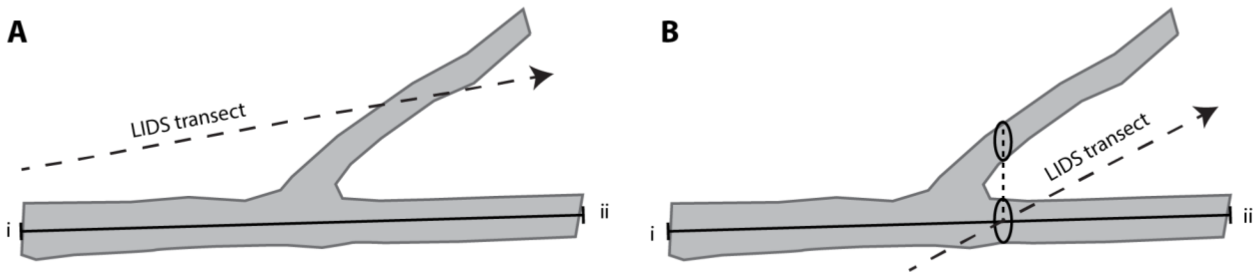

Figure 12. A log with a simple fork may be skipped (A) or tallied (B) depending on where the LIDS transect intersects the central axis. (A) The transect misses the central axis, defined as the line between i and ii, and the log is not tallied. (B) The transect intersects the central axis and diameter measurements for the log and fork are made perpendicular to the central axis; the RD_E of the log + fork are used to determine whether the log is tallied.

B.3.2 Multiple forks across different diameter classes

For a simple split with only two forks, and each intersected fork is in a different diameter class:

1. Consider each fork as an independent CDW particle.

2. Determine the RD_E using the auto-calculated field in the *CDW: Tally [PROD]* app for each fork to determine whether the fork should be tallied.

3. Record required diameter(s) and log-level attributes separately for each fork (one child-level record per fork).

   - Use a unique **logID** for each fork. Use alpha characters in the **logID** to differentiate forks (as in the Vegetation Structure protocol, RD[08]). For example:
     - Largest fork: **logID** = 1234
     - Additional fork in smaller size category: **logID** = 1234A
   - Pay attention to diameter class breakpoints when determining **logLength** and the shape of the log's central axis.

For compound splits with > 2 forks:

1. Consider groups of connected forks that are in the same diameter category separately from those forks, or groups of connected forks, that are in different diameter categories. Subsequent steps assume a CDW log of this nature (see **Figure 13**).

2. Determine whether to tally each group of connected forks within a given diameter size category one at a time. Use a single round diameter equivalent (RD_E) for each group of connected forks within the same diameter size category.
   - The diameter of each group of connected forks that intersects the transect should be combined into a single RD_E using the *CDW: Tally [PROD]* app.
   - If the tablet fails, a single RD_E can be estimated with **Table 20** in Appendix A.3. If there are > 2 forks, combine forks two at a time using the table, using intermediate RD_E values from each pair of forks until all forks have been combined into one RD_E.
3. Within a group of connected forks all in the same size category:
   a. Create one child-level record with a unique **logID** (e.g., **logID** = 1234, 1234A, etc.)
   b. Record log-level attributes for the group of connected forks.
   c. Record required diameters for each fork. For forks that are roughly circular, **minorAxisDiameter**(s) are not required.
   d. Pay attention to diameter class breakpoints when determining **logLength** and the location of the log's central axis.

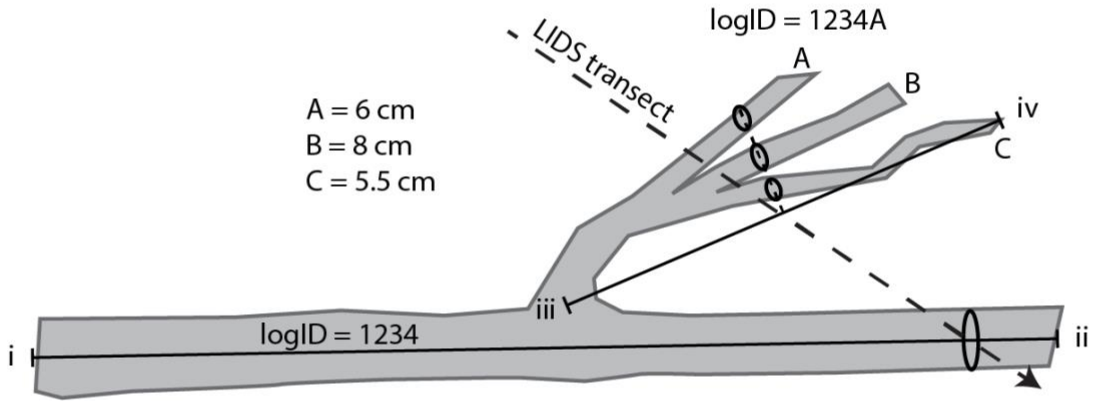

Figure 13. LIDS transect intersecting a log with compound forks in two different size categories. Forks in different size categories are assigned unique and related logIDs. The central axis for the main log is defined by the capped line connecting i-ii, and the central axis for the smaller size category compound forked branch is defined by the iii-iv capped line. Measurement locations for each are marked with ellipses.

EXAMPLE

*The transect crosses the main bole of a downed tree that has main bole diameter = 25 cm @ intersect point, then crosses three forks of a connected branch with diameters of 8 cm, 6 cm, and 5.5 cm @ intersect points (***Figure 13***). The connected branch is 9.5 cm diameter where it emerges from the main bole.*

Here, the main bole is considered independently from the forked branch because it is in a different diameter class; the RD_E = 25 is used with **Table 18** *or* **Table 19** *to determine whether to tally and further measure the main bole.*

For the three forks of the connected branch that also intersect the transect, given the input intersect diameters above, the RD_E = 11.4 cm (using the Fulcrum app auto-populated RD_E field). The RD_E = 11.4 value is used with the CDW: Tally [PROD] app (or **Table 18** */* **Table 19***) to determine whether to tally and further measure the forked branch; if the forked branch qualifies for measurement, a separate record is created and a logID with an alpha suffix is used since the forked branch is in a different size category. If the branch is tallied, the* ***logLength*** *is measured from the origin of the branch (where it is 9.5 cm diameter) to either the branch tip, or the point at which diameter is < 5 cm, whichever comes first. Be mindful that* ***decayClass*** *may be more advanced for the forked branch than for the main bole, due to its smaller diameter.*

B.3.3 Multiple forks within the same diameter class

1. Consider connected forks originating from a common central axis AND that are in the same diameter class together as one CDW log.
2. Determine whether to tally forked CDW logs based on the round diameter equivalent (RD_E).
    a. The diameters of forks that intersect the transect are combined into a single RD_E in the auto-calculated RD_E field in the *CDW: Tally [PROD]* app. If the app is not available, use **Table 20** in Appendix A.3.
3. If the log qualifies based on the combined RD_E, record required diameter(s) for the forks (in **bForkMaxDiameter**, etc. fields in addition to the **logMaxDiameter** field), as well as log-level attributes as specified in **Table 9** in one child-level logID record.
    a. Pay attention to diameter class breakpoints when determining **logLength** and the shape of the log's central axis.

B.4 Charred CDW Logs

Charred CDW logs encountered after a fire, particularly logs with extensive and/or deep charring, cannot be easily assigned to existing decay classes due to a lack of required diagnostic features associated with these classes (**Table 11**). For the same reason, assigning **taxonID** is also difficult for extensively charred logs. Here, we define categories for 'char extent', 'char depth', and a modified assessment of decay status to determine the decay class and char status for charred CDW. We also provide guidance for assigning **taxonID** when logs are charred.

Char Extent

When assessing CDW particles for tally and bulk density in areas that have burned, an assessment of char extent should first be carried out – i.e., determine the % of the total log surface area that is charred. The word 'log' is defined to include the bole(s) plus any remnant branches, branch nubs, etc. Char extent levels are:

- 0% to < 5% char
- 5% to < 25% char
- 25% to < 50% char
- 50% to < 75% char
- 75% to < 95% char
- ≥ 95% char

By scoring all logs tallied in burned areas, it will be possible for data users to quantitatively compare the extent and intensity of fires within NEON sites. For logs with relatively less charring and that still retain features that are required for assessing **decayClass** according to standard guidance, continue to use the standard approach in **Table 11**.

Char Depth

When a CDW log is charred, the charred portion(s) of the log should also be assessed for average char depth. Try to make a representative measurement and make a note in remarks if the depth of char is variable. Choose from the following **charDepth** categories:

- None: No charring.
- Moderate (0-1 cm): Chaining pin can be pushed into char ≤ 1 cm, bark may still be present in charred areas depending on decay status prior to fire.
- Deep (> 1 cm): Chaining pin can be pushed into char > 1 cm, char may appear textured like alligator skin.

For logs with relatively extensive char and for which diagnostic features required to implement standard **decayClasses** are lacking, use the 3-level assessment of decay in **Table 12**.

Char and TaxonID

When assigning **taxonID** to charred logs:

- For logs with relatively less charring and that retain diagnostic features on either uncharred or lightly charred areas, assign **taxonID** according to the standard approach.
- For extensively charred logs:
  - If unburned trees or other, relatively uncharred logs are present nearby, use this taxonomic information to assign the **taxonID** of the extensively charred log.
    - *Example:* Surrounding relatively uncharred logs are clearly > 50% hardwood or > 50% softwood but these surrounding logs cannot be assigned to a higher taxonomic resolution (e.g., family). Assign the extensively charred log to '2PLANT-H' or '2PLANT-S' as appropriate.
    - *Example:* Surrounding relatively uncharred logs are clearly mostly *Fagaceae* (e.g., oak). Assign the extensively charred log to *Fagaceae* with idQ = "cf. family".
  - For intense fires that have extensively charred all logs in the vicinity of the plot – i.e., there is no relevant taxonomic information for surrounding trees or logs that might be applicable to the log in question – use average pre-fire 'Vegetation structure' **sizeCategory** x **taxonID** data from the plotID in question to assign '2PLANT-H' or '2PLANT-S' to all unidentifiable logs. A higher-resolution taxonomic resolution may be appropriate depending on the pre-fire species assemblage.
    - *Example:* More than 50% of all trees with DBH ≥ 10 cm in the plot pre-fire were hardwood species, but of the hardwood species that were in the plot there was more than one family. Assign taxonID = "2PLANT-H" to unidentifiable logs.
    - *Example:* More than 50% of the pre-fire trees with DBH ≥ 10 cm in the plot were *Pinaceae spp.*. Assign **taxonID** of all unidentifiable logs to "Pinaceae" with idQ = "cf. family".

B.5 Troubleshooting

Guidance on too few CDW logs, too many CDW logs, and other issues can be found in **Table 14** and **Figure 4**.

Table 14. Troubleshooting common issues encountered when tallying and measuring CDW in the field.

<table>
<tr><th>Issue</th><th>Description</th><th>Action</th></tr>
<tr><td>Too few CDW logs</td><td>< 5 logs were tallied at > 20% of the sampled plotIDs.</td><td rowspan="3">Issue a problem ticket to procure a different volume factor (F) and transect length for sampling CDW at the site.
Record the new F value at the top of each new datasheet.
If there are still plots with zero or few logs, even with the lowest F value, sampling is still warranted. Documenting these plots has value at the continental scale.</td></tr>
<tr><td>Zero CDW logs</td><td>Zero logs were tallied at > 1 of the sampled plotIDs.</td></tr>
<tr><td>Too many CDW logs</td><td>> 20 logs per plot were tallied at > 20% of the sampled plotIDs.</td></tr>
<tr><td>Transect intersects boundary</td><td>A LIDS transect encounters a boundary before the limiting distance is reached, and the boundary prevents further sampling (e.g., fence, poison oak thicket, impenetrably dense vegetation, property boundary, river, etc.).

Note: Transitions between habitat/land cover (e.g., from forest to agricultural field) along a transect do not meet the definition of a boundary.

Note: Discontinue transect reflection and follow transect normally in subsequent sampling events if the boundary requiring a reflection was temporary.</td><td>At the boundary, turn 180˚, reflect the transect back onto itself, and continue walking back toward (and possibly past) the transect origin, tallying until the total distance traveled equals the distance originally desired for the transect (Gregoire and Monkevich 1994).
Logs large enough to qualify at the new, longer distance will be re-tallied.</td></tr>
</table>

Issue	Description	Action
Transect intersects road	A road is encountered before reaching the specified transect length.	• Continue along the transect across the road. • Note in the **remarks** how much of the transect length (m) was a road crossing. • No additional action required. The road reflects the conditions on the ground.
Uncertainty in **taxonID**	Cannot identify log to species, genus, or family rank.	• Determine whether log is "softwood spp." or "hardwood spp." • In the **taxonID** field, record either '2PLANT-S' (unknown softwood) or '2PLANT-H' (unknown hardwood). Use nearby logs/trees to inform decision of Hardwood vs. Softwood. • If possible, take a photo to enable an experienced botanist to help determine the **taxonID**.
Log irregularity	Log has an irregular base – e.g., a stem base or root mass that is wider than the rest of the trunk.	• Move diameter measurement point to the nearest "regular" point on the log – i.e., the first point at which the diameter stops changing.
CDW log intersects > 1 transect	Log is tallied on more than one transect; that is, when plots are relatively dense, a log intersects two transects that originate from different plots.	• Only one tag is required. • Tally the log on each transect it intersects; that is, the log will generate two data records. • In **remarks** fields for each record of the log, note: 'also tallied in [plotID]'.
Slash piles	The transect intersects a log that is part of a 'slash pile.' Slash piles are heaped collections of waste CDW logs created mechanically after logging or other clearing activities. Slash piles are not tallied because slash piles do not meet the assumptions of the LIDS method – i.e., slash piles are not logs, and it is not possible to accurately see and count the logs contained within them.	• The LIDS tally method cannot estimate the volume of slash piles: Do not tally or measure logs that are part of these piles. • For each slash pile encountered, note in the **remarks**: "Slash pile @ X meters". Also record in the **remarks** the approximate diameter and height (in meters). • Continue the transect straight through the slash pile; do NOT adjust

Issue	Description	Action
	Note: Individual logs with cut ends do not constitute a slash pile.	transect length to accommodate interruption by a slash pile.
Rapidly tapering short log	The distance between points A and B in **Figure 11** is < 1 m length.	• Do not tally.

