TOS PROTOCOL AND PROCEDURE: COARSE DOWNED WOOD

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A_DRAFT	01/28/2015	ECO-02135	Initial draft 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 7); updated codes for \`unknown hardwood\` and \`unknown softwood\` • Updated Branch Bark Cover percent categories and guidance for remarks(SOP B.1, Step 8) • Table 9 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 10 • 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 F - Table 20) • Expanded minimum round diameters table (Appendix F - Table 21) • Expanded Split CDW/Round Diameter Equivalents Table (Appendix F - Table 22)

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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 C and nutrients over decades, and can enhance seedling germination for trees and other plants (Harmon and Sexton 1996). Because coarse downed wood particles can persist in the environment from decades to centuries, these particles have “afterlife” effects on ecosystem function of similar magnitude to those of live trees. In addition, knowledge about the quantity and size distribution of CDW pieces 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).

There are two components to 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, 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 will employ, termed Line Intercept Distance Sampling (LIDS; Affleck 2008), tallies logs with probability proportional to volume and restricts the search for logs to a transect or 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. In order to capture variation in density throughout the course of log decay, NEON will categorize sampled CDW particles within five standard decay classes defined by the U.S. Forest Service (Valentine et al. 2008), and all CDW particles will be 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 throughout this document, but 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.001155	NEON Training Plan
AD[05]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[06]	NEON.DOC.000914	NEON Science Design for Plant Biomass and Productivity
AD[07]	NEON.DOC.014051	Field Audit Plan
AD[08]	NEON.DOC.000824	Data and Data Product Quality Assurance and Control Plan

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.005003	NEON Scientific Data Products Catalog
RD[04]	NEON.DOC.001271	NEON Protocol and Procedure: Manual Data Transcription
RD[05]	NEON.DOC.002121	Datasheets for TOS Protocol and Procedure: Coarse Downed Wood
RD[06]	NEON.DOC.001921	NEON Raw Data Ingest Workbook for TOS Coarse Downed Wood: Field Tally Data
RD[07]	NEON.DOC.001922	NEON Raw Data Ingest Workbook for TOS Coarse Downed Wood: Bulk Density Field and Lab Data
RD[08]	NEON.DOC.000987	TOS Protocol and Procedure: Measurement of Vegetation Structure
RD[09]	NEON.DOC.001710	TOS Protocol and Procedure: 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

2.3 Acronyms

Acronym	Definition
C	Carbon
CDW	Coarse Downed Wood
FWD	Fine Woody Debris
LIDS	Line Intercept Distance Sampling
LIS	Line Intercept Sampling
PPE	Personal Protective Equipment

2.4 Definitions

Common terms used throughout this document are defined here, in alphabetical order.

Term	Definition
Coarse downed wood (CDW)	Any fallen stem, and all of its connected branches, with diameter ≥ 2 cm at the point where the CDW particle intersects the LIDS transect. Qualifying 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).

3 METHOD

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

Sites lacking dead wood particles that fit the NEON definition of coarse downed wood stated above are not sampled according to this protocol.

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 B: Tallying and Measuring CDW in the Field.** 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: Bulk Density Sampling in the Field.** Includes field-sampling log cross-sectional disks used for bulk density estimation, and for larger logs, 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.

Overview of SOP B

To implement SOP B, sampling locations are established at the center of each Tower Plot, and also at the center of 20 randomly selected Distributed Plots that are used for co-located LAI, herbaceous biomass clip harvest, and vegetation structure measurements (RD[11]). At each sampling location, three LIDS transects are established that radiate outward, with 120˚ separating each transect (**Figure 1**). The azimuthal orientation of each group of transects is chosen randomly for each of the sampling locations, in order to minimize effects of topography, directional blowdown, logging management, etc., on selection of CDW particles across all sampling locations.

CHOOSING RANDOM AZIMUTHS

The per-plot random azimuths for LIDS transects are provided by Science Operations.

Technicians search each of the 3 transects for qualifying pieces of CDW that intersect the transect, with the total transect distance searched being positively related to the cross-sectional area of the log perpendicular to the point at which it intersects the transect. In other words, the LIDS technique dictates that technicians will search for larger logs over longer transect distances in order 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 Appendix E, and Appendix E should be used in the field as a reference to help determine whether specific logs should be included or not in a given plot's tally. 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 (i.e., species, genus, family or "unknown hardwood" or "unknown softwood"). The latter two designations are only to be used as a last resort.