B.6 Post-Field Sampling Tasks

Document Incomplete Sampling Within a Site

Coarse Downed Wood sampling is scheduled to occur at all prescribed sampling locations according to the frequency and timing described in Section 4 and **Appendix C.** The plot type scheduled for a given year (Distributed or Tower) is listed in the Inter-annual Schedule on Sharepoint, with additional guidance on plot sampling priority provided in the Plot Prioritization list. Ideally, sampling will occur at these sampling locations for the lifetime of the Observatory (core sites) or the duration of the site's affiliation with the NEON project (gradient sites). However, sampling may be shifted from one location to another when sampling is compromised. In general, a sampling location is compromised when sampling becomes so limited that data quality is significantly reduced. If sampling at a given plot becomes compromised, an incident ticket should be submitted by Field Operations to Science.

There are two main pathways by which sampling can be compromised. First, sampling locations can become inappropriately suited to answer meaningful biological questions (e.g., a terrestrial sampling plot becomes permanently flooded or is compromised after road-building activities). Second, sampling locations may be located in areas that are logistically impossible to sample on a schedule that is biologically meaningful.

For Coarse Downed Wood tally sampling, criteria for considering a plot compromised are the same for both Distributed and Tower Plots:

- These plots are sampled every 5 y; if sampling cannot be completed for 2 consecutive bouts then the plot should be considered compromised.
  - Report compromised plots by submitting an incident ticket that contains the **domainID**, **plotID**, and 3-letter sampling module in the description.
    - ***Example***: 'D05 STEI_047 canceled for CDW'
  - When sampling cannot be completed at a plot, consult published data to determine whether cancellation has occurred over two consecutive bouts, and whether a request for a replacement plot is warranted due to a compromised plot.
- Report compromised plots to Science, and Science will provide a replacement plot for the current sampling bout.
- Submit a problem ticket if sampling at a plot assigned to CDW for a given bout is not possible.

<u>To document locations not sampled during the current bout:</u>

1. Review the completed sampling effort and create **Sampling Impractical** records as described in Section 4.6 for plots at which sampling was scheduled but was not completed.
2. To document whether a location is compromised according to the criteria above:

   a. Review **Sampling Impractical** records from the *CDW: Tally [PROD]* application and Portal data to identify locations where sampling was scheduled but was not completed due to environmental or site management factors.

3. Create an incident with the following naming convention to document the missed sampling and compromised location: 'TOS Sampling Incomplete: CDW – [Root Cause Description]'
   a. *Example*: 'TOS Sampling Incomplete: CDW – Could not access plots 012 and 123 due to permanently closed road, sampling location compromised'.

B.7 Re-Tallying Previously Surveyed LIDS Transects

Re-tallying previously surveyed transects generally follows the guidance in SOP B.2. Additional points pertinent to re-tally include:

1. The transect azimuth will be difficult to re-establish identically from bout to bout.
    a. Previously tagged logs can be used to guide transect re-establishment, but do not assume there is a 'true' transect. That is, do not attempt to perfectly re-create the previous transect. If a previously tagged log is no longer intersected by the "new" transect then do not record data for that previously tagged log. However, leave the tag in place in case it is intersected again in a future bout.
    b. When the transect intersects a qualifying log, DO check for a tag.
    c. If a tag cannot be found, DO use previously collected data to determine whether it is likely that a **logID** was previously assigned.
2. If it is known that a previous transect was incorrect due to azimuth inaccuracies, do NOT correct past data.
3. When illegible tags are encountered or a log may have been tagged in a previous bout but the tag cannot be found:
    a. Consult previously collected **logID** data to aid with log identification (see **logID** list prepared in SOP A.2).
    b. If the previous **logID** can be determined with ≥ 90% confidence: Re-stamp a blank tag with the previous logID, and record **tagStatus** = 'replaced'.
    c. Else, re-tag the log with a new **logID**, and record **tagStatus** = 'ok'.
4. When tags are attached from a previous bout:
    a. Previously collected **logID**, **logDistance**, **logMaxDiameter**, **taxonID** and **decayClass** data may be used to help guide assessments in the current year.
    b. Previously collected data are ***only*** a guide. Current-year assessments should ultimately be made according to the protocol and current-year observations. That is, do not assume previous staff were correct 100% of the time.
    c. If the log no longer qualifies (e.g., due to diameter decreasing due to decay, the log has fragmented into smaller pieces and the fragment intersecting the transect is too short to qualify, etc.):
        i. Do not tally and do not create a record.
        ii. Collect the tag and remove it from the plot.

SOP C Field Sampling: Bulk Density Sampling in the Field

C.1 Sampling strategy overview

Goals

- Collect bulk density samples from logs that represent the most abundant **decayClass** x **sizeCategory** x **taxonID** (DST) combinations at the site. SOP B must have been completed in both Tower and Distributed plots before bulk density Bout 1 begins to ensure that a complete census is available for a comprehensive DST rank abundance list (see Section 4.3).
- Enter data into the ***CDW: Field Bulk Density [PROD]*** mobile application. See the Coarse Downed Wood Fulcrum Manual (RD[13]) for data entry details.
- Do NOT collect bulk density samples from logs that intersect LIDS transects.
- Collect bulk density samples twice at each site:
    - Bout 1 occurs within the first 3 y of site operations.
    - Bout 2 is scheduled 5-6 y after the first sampling event.
- When paired with volume estimates by DST, bulk density allows calculation of CDW mass and carbon stocks.

Sampling cross-sectional disks from downed logs

For logs ≥ 10 cm diameter, it is ideal to:

- Cut cross-sectional disk samples with a chainsaw; however, if there are restrictions on chainsaw use, a buck or cross-cut type saw is an alternative.
- Cut cross-sectional disk samples at least 1 m in from the end of the log; and
- Repeat sample the same logs across both sampling bouts.
- Preferentially sample logs ≥ 3 m length so that two disks can be cut from the same log at a 5-6 y interval while still cutting each disk at least 1 m in from the end of the log in each bout.
- For logs ≥ 10 cm diameter and ≥ 5 m length, cut two disks per log per bout: At each of the two sampling bouts, disks are cut at least 1 m in from either end of the log.

Logs with diameter < 10 cm are not repeat sampled, and disks may be cut 50 cm from the end of the log.

Where to sample

Cutting cross-sectional disks from logs for bulk-density sampling is carried out in and around Tower plots and Distributed plots. Because sampling involves cutting and removing small sections of downed logs, individual site hosts may impose additional restrictions on where sampling is allowed within a site. Be sure to check with your Domain Manager regarding potential sampling restrictions.

Additional restrictions (**Figure 14**):

- Avoid sampling logs < 10 cm diameter within approximately 10 m of the plot centroid, as these logs are frequently tallied via SOP B.
- When sampling within Distributed plots, do not cut CDW logs where doing so would cause a change in plant diversity data collection from 1 m^2 nested subplots (e.g., a change in the percent abiotic cover).
- Be cognizant of trampling effects and do not select logs for cross-sectional disk sampling that will require working within 10 m^2 nested subplots.
- To facilitate re-sampling logs during the second of the two prescribed bulk density sampling bouts, logs may be selected up to approximately 50 m from the plot centroid. Logs > 50 m from the centroid may be difficult to re-locate and should be avoided. Be sure **the site host has granted permission for sampling logs outside plot boundaries.**

Prioritizing sampling effort

For estimation of bulk-density, the goal is to sample logs for the most abundant DSTs, as identified by Science (see ranked lists of DSTs in the TOS Support Library). An example of target sample sizes for different **sizeCategories** is provided in **Table 15**). When performing bulk density sampling for Bout 1:

- Target the most common CDW 'decayClass x sizeCategory x taxonID' combinations (DSTs) at a given site.
- Search all plots designated for CDW sampling, and opportunistically sample while traveling between plots (if allowed).
- Preferentially sample the largest diameter logs, as these logs are typically rarer, and also comprise the majority of CDW mass in an ecosystem (Keller et al. 2004) (**Table 15**).
- To enable repeat bulk density sampling of the same logs over the two bulk density sampling bouts, first try to find logs ≥ 3 m length for sampling. Search across all plots for logs meeting this criterion before sampling smaller length logs in any given plot.

Table 15. Example of desired Bout 1 CDW bulk-density sample size across multiple decay and diameter classes for an abundant species. Below, only the first two decayClasses for one taxon are shown for the sake of brevity.

taxonID	decayClass	sizeCategory	sampleSize
Acer rubrum	1	2-5 cm	5
		5-10 cm	5
		≥ 10 cm	10
	2	2-5 cm	5
		5-10 cm	5
		≥ 10 cm	10
	etc…	etc…	etc…

Guidelines and caveats for conducting bulk density sampling during Bout 1:

- For widespread taxa that occur throughout the site, generate samples from as many plots as is feasible. For uncommon DSTs, it is acceptable to meet the desired sample size in only one plot.
- It may be difficult to achieve the desired sample size for DSTs associated with “unknown hardwood”, “unknown softwood”, or family-level **taxonID**s if most logs are identifiable to higher taxonomic resolution. If samples with coarse taxonomic resolution can’t be found because they can now be identified to a finer taxonomic resolution, then samples with coarse-level taxonID can be dropped if there are already ample samples with the finer taxonomic resolution.
- Sample sizes listed in Appendix G may be achieved over up to two field seasons; however, completing sampling in one field season is preferred.

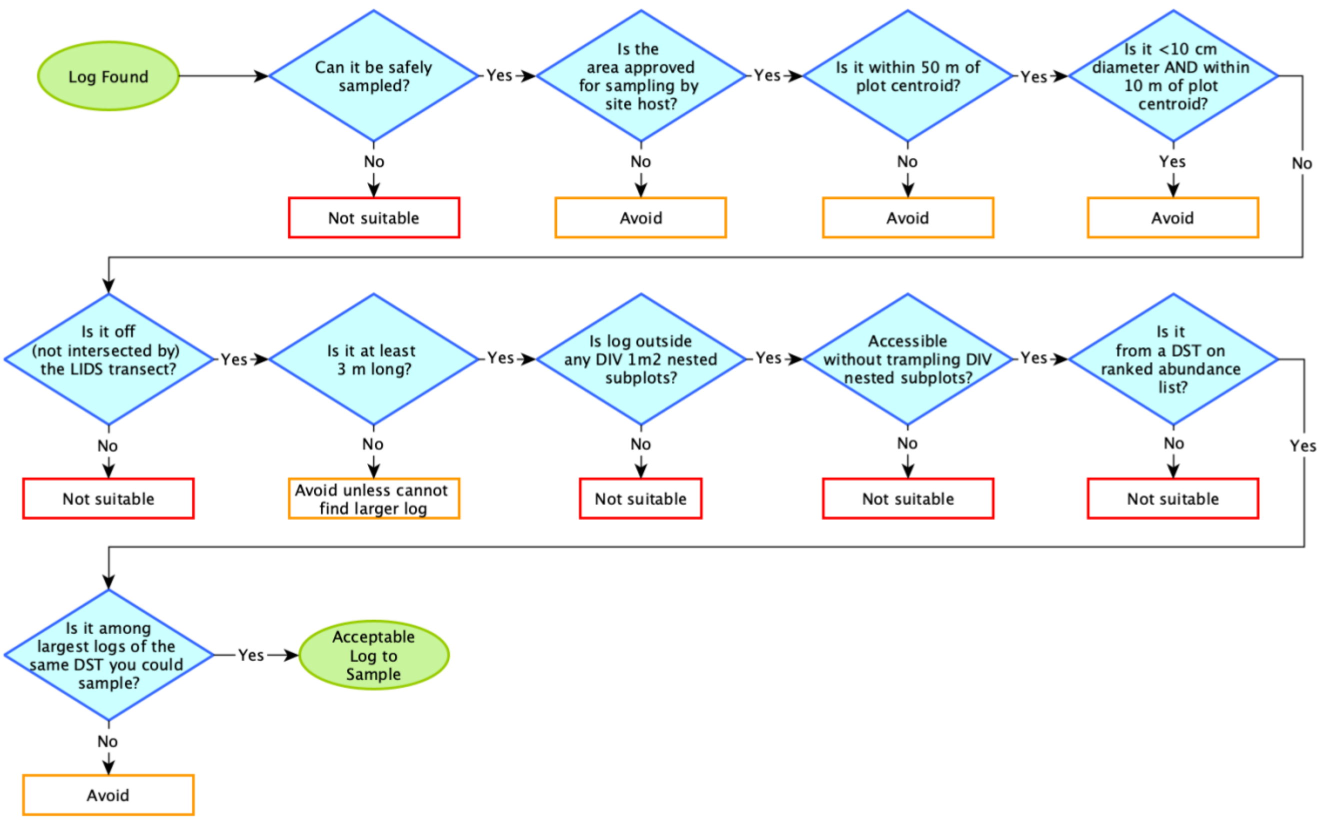

Figure 14. Workflow for determining if a log is appropriate to use for CDW bulk density sampling during Bout 1.