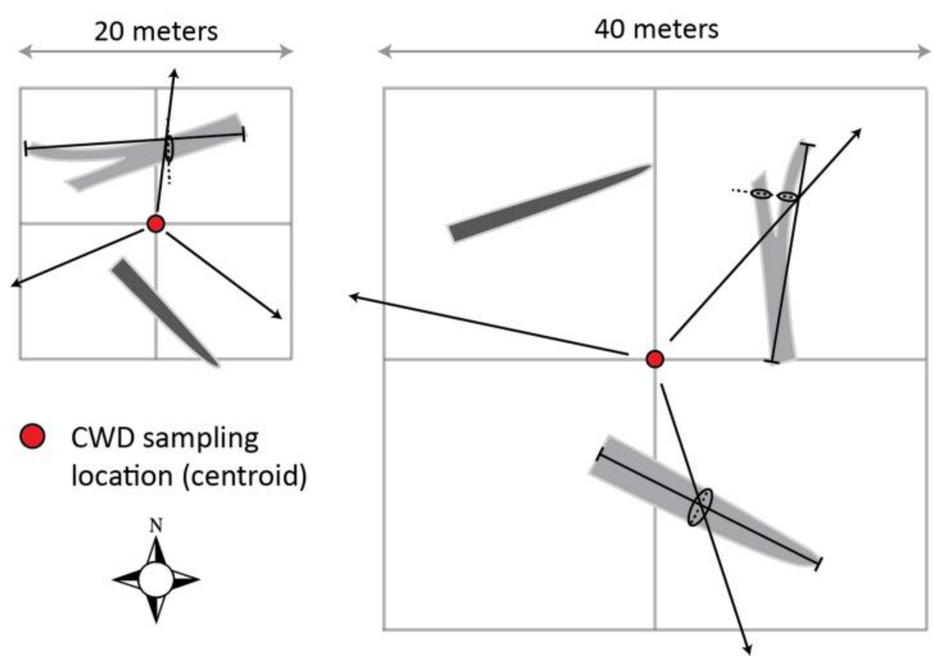

Figure 1. Illustration of three randomly oriented LIDS transects (arrow vectors) superimposed over a 20m x 20m plot (*left*), and a 40m x 40m plot (*right*). There is a 3m gap between the sampling location (i.e. the plot centroid), and the start of each transect

which minimizes the chance that CDW particles close to the plot centroid get double- or triple-counted. Gray shapes represent CDW particles, dashed lines show the location and orientation of cross-sectional area measurement(s) (ovals) for those particles that intersect a LIDS transect, and capped black lines imply the particles' central axes that should be measured for length. Darker gray CDW particles do not intersect LIDS transects and are suitable for bulk-density sampling. Note that selected CDW particles may lie outside of the plot boundary.

Overview of SOP C

SOP C details the field procedure for sampling of CDW for bulk density. This SOP is implemented once within the first 3 years of a site going into Operations, and once more 5 years after the first implementation. Bulk density is sampled from three different diameter size classes (≥ 10 cm, 5-10 cm, and 2-5 cm), from logs that do not intersect the LIDS transects, but that are adjacent to the transects (**Figure 1**). A chainsaw, or less ideally, a buck saw, is used to cut a 5-10 cm height cross-sectional disk from each sampled CDW particle. The diameter and height of the disk are measured to enable calculating the volume of the disk, and the disk fresh weight is recorded in the field. For the two largest size classes, wedge-shaped pieces are sub-sampled from the disk, and these sub-samples are also weighed for fresh weight in the field. Subsamples are then transported back to the laboratory to calculate the disk's fresh weight : dry weight ratio. Disks sampled from the smallest size class 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. Throughout the bulk density SOP, proper sample labeling and tracking of sample metadata is critical.

Overview of SOP D

SOP D describes the procedure for measuring, drying, and weighing cross-sectional disks in the laboratory (or wedge-shaped subsamples generated from these disks). Knowledge of the wood sample dry weight allows calculation of bulk density (°) as:

(1) $$\circ = \frac{d \quad d \quad w \quad ht\,(g)}{d \quad v(\quad (c \quad ^{3})}$$

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

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. In the event that 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.

The procedures described in this protocol will be audited according to the Field Audit Plan (AD[07]). Additional quality assurance will be performed on data collected via these procedures according to the NEON Data and Data Product Quality Assurance and Control Plan (AD[08]).

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

The frequency and timing of CDW sampling depends on the SOP being implemented, as SOP B, "Tallying and Measuring CDW in the Field", may be carried out independently from SOP C and SOP D. The bulk-density SOPs (SOP C and SOP D) must always be performed together, and may be carried out over more than one year in order to achieve the desired sample size (**Table 11**).