Determining when Bout 1 sampling is complete

The bulk density sampling effort is inherently variable from site to site, as it is driven by the number of DSTs, which is strongly dependent on site-level tree diversity. For each site, Science uses CDW tally data to create a list of DSTs ranked by tally abundance.

- Once the desired sample size is achieved for a given DST, stop searching for that combination in other plots. Consider sampling complete once all rank-ordered DSTs that cumulatively make up 80% of the total tallies have been sampled (see the TOS Support Library for per site lists of ranked DSTs).
- Desired sample sizes may not be achievable for all DSTs. Sampling can be considered complete for a given DST if all plots with **applicableModule** = 'cdw' have been searched within an approximately 50 m radius of the centroid and the desired sample size has not been met.

C.2 Data Quality Assurance

To quantify measurement uncertainty that informs derived bulk density uncertainty, 5% of disk samples are re-measured independently in the field by a different technician than the person who originally measured the disk. Re-measurement means independent collection by a second person of the following parameters:

- Disk diameter and heights
- Disk fresh mass
- Subsample fresh mass (if applicable)

The same samples selected for QA in the field are also later selected for dry mass QA in the lab (SOP D). In the lab, re-measurement means independent weighing of the oven-dried QA sample by a second person. Ideally, the mass measured by the first person is not known by the second person.

C.3 Initial bulk-density sampling in the field (Bout 1)

The field procedure described below enables calculation of both the volume and fresh mass of cross-sectional disks cut from pieces of CDW, both of which are required to determine CDW bulk density.

Required pre-sampling checks:

- **Permitting**: Be sure you are permitted to obtain CDW bulk-density samples from the intended sampling areas and determine whether chainsaw sampling is a permitted activity.
- **Land Use Agreement:** If applicable, make sure that any Land Use Agreement allows for CDW bulk-density sampling.
- **Quarantine(s)**: Ascertain whether any wood quarantines affect your site (**Table 26**). For example, sampling at Emerald Ash Borer (EAB) affected sites must occur during the non-flight season for EAB, and all samples must be double bagged for transport back to the Domain Lab. See Appendix F for additional instructions.

To Generate Bulk Density Samples:

1. To help target the bulk density sampling effort, use the ranked list of DSTs for your site in the TOS Support Library. Tally each sampled log in the table to track sampling progress across DSTs.
2. Navigate to a desired plot that is suitable for CDW bulk-density sampling.
   - ***With site host permission***, logs may be selected up to approx. 50 m from the plot centroid.
3. Search for CDW logs that qualify for bulk density sampling. The most common CDW taxa for a site should be targeted first:
   - For CDW < 10 cm diameter: Logs must be ≥ 1 m length, and only one bulk density sample per log is allowed.
   - For CDW ≥ 10 cm diameter:
     - Logs must be ≥ 2 m length, but ideally ≥ 3 m (to enable tagging and repeat sampling at two timepoints).
     - **Sample as many logs as you can that are ≥ 3 m length during Bout 1**. Repeat sampling of the same logs in Bout 2.
   - If sampling within an established NEON plot:
     - Use the LIDS Angle List to avoid collecting bulk density samples from logs that intersect a LIDS transect. If you are unsure, be conservative and do NOT sample.
     - Do not sample logs in 10 m^2 or smaller nested subplots.
4. When a log is encountered from which a bulk density disk will be collected, create a parent-level **plotID** record in the *CDW: Field Bulk Density [PROD]* app and enter required sampling meta-data:
   a. Select the **domainID**, **siteID** and **plotID**; if working outside established plot boundaries, choose the plotID of the nearest plot.
   b. **collectDate**; enter the date the sample was collected, *YYYY-MM-DD* format.
   c. **yearBoutBegan**; for bouts that span > 1 calendar year enter the earliest applicable year; *YYYY* format.
   d. **mappingMethod**; select 'Not Mapped' for logs that will NOT be repeat sampled. For logs ***≥ 10 cm diameter AND ≥ 3 m length*** that WILL be repeat sampled, select a **mappingMethod** from the drop-down:
      i. 'Relative': This is a suitable method when the log is in sight of a plot marker. Record the **pointID** of the nearest plot marker (**Figure 2** shows available pointIDs). Also record the **logAzimuth** from the log pointing back to the pointID, and the **logDistance** from the log to the pointID.

Note: The mapping procedure is similar to VST (RD[08]), but for CDW bulk density sampling the **logAzimuth** is measured in the opposite direction from the log back to the pointID.

ii. 'GPS': Record **sampleEasting** and **sampleNorthing**. A suitable method when logs are far from a plot marker and/or line of sight is obscured. Easting and northing allow easier re-location compared to decimal degrees.

5. Record required Log Data:

   a. **sizeCategory**; choose from: diameter ≥ 10 cm, 10 cm > diameter ≥ 5 cm, or 5 cm > diameter ≥ 2 cm.

   b. **logLength**; Length of the log central axis; nearest 0.1 m. Use a meter tape or the TruPulse 360 (SD mode). Must be measured before the log is cut.

   c. Enter the **logID**. This is an identifier used to link log-level data with field and lab data associated with cross-sectional disks sampled from the log.

      i. <u>*For logs ≥ 10 cm diameter AND ≥ 3 m length*</u> that will be repeat sampled: Affix a red, numbered tag to the middle of the log, and record the number in the **logID** field.

      ii. <u>*For logs not meeting these criteria:*</u> **logID** = 'LXX', where 'XX' are sequential numbers assigned in the field that start over at '01' at each new plot. Always use the 'L' prefix for these logs to enable separation from tagged logs in the NEON database.

      iii. For logs ≥ 10 cm diameter previously tagged for VST:

         a) Add a red tag next to the VST tag; the red tag is the **logID**.

         b) Leave the VST tag and record in the **vstTagID** field.

   d. Record the **tagStatus**; choose 'ok' to indicate that a new tag was attached as part of Bout 1 sample collection.

   e. **taxonID**; assign as described in SOP B.2 and identify to the finest taxonomic resolution possible.

      i. Genus-species or Genus should be possible for logs in **decayClass** 1-3; lower resolution **taxonID**s are more likely for **decayClasse**s "4 - Rotten throughout" and "5 - No structural integrity", as well as for the char **decayClasses** (SOP B.4).

      ii. See **Table 9** for additional **taxonID** guidelines.

   f. **identificationQualifier**; select from the available list if relevant (see **Table 10**).

   g. **decayClass**; required for all logs, select from the available list (see **Table 11**).

h. Record decay class characteristics. Required for logs ≥ 10 cm diameter and may be relevant for smaller logs:

- **leavesPresent** (or needles); 'Y' or 'N'
- **twigsPresent**; 'Y' or 'N'. Twigs are defined as < 2 cm diameter woody structures attached to the main log or portion of log from which a disk will be cut or attached to other branches emerging from the main log.
- **branchesPresent**; 'Y' or 'N'. Branches are defined as ≥ 2 cm diameter woody structures attached to the main log or portion of log from which a disk will be cut.
- **branchBarkCover**; The % cover of bark on any branches; assign from the following categories: <5%, 5-10%, 11-25%, 26-50%, 51-75%, 76-95%, >95%.
- **logBarkCover**; The % cover of bark on the main log or portion of log from which a disk will be cut. Use the same % cover categories as above.
- **logHandBreakable**; 'Y' or 'N'. Pieces of the log (not bark) can be broken apart by hand; focus on whether relatively large pieces can be removed using a full-handed grip rather than whether it is possible to break off small pieces with a prying finger or fingernail.
- **logHoldsShape**; 'Y' or 'N'. The log holds its original shape and does not slump or conform to the shape of the substrate upon which it lies. Breaks or indentations due to the impact of falling do not count.
- **charExtent** and **charDepth**; If a log has been charred by a fire, record these fields using guidance in SOP B.4. Otherwise, these fields remain blank.

6. Prepare a label and a breathable sample bag for the disk (or disks) that will be cut from the selected log. Create the label by affixing a Type I barcode to a pre-cut piece of 'Rite-in-the-Rain' type paper (see SOP A.4). Breathable sample bags may be muslin bags for heavier samples, or paper bags for lighter samples. Paper bags tear and are not suitable for heavier samples.
   - **For logs ≥ 5 m in length**, two disks will be cut, one from either end of the log, and two labels are therefore required.
   - **For all logs**, record on the label:
     - **collectDate**: The date the bulk density sample is collected in the field, *YYYYMMDD* format.
     - **plotID**: The unique identifier for the plot (or closest plot).
     - **logID**: The logID previously recorded in step (5.c) above
     - **diskID**: A technician assigned numeric identifier for the disk, either '1' or '2'.

7. Cut a cross-sectional disk (or disks) from the log using a method approved by the site host (if approved, chainsaws are always preferable). If only sampling from one end of the log – i.e., the log is < 5 m length – randomly choose an end to sample. Use the guidelines in **Table 16** below and see **Figure 15**.
    a. When feasible, use the Cant Hook and attached log stand to maneuver the CDW log into a safe cutting position, elevated off the ground with the log stand.
    b. If applicable, spend a minute or less before cutting the log to remove any moss from the surface of the log where the disk will be cut. Avoid cutting a disk at a location where shelf fungus are attached.
    c. **For highly decayed logs that do not hold their shape**: It will be impossible to remove and measure a cross-sectional disk without it crumbling in the process. To deal with this situation, two cuts are made approximately 10 cm apart in the rotten log.
        i. When cutting, keep the chain at the highest speed and cut quickly to make a clean cut and prevent rotten material from being thrown by the saw.
        ii. Have a bag nearby to facilitate retrieving particles from the "disk" that were spit out by the chain and clearly came from the disk.
        iii. When both cuts are complete, simply scoop out the "disk" between the cuts by hand into a labeled sample bag.
        iv. Thoroughly mix the sample by hand.

Table 16. Guidelines for cutting cross-sectional disks from CDW with different diameter and decayClass combinations.

Decay Class	Size: ≥ 10 cm diameter log	Size: < 10 cm diameter log
decayClasses 1-3	• 5+ cm width disk • ≥ 1 m buffer from log end	• 10 cm width disk • ≥ 50 cm buffer from log end
decayClasses 4-6 plus charred decayClasses	• 10 cm width disk • ≥ 1 m buffer from log end • Chain at highest speed before initiating cuts	• 10 cm width disk • ≥ 50 cm buffer from log end • Chain at highest speed before initiating cuts

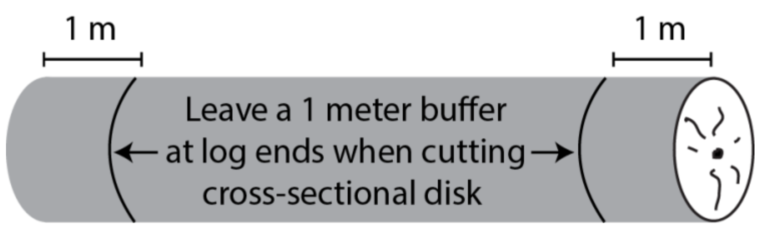

Figure 15. A minimum 1 m buffer should be left on either end of a ≥ 10 cm diameter CDW piece when cutting a cross-sectional disk for bulk-density sampling. The log depicted is ≥ 5 m length and is sampled from both ends at each of the two sampling timepoints. Qualifying logs < 5m length are only sampled at one end.

8. Create a child-level 'Disk Data' record in the *CDW: Field Bulk Density [PROD]* app, and record:
    a. **bagNumber**; the permanent number labeled on each muslin sample bag. The **bagNumber** is used to track the sample through drying and weighing. For paper sample bags, a bagNumber is not required and the **subsampleID** is written directly on the bag.
    b. **diskID**; a technician assigned numeric identifier for the disk, either '1' or '2'.
    c. **qaSample**; defaults to 'No'; select 'Yes' when a child-level QA record is desired within the existing parent record. 5% of disks should be selected for QA.
        i. For QA, a second staff member who did not record the initial data should complete independent re-measurement of **diameter**(s), **height**(s), total disk **fresh mass**, and **subsample fresh mass** (if applicable) for each disk selected. Identify the sample and make the QA re-measurement of total disk fresh mass before subsampling (if subsampling is required).
        ii. Measure QA samples first to ensure that QA is not forgotten.
    d. **subsampleBarcode**; scan the sample barcode label to associate with the child-level disk record. The barcode will speed data entry in the laboratory.
        i. ***!!!Note:*** Do NOT scan the barcode a second time for QA samples. Doing so will cause a duplicate barcode error when the records are ingested by the parser.
9. Measure the required disk dimensions, and record:
    a. **For disks with structural integrity that hold their shape:**
        i. *For disks ≥ 5 cm diameter:*
            - Measure diameter with a diameter tape. Record to the nearest 0.1 cm:
                - **diameter**: The diameter of the cross-sectional disk
                - **ninetyDiameter**: Leave blank
            - Measure disk heights with calipers. Record to the nearest 0.1 cm:
                - **maxDiskHeight**: The maximum disk height
                - **minDiskHeight**: The minimum disk height
                - **aDiskHeight**: Representative intermediate disk height
                - **bDiskHeight**: Representative intermediate disk height
        ii. *For disks < 5 cm diameter:*

- Measure diameter with calipers. Record to the nearest 0.1 cm:
  - **diameter**: The maximum disk diameter – i.e., the major ellipse axis
  - **ninetyDiameter**: The minimum disk diameter – i.e., the minor ellipse axis
- Measure disk heights with calipers. Record to the nearest 0.1 cm:
  - **maxDiskHeight**: The maximum disk height (goal is width specified in **Table 16**; record actual maximum thickness here)
  - **minDiskHeight**: The minimum disk height (goal is width specified in **Table 16**; record actual minimum thickness here)
  - **aDiskHeight**: Leave blank
  - **bDiskHeight**: Leave blank

b. **For "disks" lacking structural integrity that do NOT hold their shape,** and have already been manually scooped into a plastic bag:

i. *For "disks" ≥ 10 cm diameter:*

- Measure diameters on both faces of the remaining cut log using calipers (**Figure 16**). For each field below, record the average of both cut faces, to the nearest 0.1 cm:
  - **diameter**: The maximum disk diameter – i.e., the major ellipse axis
  - **ninetyDiameter**: The minimum disk diameter – i.e., the minor ellipse axis
- Measure disk height with calipers – i.e., the width of the scooped out log area; "C" in **Figure 16**. Be sure to subtract 2X the width of the saw kerf from the measured height (i.e., 2X the width of the saw blade). Record to the nearest 0.1 cm:
  - **maxDiskHeight**: The maximum disk height (goal is width specified in **Table 16**; record actual maximum thickness here)
  - **minDiskHeight**: The minimum disk height (goal is width specified in **Table 16**; record actual minimum thickness here)
  - **aDiskHeight**: Representative intermediate disk height
  - **bDiskHeight**: Representative intermediate disk height

ii. *For "disks" < 10 cm diameter:*

- Measure diameters on both faces of the remaining cut log using calipers as above for ≥ 10 cm logs. Record to the nearest 0.1 cm.
  - **diameter**: The maximum disk diameter – i.e., the major ellipse axis
  - **ninetyDiameter**: The minimum disk diameter – i.e., the minor ellipse axis
- Measure disk height with calipers as above for ≥ 10 cm logs. Record to the nearest 0.1 cm:
  - **maxDiskHeight**: The maximum disk height
  - **minDiskHeight**: The minimum disk height
  - **aDiskHeight**: Leave blank
  - **bDiskHeight**: Leave blank

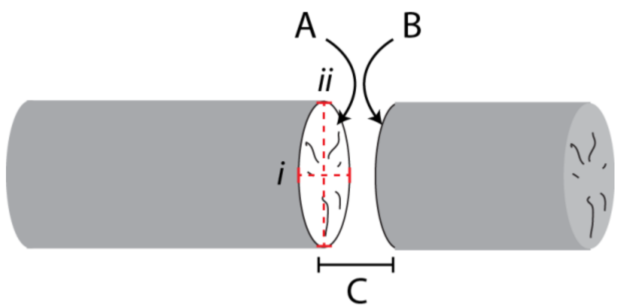

Figure 16. Measurements required for the space from which a crumbly "disk" was extracted by hand from a highly decayed log. Freshly cut surfaces are indicated by A and B, and C shows the height of the "disk." Highly decayed logs are often collapsed under their own weight, and show elliptical cross-sections (i.e., the red dashed lines *i* and *ii* where *i* > *ii*, which represent the major and minor ellipse axes, respectively). In the steps above, **diameter** is typically the average of A.*i* and B.*i* ; **ninetyDiameter** is typically the average of A.*ii* and B.*ii*

10. Measure the fresh mass of the entire cross-sectional disk sample using a spring scale.
    a. Choose an appropriately sized spring scale for the disk sample. It is important to use the smallest possible spring scale for the sample to ensure measurement uncertainty is minimized. Larger spring scales have larger measurement uncertainty.
    b. Break up unwieldy pieces that do NOT exceed the spring scale limit with a hatchet (or wedge and maul), and weigh together, if feasible.
    c. Break up large pieces that DO exceed the spring-scale limit with a hatchet (or wedge and maul), and weigh pieces one at a time:
        i. Generate as few pieces as possible to prevent compounding mass measurement error.

   ii. Do NOT use a chainsaw for breaking the disk, as the saw will remove wood mass.

d. Check the tare before each weighing.

e. Record in the *CDW: Field Bulk Density [PROD]* app:

   i. **diskFreshMass**; precision is determined by the spring scale that was used (not all scales are listed below).

   - 20 kg scale: Estimate to the nearest 100 g
   - 1000 g scale: Estimate to the nearest 5 g
   - 300 g scale: Estimate to the nearest 1 g

11. Cut an approximate 100 – 400 g subsample from the disk to take back to the laboratory and determine the fresh:dry mass ratio (see below for subsampling guidelines).

- Record 'Disk Subsample Created = No' and skip this step if the entire disk has a fresh mass < 400 grams.
- When subsampling disks:
  - Larger masses, closer to 400 g, will be needed to generate a representative, wedge-shaped subsample from large-diameter disks (**Figure 17**A).
  - Smaller masses, closer to 100 g, will be sufficient for smaller-diameter disks (**Figure 17**B).
- If decay throughout the disk appears non-uniform – i.e., a portion of the disk is more decayed than the rest:
  - Generate two subsamples that weigh approximately 100 – 400 g total, with volume of the two subsamples roughly proportional to the affected areas of the disk.
  - Both subsamples can be placed into the same, labeled sample bag (muslin or paper).
- **For "disks" lacking structural integrity that do NOT hold their shape**:
  - Subsample approx. 400 g of well mixed sample by hand from the plastic bag.

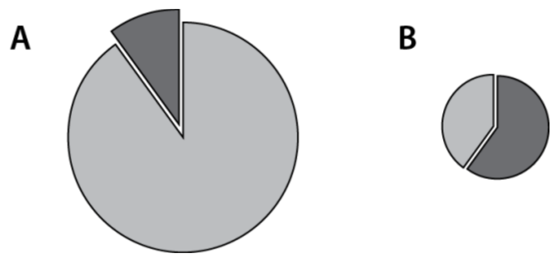

Figure 17. Creating wedge-shaped subsamples from cross-sectional disks from relatively large disks (A), and relatively small disks (B). In both A and B, the dark grey area is between 100-400 g, and the light grey is discarded.

12. Weigh the subsample created in step 11, and determine the fresh mass with an appropriately sized spring scale. Always tare the scale first (see SOP A.3). In the *CDW: Field Bulk Density [PROD]* app:
    a. Record the **sampleFreshMass**: Fresh mass of the disk subsample; nearest 1 g (or the finest resolution provided by the selected spring scale).
    b. Save the child-level disk record.
13. Place the sample into a labeled sample bag (see SOP A.4), along with its associated barcoded label, and close the bag.
14. Create another child-level disk record if a second disk can be collected from the log.
15. Return to step (3), above.

C.4 Post-field sampling tasks

1. Place labeled sample bags (muslin and/or paper) containing cross-sectional disks, or subsamples of disks, into the 105 ˚C drying oven(s).
    - Track drying progress with the general-purpose Drying Datasheet (see SOP D.1 for details).
    - Bulk density samples can air-dry for up to 5 days before going into the oven if oven-space is not immediately available.
2. Perform routine chainsaw maintenance:
    - Sharpen chain if necessary.
    - Check controls, chain tension, and all bolts and handles to ensure they are functioning properly and adjusted according to the manufacturer's instructions.
    - Make sure the lubrication (bar oil) reservoir is full. ALWAYS fill the bar oil reservoir when re-fueling to ensure it does not run dry.

SHARPENING THE CHAIN

Keep in mind that during sampling of downed logs, the chain may come into frequent contact with the ground, and could dull quickly. However, the chain does not have to be particularly sharp to cut decayed logs, so only sharpen if you find you are having difficulty making straight(ish) cuts.

C.5 Repeat bulk-density sampling in the field (Bout 2)

The intent of CDW bulk density Bout 2 sampling is to obtain a time series of bulk density estimates and other metadata from logs sampled and tagged in Bout 1 that were previously ≥ 10 cm diameter. The DST list is not used for Bout 2 bulk density sampling. The process of recording data, cutting, measuring, weighing, and subsampling cross-sectional disks from selected logs is similar to that described for Bout 1 sampling in SOP C.3. Modifications for Bout 2 are described below and in **Table 17** and **Figure 18**.

Table 17. Summary comparison of Bout 1 versus Bout 2 bulk density sampling.

Sampling Criteria	Bout 1 (see SOP C.3)	Bout 2
Which particles to sample?	Use DST list.	Resample those logs previously sampled for bulk density in Bout 1 (metal tagged logs).
Diameter	Sample all diameter classes (2-5 cm, 5-10 cm, and > 10 cm)	Sample only tagged logs that were ≥ 10 cm diameter in Bout 1. Collect a sample in Bout 2 even if the log has decayed, so long as diameter is still > 2 cm.
Length	Logs ≥ 10 cm diameter: Target length ≥ 3 m (preferred); ≥ 2 m acceptable. Logs < 10 cm diameter: ≥ 1 m length.	For current diameter ≥ 10 cm: length ≥ 2 m required. For current diameter < 10 cm and ≥ 2 cm: length ≥ 1 m required.
Disk number and location	Logs ≥ 10 cm diameter and ≥ 3 m length BEFORE sampling: 2 disks, collected 1 m from each end. Logs ≥ 10 cm diameter, and length ≥ 2 m and < 3 m: 1 disk, collected 1 m from one end. Logs < 10 cm diameter: 1 disk, collected ≥ 50 cm from one end.	Logs ≥ 3 m length AFTER Bout 1: 2 disks, collected 1 m from each end. Logs ≥ 2 m and < 3 m length AFTER Bout 1: 1 disk, collected 1 m from one end. Logs ≥ 1 m and < 2 m length AFTER Bout 1: 1 disk, collected ≥ 50 cm from one end.

For all logs that were previously ≥ 10 cm diameter and tagged in Bout 1:

1. To re-find logs mapped with **mappingMethod** = 'relative', submit a request to Science to complete the following steps:
   a. Download **plotID**, **pointID**, **logAzimuth**, and **logDistance** data from the NEON Data Portal.
   b. Add 180˚ to the **logAzimuth** data to obtain the angle from the **pointID** back to the log.
   c. Use **pointID**, **logAzimuth**, and **logDistance** data to calculate the log location in decimal degrees.

2. To re-find logs mapped with mappingMethod = 'GPS', navigate to the log using the GPS unit. *Note*: It is easiest to find logs using this method when GPS coordinates are displayed in UTM format (as opposed to decimal degrees); not all units can display UTMs.
3. Spend 15-20 minutes looking for each tagged log, keeping in mind that relative mapping measurements may be less accurate in thick vegetation and that extensive disturbance may also make it harder to relocate tagged logs.
    a. Use a metal detector to locate tags if needed.
    b. Log-specific data from Bout 1 may also aid in finding tagged logs (e.g., diameter, length, taxonID).
    c. Finding a cut end from Bout 1 is excellent confirmation that a log was previously sampled in Bout 1, but finding a previously cut end is not required to collect a Bout 2 sample.
    d. If the log is forked, attempt to resample the same fork in Bout 2 as in Bout 1 but do not spend an excessive amount of time determining which fork to sample.
4. Determine the length and diameter of the log. If rates of decay, burning, etc. are high, then logs with a diameter ≥ 10 cm and length ≥ 2 m in Bout 1 may have been reduced to lesser dimensions for Bout 2. However, if the Bout 2 diameter is ≥ 2 cm and the length of the largest intact fragment is ≥ 1 m, continue to evaluate the suitability of the log for sampling via the following steps:
    a. When measuring length and diameter do not include log remnants at or below the surface level of the ground (below surface litter is okay).
    b. If a break or crack in a log creates a gap ≥ 1 cm, then measure the length and diameter and collect a sample from the longest remaining intact fragment.
    c. If a log has decayed in an irregular manner and is no longer an ellipse (e.g., only a half-moon remains or a portion has been carved away by fire, etc.):
        i. Record the maximum and minimum diameters to the greatest accuracy possible even though the log is no longer elliptical and note the shape in the **remarks**.
5. Do NOT collect a Bout 2 bulk density sample if any of the criteria below are met. For these cases, a meaningful bulk density calculation is not possible. Communicate with Science if it is unclear whether a given log should be re-sampled.
    a. Any of the following preclude sampling:
        i. The log is likely > 25% live root biomass,
        ii. The log has live plants with height > 10 cm rooted in it, or

iii. The log has no remaining internal material for which a bulk density calculation could be made (e.g., there may be a shell of bark delineating the boundaries of what used to be a log but the contents are hollow or minimal).

b. If the tagged log no longer qualifies, record:

i. **logStatus** = “unsuitable for density calculations”.

ii. **decayClass**

iii. **diameter**; measured at the mid-point of the log's central axis.

iv. **taxonID**

v. **logLength**; the length of the largest remaining fragment.

vi. Data related to disk dimensions are not collected.

6. Logs qualify for Bout 2 sampling if the current log diameter is ≥ 2 cm and length is ≥ 1 m, the log has a volume that is likely < 25% live root biomass, has no live plants ≥ 10 cm tall rooted in it, and on average is not hollow. Disk collection is carried out as for Bout 1 as described in SOP C.3, with steps modified as follows:

   a. If there is denser and less decayed heartwood surrounded by less dense and more decayed sapwood, collect a disk that represents the presence of both wood types as proportionally as possible so that the resulting bulk density is representative of the log. Use the disk sampling guidelines in **Table 16**.

   b. If relevant, record **remarks** about the estimated percent of the log comprised of roots and note the height of rooted vegetation.