Sampling in Tower plots should be prioritized over sampling in Distributed plots if sufficient labor is not available to complete sampling in both Tower and Distributed/Gradient plots in a given sampling year.

Table 1. Sampling frequency, sampling effort, and timing guidelines for coarse downed wood sampling on a per-SOP basis.

SOP	Plot Type	Plot Number	Sampling Events	Yearly Interval	Remarks
SOP B: Tallying and Measuring CDW in the Field	Distributed	20 max*	1X per sampling year	Every 3 y (one site per domain per year	Distributed and Tower plots should be sampled in the same growing season; sampling should take no longer than 3 months. SOP B should be completed prior to SOP C in order to prepare a list of taxonIDs, size classes, and decay classes from SOP B data to prioritize collection in SOP C.
	Tower	20-30 †			
SOP C:Bulk Density Sampling in the Field	Distributed	20 max*	Once within first 3 y of Operations; second time 5 y later	5-6 y	Sampling occurs twice per site. A given sampling event may occur over multiple years if target sample size cannot be achieved in one year; however, completing sampling in one season is ideal.
	Tower	20-30 †			

SOP	Plot Type	Plot Number	Sampling Events	Yearly Interval	Remarks
SOP D: Processing Bulk Density Samples in the Laboratory	Distributed	20 max*	Once within first 3 y of Operations; second time 5 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 randomly selected Distributed plots that are used for other plant biomass protocols; not all Distributed Plots will be sampled if CDW particles are absent from selected plots.

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

4.2 Criteria for Determining Onset and Cessation of Sampling

Because CDW is often produced during periods of seasonal storm activity, CDW sampling should be timed to occur *after* the period of maximal expected storm activity for a given site. Refer to Appendix C **Table 14** for sampling onset guidelines; however, provided dates are guidelines only, and it is incumbent upon Field Operations to select sampling onset dates that are appropriate for each site and consistent with the periods of storm activity described above. For example, CDW sampling in D03 should not occur during the summer and autumn hurricane season, but may occur during winter and/or spring. However, at north-temperate sites in D16, CDW sampling should occur in summer and/or autumn, as maximum storm activity typically occurs during the winter in this domain. Regardless of sampling onset date, the temporal window in which CDW sampling in a given year must be completed is relatively long – it is only required that CDW field sampling be completed before the season of maximum storm activity resumes.

4.3 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, samples will be placed in the drying oven within 24 hours of collection in the field. However, if this is not logistically feasible, keep samples in muslin sample bags in a dry place, and place in the drying oven within 5 days of collection in the field. Keeping samples in a cloth bag is important (as opposed to plastic) because air-drying at room temperature can begin before the sample is placed in the drying oven.

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 weighing and processing.

4.4 Sampling Timing Contingencies

Table 2. Guidance indicating how to respond to unanticipated delays in field tally work (SOP B), and the consequences of potential delays

Delay/Situation	Action	Outcome for Data Products
Hours to days	If delay prevents completion of any of three LIDS transects originating within a given plotID, record in a field notebook: 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 notebook.	None anticipated
	If delay occurs between plots, resume CDW survey at next plotID ASAP.	None anticipated

Table 3. Guidance indicating how to respond to unanticipated delays in bulk density sample collection (SOP C), and the consequences of potential delays

Delay/Situation	Action	Outcome for Data Products
Hours to days	If delay prevents completion of bulk-density disk sampling: 4. Label cross-sectional disk, place any "wedges" into a labeled sample bag, and transport samples to an indoor work area. 5. Complete required disk measurements and record disk data on field datasheet. 6. 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

At least 10% of bulk density samples per sampling bout should be randomly selected for QA/QC for the measuring and weighing of bulk-density disks (and subsamples from disks; SOP D). Technicians re-measure, re-weigh, and record QA data in a new row on the datasheets, and mark the qaSample field appropriately. Normal data and QA data are then transcribed in the appropriate data ingest tables (RD[06], RD[07]).

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 Operations Field Safety and Security Plan (AD[02]) and EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

SOP C requires that technicians produce cross-sectional disks from coarse downed wood particles for generation of bulk density data. The most efficient way to generate cross-sectional disks 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 by OSHA (https://www.osha.gov/OshDoc/data_Hurricane_Facts/chainsaws.html), USFS S-212, and the MTDC Chain Saw and Crosscut documentation. NEON staff should adhere to these regulations at all times in order to ensure safe operation of the chain saw.

Personal Protective Equipment Requirements

- Personal Protective Equipment (PPE) for the head, ears, eyes, face, hands, and legs must be worn when operating the saw to prevent or lessen the severity of injuries to workers using chain saws.
- PPE must be inspected prior to use to ensure it is in serviceable condition.
- Do not wear loose-fitting clothing

Before Starting the Saw

- 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

- 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.
  - Safety is paramount with the saw, as is preserving chain sharpness.
  - Cut less decayed classes first, as more decayed pieces 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 piece to be cut so the chain avoids contact with soil or rocks.
- Look for nails, spikes, or other metal in the tree before cutting.
- Keep hands on the handles, and maintain secure footing while operating the chainsaw.
- Be careful that the trunk or tree limbs will not bind against the saw. Watch for branches under tension, they may move suddenly when cut.
- Do not cut directly overhead.
- Shut off or release throttle prior to retreating.
- Shut off or engage the chain brake whenever the saw is carried more than 50 ft, 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

- Fuel the saw at least 10 feet from sources of ignition.
- 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, Factory Mutual (FM), the Department of Transportation (DOT), or other Nationally Recognized Testing Laboratory
- Dispense fuel at least 10 feet from any source of ignition.
  - 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.
  - Refuel over a tarp, so small spills can evaporate before entering soil.
- Use a funnel or flexible hose when dispensing fuel into the saw.
- Never add fuel to a running or hot saw.

6 PERSONNEL AND EQUIPMENT

6.1 Equipment

The following equipment is needed to implement the procedures 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 4. Equipment list for SOP B. Item quantitites are sufficient for a team of two technicians to perform CDW tallying and mensuration.

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Durable items					
MX103218	R	Foliage filter	Allow laser rangefinder use in dense vegetation	2	N
	R	*Handheld caliper, 20 cm	Measure CDW pieces up to 20cm diameter	1	N
	R	*Handheld caliper, 50 cm	Measure CDW pieces up to 50cm diameter	1	N
	R	*Handheld caliper, 95 cm	Measure CDW pieces up to 95 cm diameter	1	N
	R	Hammer	Drive nails	1	N
MX104369	R	Measuring tape, minimum 50 m	Delineate transect; determine whether logs central axes intersect transects		N
MX100322	R	Laser Rangefinder, ½ foot accuracy	Delineate transect; measure log distance to transect origin	1	N
MX104359	R	White reflector or reflective tape	Reflective target for laser rangefinder; aids in measuring distance to target accurately	1	N

Item No.	R/S	Description	Purpose	Quantity	Special Handling
	R	Field guide, regional flora reference guide and/or key	Identify downed logs to functional group (hardwood vs. softwood)	1	N
MX100703	S	GPS receiver, recreational accuracy	Navigate to sampling location	1	N
MX104361	S	Chaining pins or other suitable anchor	Anchor measuring tapes	1 set	N
	S	Reflector pin-pole kit	Hold reflective target	1	N
MX100320	S	Compass with mirror and declination adjustment	Delineate transect	1	N
Consumable items					
	R	Per plot LIDS angle lists	Identify randomly assigned angles for LIDS transects in each plot	Varies	N
RD[05]	R	Coarse downed wood field datasheet	Record sampling data	Varies	N
	S	CR123A battery	Spare battery for laser rangefinder	2	N
	S	AA battery	Spare battery for GPS receiver		
	R	Numbered aluminum tag, red	Tag downed logs ≥ 10 cm	As needed	N
	R	Aluminum nail	Affix tags to logs ≥ 10 cm	As needed	N

R/S=Required/Suggested

* 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. Field offices may want to purchase more of the larger calipers depending on the average size of CDW at sites.

Table 5. Equipment list for SOP C. Quantities are sufficient for a team of two technicians to perform CDW bulk-density sampling.