7. If the log qualifies, record the data described in steps 4 and beyond of SOP C.3 for Bout 1, with the following modifications:

   a. **mappingMethod**; leave blank. Mapping data are not recorded for Bout 2.

   b. **logID**; record the value from the existing tag.

   c. Use the disk sampling guidelines in **Table 16** based on the diameter observed for Bout 2.

   d. For **tagStatus**; choose one of the following:

      i. 'ok'; existing tag present and value is consistent with previously entered value.

      ii. 'tag lost but confident of ID'; log was tagged previously (> 90% probability) and tag is presently missing. It is known with > 90% probability what the previous tagID value was based on log-specific data from Bout 1 or evidence of cuts from Bout 1.

8. Collect cross-sectional disk samples as in steps 6 and beyond of SOP C.3 for Bout 1, with the following modifications:
    a. For logs ≥ 3 m length (that were ≥ 5 m length in Bout 1) (Figure 18A):
        i. Cut two cross-sectional disk samples, 1 meter in from each end of the log.
    b. For length ≥ 2 m and < 3 m (that were < 5 m length in Bout 1) (Figure 18B):
        i. Cut one cross-sectional disk sample, 1 meter in from either end of the log.
    c. For logs exactly 2 m long
        i. Cut the disk from the center of the log.
    d. For length ≥ 1 m and < 2 m
        i. Cut one cross-sectional disk sample, 50 centimeters in from either end of the log.

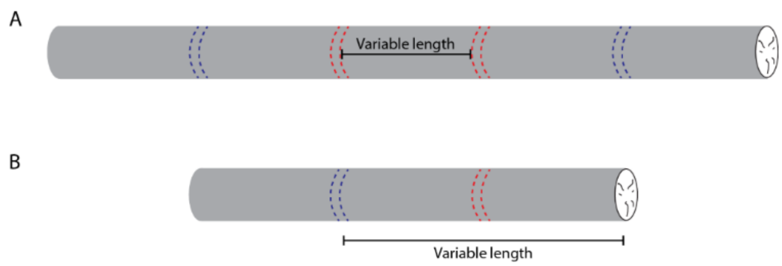

Figure 18. Strategy for generating cross-sectional disks from logs re-sampled for bulk density in Bout 2. (A) Logs ≥ 5 m length in Bout 1 and ≥ 3 m length in Bout 2; (B) Logs < 5 m length in Bout 1 and < 3 m length in Bout 2. Pairs of blue dashed lines represent Bout 1 disks, and pairs of red dashed lines indicate Bout 2 disks.

SOP D Processing Bulk Density Samples in the Laboratory

Goals

- Oven-dry bulk-density samples from SOP C to constant mass in the laboratory.
- Record dry-weight mass values in the ***CDW: Lab Bulk Density [PROD]*** application so that bulk-density can be calculated for abundant DSTs that occur at each site. See the Coarse Downed Wood Fulcrum Manual (RD[13]) for data entry details.
- Calculation of bulk density by DST allows accurate estimation of CDW mass and carbon stocks when paired with volume estimates from SOP B.

D.1 Drying and Weighing Samples

1. Record on the Drying Datasheet:
   a. **bagNumber**
   b. The **ovenStartDate** and **time** the samples are placed in the drying oven.
   c. ***Tip:*** Dry disk samples/subsamples from the same log at the same time to take advantage of 'batch' entry of oven drying data.
2. Place labeled sample bags into a 105 ˚C drying oven until samples are dried to a constant mass. Drying may take up to 5 days (120 h) or longer.
3. Check the drying progress using the Drying Datasheet.
   a. Choose 5 sample bags per **ovenStartDate** to monitor for drying time. If there are different size categories of sample (e.g., wedges from larger logs vs. cylinders of various sizes from smaller logs), choose 5 samples per size category and perform the steps below separately for each size category.
   b. Record the mass of the sample in these 5 bags through time to track drying progress. There is no need to remove samples from the bags: Simply record the mass of the bag + the sample inside.
   c. Each time drying progress is checked, calculate the difference in mass between the last two timepoints for each bag + sample(s). Spreadsheet calculators to monitor drying are available on the Field Science SSL.

> **!!!CRITICAL STEP:**
>
> Recording the **bagNumber** allows for easy tracking of drying progress for individual bags without having to open bags to see the label and enables assessment of how long different batches of wood samples have been in the oven. Trackable, numbered bags are especially useful when samples from different days are in the same oven. The same bags may be re-used for subsequent disk collections.

   d. Samples are dry when the average difference between the last two timepoints equals zero (i.e., the change in mass averaged across all 5 bags = 0, to within ± 0.5 g or ± 1% of the previous timepoint mass, whichever is larger).

   e. The time difference between weight checks may need to be longer than 24 h, depending on wood water content and sample size.

4. Remove dried bulk-density samples from the drying ovens, let cool until safe to touch, and weigh as soon as possible.

   - Oven-dried wood will readily absorb water from the air, particularly in humid environments. Weigh samples one or two at a time soon after removal from the oven to prevent this problem.

   - ***If not weighing samples within 1 h after removing from the oven***, record **ovenOutDate/Time** on the label, and place in temporary storage. Samples not weighed within 1 h from when they are removed from the oven must be returned to a 105 ˚C drying-oven for 24 h prior to weighing.

5. Remove dried wood from the sample bag, tare the balance + weigh boat, weigh each individual disk sample or subsample using a mass balance (0.01 g accuracy), and record data in the *CDW: Lab Bulk Density [PROD]* app.

   a. **logID**; for the logID linked to the disk sample, find an existing parent-level record in the *CDW: Lab Bulk Density [PROD]* app, or create one if none exists. Barcodes will help avoid creating duplicates when a parent-level record for another disk cut from the same **logID** has already been created.

      i. In the main app, scan the barcode affixed to the sample label. If a parent-level record for another disk cut from same **logID** has already been created, it will be identified.

         a) Edit the record to create another child-level **diskID** record for the sample in hand.

      ii. If scanning the barcode in the main app does not bring up any existing records:

         a) Create a new parent-level **logID** record.

         b) In the **Select logID** field, scan the sample barcode to auto-populate sample meta-data previously entered in the *CDW: Field Bulk Density [PROD]* app.

   b. **Batch Oven Times**; batch oven times may be entered if there are 2 disks cut from the same log and both disks were dried identically (same dates, duration, etc.).

      - Oven Times are only recorded for initial drying. Do not record oven data for any subsequent drying events following storage.

c. Create a child-level **Disk Data** record within the existing parent record for the sample in hand and record:

   i. **qaSample**; select 'Yes' or 'No' depending on whether the record is for QA. A minimum of 5% of samples should be selected for QA weighing by a different person. If QA weighing does not take place within 1 hour of initially removing the sample from the oven, return samples targeted for QA to a 105 ˚C drying oven for 24 h prior to re-weighing.

> **QASAMPLE**
>
> ***!!!Note***: For Lab QA, select the same samples that were QA'd in the field. This enables estimation of uncertainty for the entire bulk density calculation process.

   ii. **diskID**; select the **diskID** for the sample.

   iii. Enter **ovenStartDate/Time** and **ovenEndDate/Time** if 'batch' data were not previously entered.

   iv. **diskFreshMass**; value is auto populated from the *CDW: Field Bulk Density [PROD]* app when diskID is selected and may be changed here if necessary. Enter in grams (g).

   v. **Disk Subsample Created**; Indicate 'Yes' or 'No'. Value is auto populated from the *CDW: Field Bulk Density [PROD]* app when diskID is selected and may be changed here if necessary.

   vi. **sampleFreshMass**; the fresh mass of the disk subsample created in the field, grams (g). Value is auto populated from the *CDW: Field Bulk Density [PROD]* app when diskID is selected and may be changed here if necessary.

   vii. **dryMass**; the oven dry mass of the disk or disk subsample, nearest 0.01 grams.

   viii. Save the child-level disk record.

d. Save the parent-level **logID** record.

6. Repeat step (5) for additional dried samples.
7. Return dried wood samples to temporary storage once all data have been recorded. Paper bags may be used instead of muslin bags for temporary storage if muslin bag supply is low; write the muslin bag number and the **subsampleID** on the paper bag.
   - Samples may be discarded (in accordance with any permitting constraints or land use agreements) after all data records for a given bout have been successfully ingested by the parser, all parser errors have been resolved, and all data QC checks according to RD[04] have been completed.
   - Numbered muslin bags may be re-used for subsequent sampling events.

D.2 Equipment Maintenance

- Check balances before each use with a standard weight.
- Balances should be calibrated with a standard calibration weight set:
    - After initial installation.
    - Any time the balance is moved.
    - Every 6 months or if the check above indicates the balance is reporting masses outside the manufacturer's specified tolerances.

SOP E Data Entry and Verification

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible. Alternatively, devices should be synced immediately upon return to the Domain Support Facility.

Given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should always be carried along with the mobile devices to sampling locations. Data collected on paper data sheets must be transcribed within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

Quality Assurance

Data Quality Assurance (QA) is an important part of data collection and ensures that all data are accurate and complete. Certain QA checks can be conducted in the field (i.e., before a field team leaves a plot or site), while others can be conducted in the office (typically within a week of collection). Field QA procedures are designed to prevent the occurrence of invalid data values that cannot be corrected later, and to ensure that data and/or sample sets are complete before the sampling window closes. Invalid metadata (e.g., collection dates, plotIDs) are difficult to correct when field crews are no longer at a sampling location.

Office QA procedures are meant to ensure that sampling activities are ***consistent*** across bouts, that sampling has been carried out to ***completion***, and that activities are occurring in a ***timely*** manner. The Office QA will also assess inadvertently duplicated data and transcription errors to maintain data ***validity***. See the Data Management Protocol (RD[04]) for more discussion of QA measures.

Before digital records load to the NEON database, the data must undergo thorough quality checks. The steps needed to accomplish this are outlined in the CDW QC Checklist, which is available on the NEON SSL.

CDW-specific data entry and QC information

Data collected in the field: Tally

1. The **domainID** and the **logID** are used to create the **individualID** in the NEON database. Make sure these input data are entered correctly before saving records.

Data collected in the field: Bulk Density

1. The **yearBoutBegan**, **plotID**, and **logID** are used to create the **sampleID** in the NEON database. Make sure these data are entered correctly before saving records.
2. Saving *CDW: Field Bulk Density [PROD]* records and syncing will make **sampleIDs** available for further data entry in the downstream *CDW: Lab Bulk Density [PROD]* app.
    a. If corrections to any of the sampleID input variables are required after a sampleID has been selected in the downstream application:
        i. Make the correction(s) in the Field app and save.
        ii. Open, edit, and save each downstream parent- and child-level record to propagate the update.
    b. Consult the Coarse Downed Wood Fulcrum User Manual on the SSL for more detail.

Data collected in the lab: Bulk Density

1. The **sampleID** and the **diskID** are used to construct the **subsampleID**. Each subsampleID is associated with disk dimension, fresh weight, subsample fresh mass (if applicable) and dry mass values.
2. If **subsampleIDs** are incorrect:
    a. Discard the *CDW: Lab Bulk Density [PROD]* record.
    b. Make corrections in the *CDW: Field Bulk Density [PROD]* app as described above, then save and sync.
3. The child-level 'Disk Data' records in the *CDW: Lab Bulk Density [PROD]* app inherit **diskFreshMass** and **sampleFreshMass** data (when applicable) from the *Field Bulk Density* app. If either of these fields is incorrect and *Lab Bulk Density* records have already been created:
    a. Make updates only in the *CDW: Lab Bulk Density [PROD]* app. Published values for these two fields are only ingested from the *CDW: Lab Bulk Density [PROD]* app.

SOP F Sample Shipment

Not applicable to the CDW – Coarse Downed Wood protocol.

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APPENDIX A QUICK REFERENCES

A.1 Summary of procedures

CDW Tally Field sampling

1. Navigate to plot centroid and consult LIDS Angle List to determine sampling angles for the three transects. Create a child-level record in the Fulcrum *CDW: Tally [PROD]* app to access plot-specific LIDS angles.
2. Starting at 3 m from the plot centroid travel along each transect and look for qualifying particles that intersect the transect (logs must be >1 m long and with diameter exceeding RD_{min} for the transect distance and plot-specific volume factor).
3. For each qualifying particle record all required variables (e.g., decay class, diameter(s), taxon ID, log length, distance along transect, unique logID, etc.).
4. Add red anodized tags with the logID to measured logs ≥ 10 cm diameter if tag not already present from a previous bout.
5. For forked particles use the *CDW: Tally [PROD]* app to auto-calculate the round diameter equivalent (RD_E) to determine whether they qualify.
6. Be mindful of diameter size class breakpoints (5 cm and 10 cm). If a log comprises multiple diameter size categories, then create a record for each size category that qualifies at the distance along transect. Append a suffix (e.g., A or B) to the logID for the smaller qualifying size categor(ies).