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Durable items					
MX100322	R	Laser Rangefinder, ½ foot accuracy	Measure log distance to transect origin	1	N
MX103218	R	Foliage filter	Allow laser rangefinder use in dense vegetation	2	N
MX104359	R	White reflector or reflective tape	Reflective target for laser rangefinder; aids in measuring distance to target accurately	1	N
MX106348	R	DBH tape, 64 cm*	Measure cross-sectional disk diameter	1	N
MX106349	R	DBH tape, 200 cm*	Measure cross-sectional disk diameter	1	N
	R	Handheld caliper, 20 cm †	Measure cross-sectional disk height; measure log diameter for highly decayed CDW pieces	1	N
	R	Handheld caliper, 50 cm †	Measure cross-sectional disk height; measure log diameter for highly decayed CDW pieces	1	N
	R	Handheld caliper, 95 cm †	Measure cross-sectional disk height; measure log diameter for highly decayed CDW pieces	1	N
	R	Hatchet	Collect subsamples from cross-sectional disks	1	Y
	R	Scale, 5000 g capacity, 1g accuracy	Weigh cross-sectional disk samples for fresh weight	1	N
	R	Scale carrying case	Protect scale during transport	1	N

Item No.	R/S	Description	Purpose	Quantity	Special Handling
MX103931	R	Plastic tray	Contain cross-sectional disk for weighing	1	N
	R	Chainsaw, 18" bar, tool-less chain adjustment	Collect log cross-section samples	1	Y
	R	Chainsaw carrying case	Protect chainsaw during transport	1	N
	R	Cloth drawstring bag, minimum 10" x 12" (size will vary depending on log size)	Carry cross-sectional disk samples or wedge subsamples	As needed	N
	R	Field guide, regional flora reference guide and/or key	Identify downed logs to functional group (hardwood vs. softwood)	1	N
	S	Hammer	Drive nails		
MX100703	S	GPS receiver, recreational accuracy	Navigate to plots	1	N
	S	Reflector pin-pole kit	Hold reflective target	1	N
MX104369	S	Measuring tape, minimum 50 m	Map location of sampled logs	1	N
MX100320	S	Compass with mirror and declination adjustment	Map location of sampled logs	1	N
	S	Crosscut saw	Collect log cross-section samples	1	Y
	S	Crosscut saw leather scabbard	Protect crosscut saw during transport	1	N

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Consumable items					
	R	Trash bag	Contain highly decayed cross-sectional “disks” with no internal structure	5	N
	R	Numbered, red aluminum tags	Tag downed logs ≥ 10 cm	As needed	N
	R	Aluminum nail	Affix tags to logs ≥ 10 cm	As needed	N
	R	AA battery	Spare battery for scale	3	N
	R	Chainsaw bar and chain lubricant	Lubricate chainsaw during operation	2 qts	Y
	R	Chainsaw fuel, 1 gallon container	Fuel chainsaw during operation	1	Y
	R	Permanent marker	Label sample	2	N
RD[05]	R	Coarse Downed Wood field datasheet	Record sampling data and metadata	Varies	N
	R	Per plot LIDS angle list	Ensure bulk-density sampling does not occur on LIDS transects	Varies	N
	S	CR123A	Spare battery for laser rangefinder	2	N

R/S=Required/Suggested
* Select a DBH 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 6. Equipment list for processing wood bulk-density samples in the lab (SOP D).

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Durable items					
MX100230	R	Drying oven	Dry samples	1-2	N
MX100265	R	Balance, 0.01 g accuracy	Weigh oven dried samples	1	N
Consumable Items					
RD[05]	R	Drying QC Datasheet	Record data	As needed	N
RD[05]	R	Lab Drymass Datasheet	Record data	As needed	N
MX100689	S	Weigh boats, large	Contain dried sample while weighing	Varies	N

R/S=Required/Suggested

6.2 Training Requirements

All technicians must complete required safety training as defined in the NEON Training Plan (AD[04]). Additionally, technicians must complete protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD[05]).

As per OSHA recommendations, training requirements for chain saw use 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, 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!***

6.3 Specialized Skills

When performing field tallies and mensuration of CDW (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, and a subset of the relatively decayed logs to either genus or family.

6.4 Estimated Time

The time required to implement a protocol will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below 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.

- **SOP B**: Tallying and Measuring CDW in the Field. Trained two-person crews will require approximately 35 min per plot, on average, to complete LIDS tally sampling (range = 21-45 minutes/plot, depending on CDW particle abundance) (Affleck 2010).
    - Plots with dense vegetation may take much longer to complete, with reports from 1 – 8 hours (with a mean of 2 hours).
    - Dense vegetation primarily contributes to longer sampling times by impeding accurate placement of transect tapes and/or walking a transect.
- **SOP C**: Bulk Density Sampling in the Field. Trained two person crews will require 1-4+ hours per plot to complete bulk density sampling in the field, depending on CDW particle abundance. More accurate time ranges will be provided once NEON has implemented this protocol.
- **SOP D**: Processing Bulk Density Samples in the Laboratory. It should require no more than 1-3 minutes to handle, dry, weigh, and record data for a given wood sample.