CDW Field Bulk Density sampling and drying in the Laboratory

1. Do not begin until CDW Tally sampling at both Tower and Distributed Plots has been completed.
2. Obtain list with the most abundant decayClass x sizeCategory x taxonID (DST) combinations at the site, based on CDW Tally sampling. DST lists are posted in the TOS Support Library.
3. Search for pieces of CDW that qualify for bulk density sampling and that are on the ranked list of DSTs (note that selection criteria is different for the second bout than for the first bout).
4. Record all required fields for sampled logs. Note that decay class, diameter, and taxon ID allow for matching with the CDW Tally data and ultimately calculating the mass of logs measured in the CDW Tally procedure.
5. Cut two disks from each log (only one disk if log < 5 m long), following chain saw safety protocol if site host allows use of a chain saw.
6. Make additional measurements of disk dimensions and disk fresh mass (using spring scale).
7. Cut and weigh subsample to determine the fresh:dry mass ratio in the laboratory.
8. Place sample in a breathable bag (muslin or paper) with its associated barcoded label.
9. In the laboratory, place labeled sample bags with disks or subsamples into a 105 ˚C drying oven.
10. Weigh samples when dry (change in mass between consecutive time points is zero to within ± 0.5 g or ± 1% of the previous timepoint mass, whichever is larger.
11. For a minimum of 5% of samples make repeat QA weighing measurements (same samples QA'd in the field).

Workflow diagrams for Tally (**Figure 9,** see **SOP B**) Field Bulk Density (**Figure 19**), and Lab Bulk Density (**Figure 20**) for field staff to print and use as a quick reference to visually verify that all samples have been collected and processed.

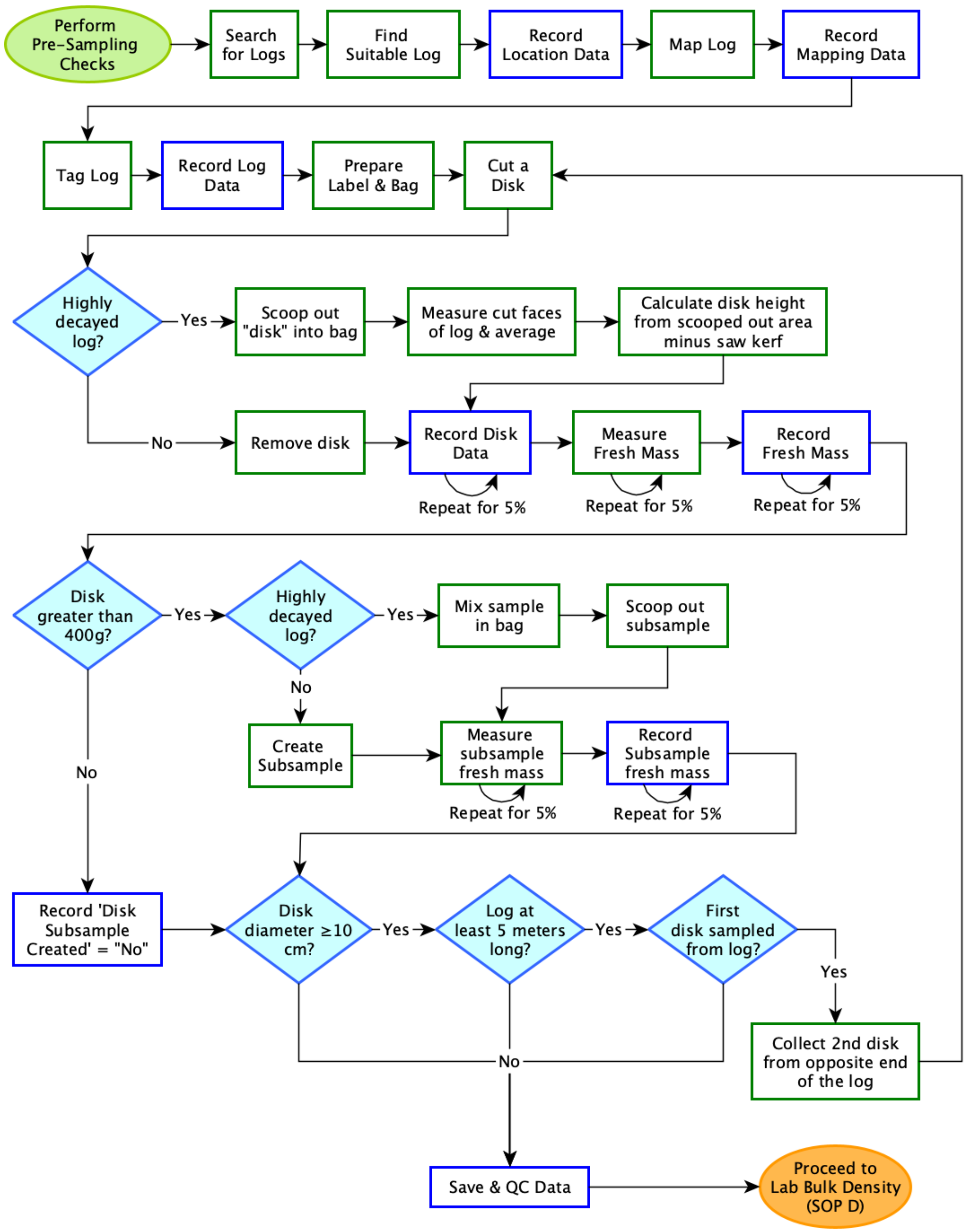

Figure 19. Overview workflow diagram of CDW Bulk Density field sampling.

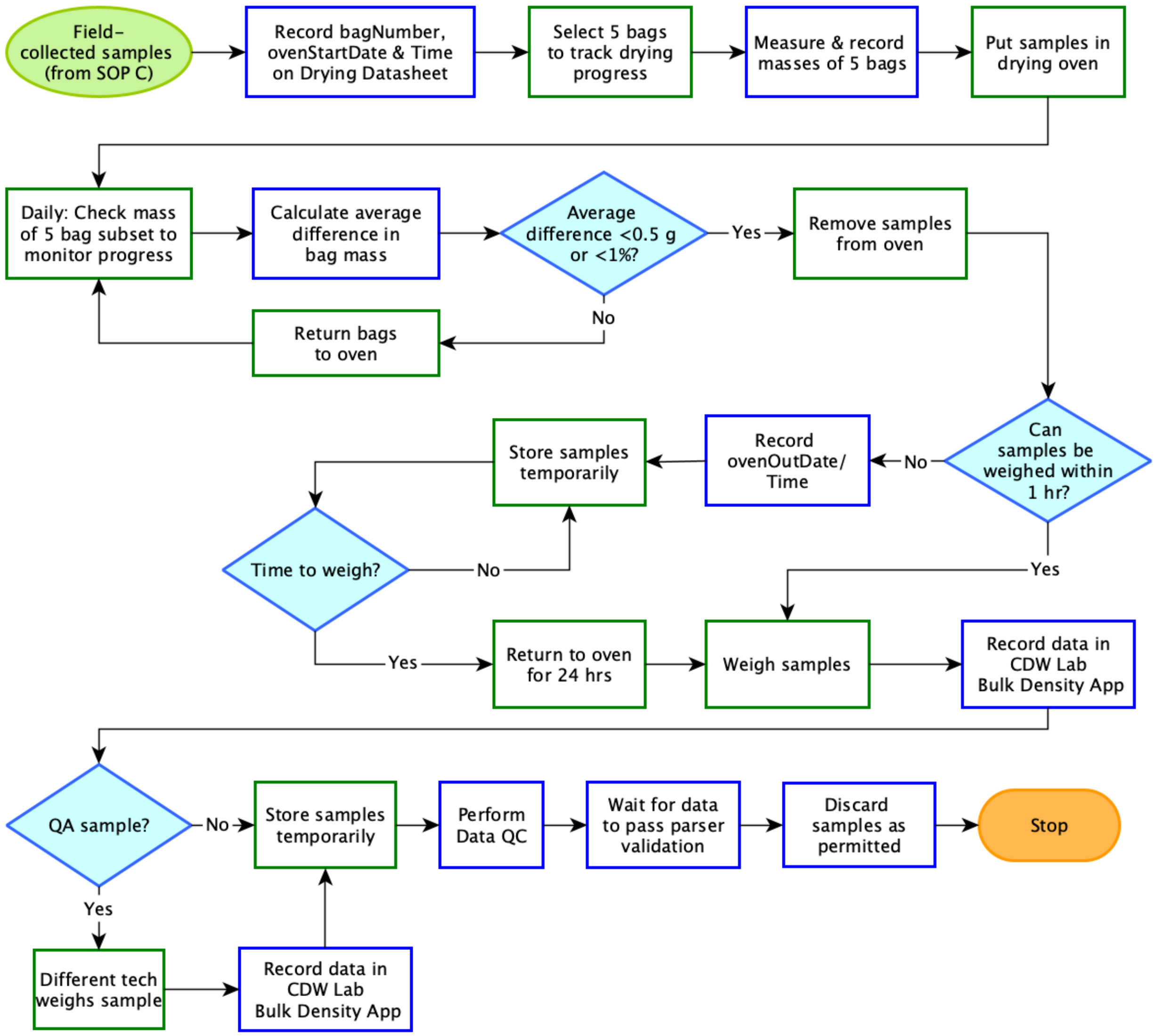

Figure 20. Workflow of CDW Bulk-Density lab process.

A.2 Minimum Round Diameters and Limiting Distance Tables

If it is unclear whether a log should be measured, err on the side of caution and measure it – RD rounds UP, D_{lim} rounds DOWN

Table 18. Limiting distances (D_{lim}) for round diameters (RD) across various LIDS volume factors (*F*). Double-lines indicate breaks between diameter sizeCategories.

RD (cm)	D_{lim} (m)				
-	F=5	F=8	F=10	F=15	F=20
2	0.3	0.21	0.16	0.11	0.08
3	0.7	0.46	0.37	0.25	0.19
4	1.3	0.8	0.7	0.4	0.3
5	2.1	1.3	1.0	0.7	0.5
6	3.0	1.9	1.5	1.0	0.7
7	4.0	2.5	2.0	1.3	1.0
8	5.3	3.3	2.6	1.8	1.3
10	8.2	5.1	4.1	2.7	2.1
12	11.8	7.4	5.9	4.0	3.0
14	16.1	10	8.1	5.4	4.0
16	21.1	13	11	7.0	5.3
20	32.9	21	16	11	8.2
25	51.4	32	26	17	13
30	74	46	37	25	19
35	100	63	50	34	25
40	131	82	66	44	33
50	205	129	103	69	51
60	296	185	148	99	74
70		252	202	134	101
80		329	263	175	132
90			333	222	167
100				274	206
110				332	249
120					296

Table 19. Minimum round diameters (RD_{min}) for fixed distances (D) for various LIDS volume factors (F). Log diameters larger than those listed are tallied at any distance. Derived from equation in Affleck (2010): RD_{min} (cm) = $\sqrt{(8 * M * F * D/Pi^2)}$, where M is transect segments (3 for NEON sampling).

D (m)	RD_{min} (cm)				
	F=5	F=8	F=10	F=15	F=20
0.5	2.5	3.1	3.5	4.3	4.9
1	3.5	4.4	4.9	6.0	7.0
2	4.9	6.2	7.0	8.5	9.9
4	7	8.8	9.9	12.1	13.9
6	8.5	10.8	12.1	14.8	17.1
8	9.9	12.5	13.9	17.1	19.7
10	11	13.9	15.6	19.1	22.1
15	13.5	17.1	19.1	23.4	27.0
20	15.6	19.7	22.1	27.0	31.2
25	17.4	22.1	24.7	30.2	34.9
30	19.1	24.2	27.0	33.1	38.2
35	20.6	26.1	29.2	35.7	41.3
40	22.1	27.9	31.2	38.2	44.1
45	23.4	29.6	33.1	40.5	46.8
50	24.7	31.2	34.9	42.7	49.3
60	27	34.2	38.2	46.8	54.0
70	29.2	36.9	41.3	50.5	58.3
80	31.2	39.4	44.1	54.0	62.4
90	33.1	41.8	46.8	57.3	66.2
100	34.9	44.1	49.3	60.4	69.7
120	38.2	48.3	54.0	66.2	76.4
140	41.3	52.2	58.3	71.5	82.5
160	44.1	55.8	62.4	76.4	88.2
180	46.8	59.2	66.2	81.0	93.6
200	49.3	62.4	69.7	85.4	98.6
220	51.7	65.4	73.1	89.6	103.4
240	54.0	68.3	76.4	93.6	108.0
280	58.3	73.8	82.5	101.1	116.7

A.3 Forked CDW and Single Round Diameter Equivalents

A CDW particle may be forked where it intersects the LIDS transect. Because tallying depends on total cross-sectional area for the piece, for forked pieces it is necessary to calculate the equivalent RD at the point of LIDS intersection as a function of the total cross-sectional comprising each fork. Equivalent RD_E values for CDW split into two forks are provided in (**Table 20**); for > 2 input forks, work in groups of two and calculate intermediate RDs until one equivalent RD is computed.

Table 20. The round diameters of forked CDW logs (RD_{INPUTS}), and corresponding calculated equivalent round diameters (RD_E).

RD_{INPUTS}	RD_E	RD_{INPUTS}	RD_E	RD_{INPUTS}	RD_E	RD_{INPUTS}	RD_E
1, 2	2.2	3, 14	14.3	7, 9	11.4	18, 22	28.4
1, 3	3.2	3, 16	16.3	7, 10	12.2	18, 24	30
1, 4	4.1	3, 18	18.2	7, 12	13.9	18, 26	31.6
1, 5	5.1	3, 20	20.2	7, 14	15.7	18, 28	33.3
1, 6	6.1	4, 5	6.4	7, 16	17.5	18, 30	35
1, 7	7.1	4, 6	7.2	7, 18	19.3	20, 22	29.7
1, 8	8.1	4, 7	8.1	7, 20	21.2	20, 24	31.2
1, 9	9.1	4, 8	8.9	8, 9	12.0	20, 26	32.8
1, 10	10.0	4, 9	9.8	8, 10	12.8	20, 28	34.4
1, 12	12.0	4, 10	10.8	8, 12	14.4	20, 30	36.1
1, 14	14.0	4, 12	12.6	8, 14	16.1	22, 24	32.6
1, 16	16.0	4, 14	14.6	8, 16	17.9	22, 26	34.1
1, 18	18.0	4, 16	16.5	8, 18	19.7	22, 28	35.6
1, 20	20.0	4, 18	18.4	8, 20	21.5	22, 30	37.2
2, 3	3.6	4, 20	20.4	9, 10	13.5	24, 26	35.4
2, 4	4.5	5, 6	7.8	9, 12	15.0	24, 28	36.9
2, 5	5.4	5, 7	8.6	9, 14	16.6	24, 30	38.4
2, 6	6.3	5, 8	9.4	9, 16	18.4	26, 28	38.2
2, 7	7.3	5, 9	10.3	9, 18	20.1	26, 30	39.7
2, 8	8.2	5, 10	11.2	9, 20	21.9	28, 30	41
2, 9	9.2	5, 12	13.0	10, 12	15.6	28, 32	42.5
2, 10	10.2	5, 14	14.9	10, 14	17.2	28, 34	44
2, 12	12.2	5, 16	16.8	10, 16	18.9	28, 36	45.6
2, 14	14.1	5, 18	18.7	10, 18	20.6	28, 38	47.2
2, 16	16.1	5, 20	20.6	10, 20	22.4	28, 40	48.8
2, 18	18.1	6, 7	9.2	12, 14	18.4	28, 42	50.5
2, 20	20.1	6, 8	10.0	12, 16	20.0	28, 44	52.2
3, 4	5.0	6, 9	10.8	12, 18	21.6	30, 32	43.9
3, 5	5.8	6, 10	11.7	12, 20	23.3	30, 34	45.3
3, 6	6.7	6, 12	13.4	14, 16	21.3	30, 36	46.9
3, 7	7.6	6, 14	15.2	14, 18	22.8	30, 38	48.4
3, 8	8.5	6, 16	17.1	14, 20	24.4	30, 40	50
3, 9	9.5	6, 18	19.0	16, 18	24.1	30, 42	51.6
3, 10	10.4	6, 20	20.9	16, 20	25.6	30, 44	53.3
3, 12	12.4	7, 8	10.6	18, 20	26.9	32, 34	46.7

A.4 Limiting Distance and Log Diameter Examples

Example 1:

Walking down the first LIDS transect with a volume factor *F*=8, you encounter a CDW particle 32 cm in diameter, and you are 56 m from the transect origin: should the CDW particle be tallied? Looking at the left-most column in **Table 18**, 32 cm falls between 30 cm and 35 cm, so round up and use RD = 35 cm. For RD = 35 and F=8, the corresponding value of D_{lim} = 63.0 meters. Because the distance along the transect of 56 meters is < D_{lim}, the CDW particle should be tallied.

Example 2:

You have walked 11 m from the origin of a LIDS transect with a volume factor *F*=15. Is it necessary to keep looking for and tallying CDW particles with diameter ≤ 20 cm? Looking at the left-most column in **Table 19**, a distance of 11 m falls between 10 m and 15 m, so round down to 10 m to be conservative. For D_{lim} = 10 and F=15, the minimum diameter is 19.1 cm, meaning any CDW particles < 19.1 cm diameter can be ignored. However, logs ≥ 19.1 cm diameter should still be tallied.

APPENDIX B REMINDERS

- Well in advance (ideally several weeks), make sure you have the necessary DST ranked lists and that they are up-to-date (derived from Tally data from both Tower and Distributed plots). If they are missing or out of date, then request a ranked DST list from HQ Science.
    - Storms and floods that create pulses of CDW after Tally was completed but before Bulk Density is implemented may make a new DST list necessary.
- Remember that CDW Tally transects don't start until 3 m from the plot centroid.
- Remember to complete chainsaw safety training before cutting disks with a chainsaw, and be aware that some chainsaw safety programs require multiple days and advance sign-up.
- Don't forget to re-measure BOTH disk dimensions AND masses for 5% of samples for QA purposes.
- Record bulk density disk measurements before subsampling. Make sure disks selected for QA are re-measured by a second person before subsampling.
- Make sure that metal objects (e.g. calipers, glasses, jewelry, piercings) are > 50 cm from the compass or rangefinder so they do not influence the compass bearing.
- Remember that the overall goal is to sample Coarse Downed Wood particle volumes in the CDW Tally (SOP B) and then use bulk density data (SOP C and SOP D) to estimate CDW mass in each decayClass x sizeCategory x taxonID (DST) combination.

APPENDIX C ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

In general, the temporal strategy for sampling is outlined in Section 4, and the primary goal is to avoid sampling during periods of maximal seasonal storm activity that potentially create large fluxes of CDW. For most north-temperate sites, maximal seasonal storm activity occurs in the winter, and as such, CDW sampling should not occur in this time period. The dates below put coarse bounds on the northern hemisphere winter season, and are derived from MODIS-EVI phenology data, averaged from 2012-2021 (Didan 2023). The 'Approximate Start Date' field corresponds to the average date of green-up, and thus presumably, the end of winter and associated storm activity. The 'Approximate End Date' field corresponds to the average date of dormancy when greenness has returned to baseline 'winter' levels, and by which winter storms have presumably begun.

The dates below (DD-MMM format) provide a coarse window only, and it is essential that domain staff monitor real-time conditions to determine when to start (and stop) sampling, as described in Section 4 of this protocol. Moreover, not all sites for which dates are listed below produce CDW; consult Appendix D and discuss with Science to determine whether the protocol should be implemented.

Table 21. Site-specific average dates of green-up and senescence, or alternative sampling guidance if specified, that bound the CDW sampling window.

Domain	Site ID	Approx. Start Date	Approx. End Date
01	BART	21-Apr	02-Nov
	HARV	21-Apr	07-Nov
02	BLAN	01-Jan (before green-up for better visibility)	17-Nov (complete in spring or autumn but not across both)
	SCBI	01-Jan (before green-up for better visibility)	15-Nov (complete in spring or autumn but not across both)
	SERC	01-Jan (before green-up for better visibility)	21-Nov (complete in spring or autumn but not across both)
03	DSNY	30-Nov (Hurricane season ends)	01-Jun (Hurricane season begins)
	JERC	30-Nov (Hurricane season ends)	01-Jun (Hurricane season begins)
	OSBS	30-Nov (Hurricane season ends)	01-Jun (Hurricane season begins)

Domain	Site ID	Approx. Start Date	Approx. End Date
04	GUAN	30-Nov (Hurricane season ends)	01-Jun (Hurricane season begins)
	LAJA	30-Nov (Hurricane season ends)	01-Jun (Hurricane season begins)
05	STEI	26-Apr	28-Oct
	TREE	26-Apr	28-Oct
	UNDE	29-Apr	23-Oct
06	KONA	05-Apr	16-Nov
	KONZ	14-Apr	07-Nov
	UKFS	28-Mar	12-Nov
07	GRSM	03-Apr	11-Nov
	MLBS	15-Apr	08-Nov
	ORNL	24-Mar	13-Nov
08	DELA	14-Mar	11-Nov
	LENO	18-Mar	17-Nov
	TALL	24-Mar	18-Nov
09	DCFS	04-May	05-Nov
	NOGP	20-Apr	13-Nov
	WOOD	12-May	02-Nov
10	CPER	06-Apr	04-Oct
	RMNP	01-May	24-Oct
	STER	27-Mar	23-Sep

Domain	Site ID	Approx. Start Date	Approx. End Date
11	CLBJ	13-Mar	07-Dec
	OAES	08-Mar	17-Dec
12	YELL	Distributed plots: 14-Apr Tower plots: 01-Jul (due to bear management area closure)	12-Nov
13	MOAB	15-May	18-Oct
	NIWO	04-May	02-Oct
14	JORN	22-Mar	15-Nov
	SRER	01-Apr	17-Nov
15	ONAQ	31-Mar	23-Sep
16	ABBY	28-Mar	05-Nov
	WREF	21-Mar	05-Nov
17	SJER	05-Oct	11-Jun
	SOAP	26-Mar	27-Oct
	TEAK	17-Apr	31-Oct
18	BARR	21-May	29-Sep
	TOOL	07-May	16-Sep
19	BONA	03-May	01-Oct
	DEJU	01-May	03-Oct
	HEAL	25-Apr	05-Oct

Domain	Site ID	Approx. Start Date	Approx. End Date
20	PUUM	21-May (start of 'dry' season)	15-Sep (end of 'dry' season)

APPENDIX D SITE-SPECIFIC VOLUME FACTORS (F) AND LIDS TRANSECT LENGTHS

Initial F-values and transect lengths come from Vegetation Characterization data analysis from Tower Plots and may be modified in subsequent years by Science following site-specific tally analysis. See SOP 0 'Troubleshooting' if you believe there is a problem with the F-value and transect length.

Table 22. Site-specific volume factors and transect lengths for LIDS coarse downed wood tally sampling.

Domain Number	siteID	Sampling by plotType	F-value	Transect Length (m)	Additional Information
01	BART	Dist: Yes Tower: Yes	5	190	
	HARV	Dist: Yes Tower: Yes	5	170	
02	BLAN	Dist: Yes Tower: Yes	5	290	Many Distributed and Tower Plots will have no CDW due to pasture, crop cover.
	SCBI	Dist: Yes Tower: Yes	8	240	Some Distributed Plots may have no CDW due to pasture cover.
	SERC	Dist: Yes Tower: Yes	5	300	Some Distributed Plots may have no CDW due to crop cover.
03	DSNY	Dist: Yes Tower: No	5	210	Some Distributed Plots may have no CDW due to pasture cover.
	JERC	Dist: Yes Tower: Yes	5	260	Some Distributed Plots may have no CDW due to crop cover.
	OSBS	Dist: Yes Tower: Yes	5	130	Some Distributed Plots may have no CDW due to wetland cover.
04	GUAN	Dist: Yes Tower: Yes	5	90	
	LAJA	Dist: No Tower: No	*NA*	*NA*	Ag site. Assess for state change every 5 y to determine whether sampling should be scheduled.
05	STEI	Dist: Yes Tower: Yes	5	110	
	TREE	Dist: Yes Tower: Yes	5	140	
	UNDE	Dist: Yes Tower: Yes	5	120	
06	KONA	Dist: No Tower: No	*NA*	*NA*	Ag site, no qualifying CDW expected.

Domain Number	siteID	Sampling by plotType	F-value	Transect Length (m)	Additional Information
	KONZ	Dist: No Tower: No	5	40	Sampling suspended in 2018 until state-change occurs. Assess for state change every 5 y to determine whether sampling should be scheduled.
	UKFS	Dist: Yes Tower: Yes	5	180	Some Distributed Plots may have no CDW due to grassland cover.
07	GRSM	Dist: Yes Tower: Yes	8	180	
	MLBS	Dist: Yes Tower: Yes	5	170	
	ORNL	Dist: Yes Tower: Yes	5	270	Some Distributed Plots may have no CDW due to pasture cover.
08	DELA	Dist: Yes Tower: Yes	5	240	Sampling discontinued from 2026 onward due to gradient site decommissioning.
	LENO	Dist: Yes Tower: Yes	8	180	
	TALL	Dist: Yes Tower: Yes	5	190	
09	DCFS	Dist: No Tower: No	*NA*	*NA*	Grassland site, no CDW anticipated.
	NOGP	Dist: No Tower: No	*NA*	*NA*	Grassland site, no CDW anticipated.
	WOOD	Dist: No Tower: No	*NA*	*NA*	Grassland site, no CDW anticipated.
10	CPER	Dist: No Tower: No	*NA*	*NA*	Grassland site, no CDW anticipated.
	RMNP	Dist: Yes Tower: Yes	Dist: 5 Tower: 5	Dist: 75 Tower: 130	Different forest types in Distributed vs. Tower Plots.
	STER	Dist: No Tower: No	*NA*	*NA*	Agricultural site, no CDW anticipated.
11	CLBJ	Dist: Yes Tower: Yes	5	160	Many Distributed Plots may have no CDW due to grassland cover.
	OAES	Dist: No Tower: No	*NA*	*NA*	Grassland and shrub/scrub site, no CDW anticipated.
12	YELL	Dist: Yes Tower: Yes	8	170	
13	MOAB	Dist: No Tower: No	*TBD*	*TBD*	Sampling in Distributed Plots suspended in 2018 until state-change occurs. Assess for

Domain Number	siteID	Sampling by plotType	F-value	Transect Length (m)	Additional Information
					state change every 5 y to determine whether sampling should be scheduled.
	NIWO	Dist: Yes Tower: No	5	110	Some Distributed Plots may have no CDW due to tundra cover.
14	JORN	Dist: No Tower: No	*NA*	*NA*	Sampling suspended in 2018 until state-change occurs. Assess for state change every 5 y to determine whether sampling should be scheduled.
	SRER	Dist: No Tower: No	*NA*	*NA*	Sampling suspended in 2018 until state-change occurs. Assess for state change every 5 y to determine whether sampling should be scheduled.
15	ONAQ	Dist: No Tower: No	5	90	Sampling suspended in 2018 until state-change occurs. Assess for state change every 5 y to determine whether sampling should be scheduled.
16	ABBY	Dist: Yes Tower: Yes	15	180	
	WREF	Dist: Yes Tower: Yes	15	180	
17	SJER	Dist: Yes Tower: Yes	5	280	Most Distributed Plots may have no CDW due to grassland cover.
	SOAP	Dist: Yes Tower: Yes	8	170	
	TEAK	Dist: Yes Tower: Yes	10	230	
18	BARR	Dist: No Tower: No	*NA*	*NA*	Tundra site, no CDW expected.
	TOOL	Dist: No Tower: No	*NA*	*NA*	Tundra site, no CDW expected.
19	BONA	Dist: Yes Tower: Yes	5	50	Some Distributed and Tower Plots may have no CDW due to shrub/scrub cover.
	DEJU	Dist: Yes Tower: Yes	5	30	Some Distributed and Tower Plots may have no CDW due to shrub/scrub cover.
	HEAL	Dist: No Tower: No	5	20	Sampling suspended in 2018 until state-change occurs. Assess for state change every 5 y to determine whether sampling should be scheduled.

Domain Number	siteID	Sampling by plotType	F-value	Transect Length (m)	Additional Information
20	PUUM	Dist: Yes Tower: Yes	8	90	

APPENDIX E EQUIPMENT

The following equipment is needed to implement SOP B (**Table 23**), SOP C (**Table 24**), and SOP D (**Table 25**) in this document. Equipment lists are organized by task. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.

Table 23. Equipment list for CDW Tally sampling (SOP B). Item quantities are sufficient for a team of two technicians to perform CDW tallying and mensuration.

Supplier/ Item No.	Exact Brand?	Description	Purpose	Quan-tity
Durable Items				
	N	Mobile data collection device (tablet or equivalent)	Collect and record data in the field.	1 per team
	N	*Handheld caliper, 20 cm	Measure CDW pieces up to 20cm diameter	1
Forestry Suppliers; 59728	N	*Handheld caliper, 50 cm	Measure CDW pieces up to 50cm diameter	1
Forestry Suppliers; 59737	N	*Handheld caliper, 95 cm	Measure CDW pieces up to 95 cm diameter	1
	N	Hammer	Drive nails	1
Forestry Suppliers; 39945	N	Measuring tape, minimum 50 m	Delineate transect; determine whether logs central axes intersect transects	
Forestry Suppliers; 92496	Y	TruPulse Laser Rangefinder 360i, 30 cm accuracy	Delineate transect; measure log distance to transect origin	1
Grainger; 5B317	N	White reflector or reflective tape	Reflective target for laser rangefinder; aids in measuring distance to target accurately	1
Compass Tools; 703512 Forestry Suppliers; 90998	Y	Foliage filter	Allow laser rangefinder use in dense vegetation	2

Supplier/ Item No.	Exact Brand?	Description	Purpose	Quan-tity
	N	Field guide, regional flora reference guide and/or key	Identify downed logs to functional group (hardwood vs. softwood)	1
Amazon; 01000781 01	N	GPS receiver, recreational accuracy	Navigate to sampling location	1
Forestry Suppliers; 39167	N	Chaining pins or other suitable anchor	Anchor measuring tapes	1 set
	N	Reflector pin-pole kit	Hold reflective target	1
Forestry Suppliers; 37184, 37036	N	Compass with mirror and declination adjustment	Delineate transect	1
Forestry Suppliers; 57522	N	Hand stamp steel die set	Label blank tags	1 set
	N	Block of wood or equivalent hard surface	Tag stamping	1
	N	Metal detector	Relocate tag affixed in previous year no longer attached to the log	1
Consumable item				
	N	Per plot LIDS angle lists	Identify randomly assigned angles for LIDS transects in each plot	Varies
RD[05]	N	Coarse downed wood field datasheet	Record sampling data	Varies
	N	AA battery	Spare battery for laser rangefinder and GPS receiver	4
NapTags; P00443-R	N	Numbered anodized aluminum tag, red (preferably integrated anodized color; less desirable workaround is a high-temperature enamel paint coating such as Rustoleum 248948)	Tag downed logs ≥ 10 cm	As needed

Supplier/ Item No.	Exact Brand?	Description	Purpose	Quan-tity
NapTags; P00443-R	N	Blank anodized aluminum tag, red (preferably integrated anodized color; less desirable workaround is a high-temperature enamel paint coating such as Rustoleum 248948)	Replace tags on previously tagged downed logs	As needed
	N	Aluminum nail	Affix tags to logs ≥ 10 cm	As needed
		Pig-tail stakes	Affix tags to highly decayed logs	As needed
Forestry Suppliers; 33506	N	Fluorescent pin flags	Track location along transect	12

* The 20cm calipers are small, light, and suitable for measuring CDW in the 2-5cm and 5-10cm size classes, as well as larger pieces of CDW up to 20cm diameter; at sites with CDW ≤ 20cm diameter, this caliper is the only caliper required. At sites with larger diameter CDW, an additional caliper is required for the larger diameter pieces.

Table 24. Equipment list for CDW Bulk Density sampling (SOP C). Quantities are sufficient for a team of two technicians to perform CDW bulk-density sampling.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan-tity
Durable Items				
	N	Mobile data collection device (tablet or equivalent)	Collect and record data in the field.	1 per team
National Band and Tag Red #137	N	Blank aluminum tag, red	Replace tags on previously tagged downed logs	As needed
Forestry Suppliers; 92496	Y	TruPulse Laser Rangefinder 360i, 30 cm accuracy	Map or re-find logs sampled for bulk density	1
Grainger; 5B317	N	White reflector or reflective tape	Reflective target for laser rangefinder; aids in measuring distance to target accurately	1
Compass Tools; 703512	Y	TruPulse Foliage filter	Allow laser rangefinder use in dense vegetation	2

Forestry Suppliers; 90998				
Forestry Suppliers; 59505	N	Diameter tape, 64 cm*	Measure cross-sectional disk diameter	1
Forestry Suppliers; 59422	N	Diameter tape, 200 cm*	Measure cross-sectional disk diameter	1
	N	*Handheld caliper, 20 cm	Measure CDW pieces up to 20cm diameter	1
Forestry Suppliers; 59728	N	*Handheld caliper, 50 cm	Measure CDW pieces up to 50cm diameter	1
Forestry Suppliers; 59737	N	*Handheld caliper, 95 cm	Measure CDW pieces up to 95 cm diameter	1
	N	Hatchet (or wedge and maul)	Collect subsamples from cross-sectional disks	1
Forestry Suppliers; 93750	N	Spring scale, 20 kg capacity, tareable	Weigh fresh mass of large cross-sectional disks	1
Forestry Suppliers; 93790, 93709	N	Spring scale, 5 kg capacity, tareable	Weigh fresh mass of medium cross-sectional disks	1
Forestry Suppliers; 93053, 93015	N	Spring scale, 1000 g capacity, tareable	Weigh fresh mass of small cross-sectional disks, and disk subsamples larger than 300 g	1
Forestry Suppliers; 93017	N	Spring scale, 300 g capacity, tareable	Weigh fresh mass of disk subsamples	1
	N	Heavy duty plastic bag	Contain cross-sectional disk for weighing with spring scale	1

	N	Chainsaw, 18" bar minimum, tool-less chain adjustment	Collect log cross-section samples; check with local foresters to determine optimal bar length of saw	1
	N	Chainsaw carrying case, or Specialized chainsaw trail pack	Protect chainsaw during transport	1
Uline; H-1851R	N	Gas can, type 2	Safely dispense fuel and mitigate fuel vapor ignition hazards	1
Forestry Suppliers; 75093	N	Cant Hook, 48" handle, LogRite brand or equivalent	Grip and maneuver CDW particles into cutting position, to enable safe cutting of bulk density disks	1
Forestry Suppliers; 75077	N	Log Stand adapter for cant hook, LogRite brand or equivalent	Temporarily elevate CDW particle off ground to enable safe cutting of bulk density disks	1
	N	Uniquely marked, muslin drawstring bags OR heavy duty kraft paper bags, minimum 10" x 12" (size will vary depending on log size)	Carry cross-sectional disk samples or wedge subsamples	As needed
	N	Field guide, regional flora reference guide and/or key	Identify downed logs to functional group (hardwood vs. softwood)	1
Amazon; 0100078101	N	GPS receiver, recreational accuracy	Navigate to plots, or previously sampled CDW logs	1
Tiger Supplies; TS24700	N	Reflector pin-pole kit; inexpensive alternative item: 361941 Plastic Driveway Marker Red 48" at Amazon	Hold reflective target	1
Forestry Suppliers; 39945	N	Measuring tape, minimum 50 m	Map location of sampled logs	1
Forestry Suppliers; 37184, 37036	N	Compass with mirror and declination adjustment	Map location of sampled logs	1
	N	Crosscut saw	Collect log cross-section samples	1
	N	Crosscut saw leather scabbard	Protect crosscut saw during transport	1

Consumable Items				
	N	Bags, 25# kraft, 8# kraft, or plastic	Contain highly decayed cross-sectional "disks" with no internal structure	As needed
	N	Numbered, red aluminum tags	Tag downed logs ≥ 10 cm	As needed
	N	Aluminum nail	Affix tags to logs ≥ 10 cm	As needed
	N	Chainsaw bar and chain lubricant	Lubricate chainsaw during operation	2 qts
	N	Chainsaw fuel, 1 gallon container	Fuel chainsaw during operation	1
	N	Permanent marker	Label sample	2
RD[05]	N	Coarse Downed Wood field datasheet	Record sampling data and metadata	Varies
	N	Per plot LIDS angle list	Ensure bulk-density sampling does not occur on LIDS transects	Varies
	N	Waterproof paper, Rite-in-the-Rain or equivalent	Material for making labels to record bulk density disk metadata in the field	10+ sheets
	N	Adhesive barcode labels (Type I)	Label samples with barcode readable labels	1 sheet
	N	AA batteries	Spare battery for laser rangefinder	2

* Select a diameter tape size to bring to the field that will enable measuring all expected CDW sizes with one tape.

† Select the caliper size to bring to the field that will enable measuring all expected CDW sizes with one caliper

Table 25. Equipment list for processing CDW Bulk Density samples in the lab (SOP D).

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan-tity
		Durable Items		
	N	Mobile data collection device (tablet or equivalent)	Collect and record data in the field.	1 per team
	N	Drying oven	Dry samples	1-2
	N	Balance, 0.01 g accuracy	Weigh oven dried samples	1
		Consumable Items		
RD[05]	N	Drying Datasheet	Record data	As needed
RD[05]	N	Lab Drymass Datasheet	Record data	As needed
	N	Weigh boats, large	Contain dried sample while weighing; a metal bread pan will reduce static compared to plastic.	Varies

APPENDIX F QUARANTINE COMPLIANCE

F.1 Summary of Quarantines by Site Affecting CDW Sampling

A summary of quarantines that affect CDW sampling is provided on a per site basis in this subsection. Additional sub-sections below describe how each quarantine affects CDW sampling, and steps that must be taken to ensure that NEON complies with quarantine regulations. Quarantine status for a given site may change mid-season, and it is therefore imperative to monitor NEON's problem tracking system for mid-season updates.

Table 26. Summary of quarantines by site that affect Coarse Downed Wood sampling.

Domain	Site	Quarantine Target(s)	Requirements
D03	JERC	Dogwood Anthracnose (*Discula destructiva*)	• Movement of any *Cornus spp.* material from GA to FL is regulated by the state of Florida. • NEON/BMI holds a letter of authorization for the collection and movement of this material as part of the NEON collection activities. • Authorization letter should be in-hand when Field Science staff move woody materials from JERC to the D03 DSF.
D06	UKFS	Emerald Ash Borer (EAB) (*Agrilus planipennis*)	• Compliance Agreement from Kansas PPQ prior to sampling. Check with Domain Manager to ensure necessary paperwork is valid and complete for the current sampling year prior to scheduling sampling. • Schedule sampling during EAB non-flight period (1st Nov to 1st March). • Follow all guidance in Appendix 0
D07	MLBS	Spongy Moth (*Lymantria dispar*)	• APHIS Compliance Agreement needed to move coarse down wood material from D07 MLBS to D07 DSF. • Agreement in-place; check with Domain Manager to ensure necessary paperwork is valid and complete for the current sampling year prior to scheduling sampling.

F.2 Emerald Ash Borer Quarantine

The Emerald Ash Borer (EAB) quarantine applies to all NEON Coarse Downed Wood samples collected in a quarantined county that are then transported to a non-quarantined county, or that pass through non-quarantined counties, when samples are brought back to the Domain Lab.

Required Steps to Comply with EAB Quarantine:

1. Schedule sampling during the EAB non-flight season only (see **Table 26**).
2. Upon returning to the field vehicle after sampling, all bagged CDW bulk density samples must be double-bagged in large plastic trash bags.
   - Knot each trash bag independently.
3. Upon arriving at the Domain Lab, once the trash bags are opened, all bagged samples must be placed directly into a 105 ˚C drying oven.
   - Once trash bags are opened, no temporary storage of the bagged samples is allowed.
   - Unopened trash bags may be stored in the Domain Lab for up to 5 days.
4. Kill any beetles found inside the trash bags. Contact USDA if any dead specimens are thought to be EAB.

APPENDIX G BULK DENSITY SAMPLING TARGETS PER SITE

Bulk Density sampling is considered complete when the specified number of disks have been sampled from each of the 'decayClass x sizeCategory x taxonID' (DST) combinations that cumulatively comprise 80% of the total number of possible logs as informed by tally sampling. Per site rank abundance lists of DSTs are provided in the TOS Sampling Support Library on the Field Science Sharepoint site.