7 STANDARD OPERATING PROCEDURES

SOP A Preparing for Sampling

A.1 Preparing for Tallying and Measuring CDW in the Field (SOP B)

1. Charge GPS and load target plot locations.
2. 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/
3. Prepare laser rangefinder according to guidelines in RD[10].
4. Print (on all-weather paper) CDW "Field Tally Datasheets" and site-specific LIDS angle list.
5. Determine the volume factor (*F*) for CDW sampling. 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. Site-specific volume factors (*F*) are provided in Appendix D. A single volume factor value should be used across a site, do not use multiple values. The per site determination of *F* is in accordance with these general guidelines:
   - Large *F* when CDW is plentiful and of relatively large diameter.
   - Small *F* when CDW is sparse and of relatively small diameter
6. Determine the appropriate LIDS transect length.
   a. Using your knowledge of the site, estimate the largest diameter CDW that will commonly be encountered across *ALL* of the plots intended for sampling. Vegetation Structure data previously collected from living trees are an excellent source of information.
   b. Given the estimated maximum CDW diameter and the provided volume factor, consult Appendix E to determine the length of the LIDS transect that should be used at the site.

Example: Looking up the Volume Factor and Determining the LIDS Transect Length at OSBS

- The volume factor F shown for OSBS in Appendix D is 10
- Previously collected vegetation structure data from OSBS indicate that maximum CDW particle diameter is approximately 55 cm (example diameter only, not based on real data).
- Looking at the left-most column of **Table 17** in Appendix E, the 55 cm maximum log diameter falls between values of 50 and 60 for RD_{min}. Round up and choose RD_{min} = 60.
- Looking at the column associated with F = 10 in the left half of **Table 17**, the LIDS transect length should be 150 meters (rounding up, not down, to the nearest 10 meters).

A.2 Preparing for Bulk-Density Sampling in the Field (SOP C)

1. Charge GPS and load target plot locations.
2. 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/
3. 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
4. Prepare battery-powered field scale
   a. Check batteries
   b. Check accuracy with 100 g standard weight
5. Cut waterproof "Rite-in-the-Rain" paper into 8 equally sized pieces for bulk density sample labels
6. Print CDW "Field Density Datasheets" and LIDS angle list
7. To guide selection of logs for CDW bulk density sampling, rank the most abundant taxonIDs (based on SOP B data). Make sure to adequately sample the most abundant taxonIDs.
8. Prepare drying oven
   a. Clear sufficient space for wood bulk-density samples
   b. Set temperature to 105°
9. Print drying QC datasheets

A.3 Preparing for Laboratory Processing of Bulk Density Samples (SOP D)

1. Print lab weighing datasheets
2. Check lab scale accuracy with 100 g standard weight.

SOP B Tallying and Measuring CDW in the Field

B.1 Procedure

At sites where CDW is present, it is tallied and measured in all Tower plots, a subset of Distributed plots (20 randomly selected plots), and Gradient plots (if this plot type exists at a given site).

1. Navigate to the plot to be sampled (using the GPS if necessary), and locate the point at the center of the plot (**Figure 1**). This center point is defined as the CDW sampling location, "*S*".
   - Qualifying CDW has the following characteristics:
     - Diameter ≥ 2 cm AND length ≥ 1 m, with central axis that intersects the transect (**Figure 1**). Woody particles < 2 cm diameter are ignored for this protocol.
     - Suspended logs should *not* be tallied if the angle from the ground exceeds 45˚ *or* the piece is ≥ 2 m above the ground.
     - Are *not* dead stems attached to a living plant and do *not* exhibit a decumbent, but living, growth form.
   - If there is no chance you will encounter qualifying CDW along any of the three transects (e.g. the plot is grassland vegetation), go on to the next plot and record in the "Field Tally Datasheet":
     - **plotID**
     - "**targetTaxaPresent = N**"; because there is no **remarks** field on the datasheet, write in the **taxonID** field.

       *** ***NOTE:*** Recording the absence of CDW is equally important to measuring how much CDW is present. Do NOT skip this step if CDW is absent from a plot.
   - If there is any chance you will encounter qualifying CDW along any of the three transects, continue to step (2).
2. While standing at *S*, use the "LIDS Angle List" to determine the azimuth relative to true north for the first LIDS transect. Azimuths for 3 LIDS transects per plot are provided by Science Operations in the site-specific LIDS Azimuth Lists.
3. Sight along the desired azimuth using a declination-corrected mirror-site compass or the TruPulse 360 rangefinder. Select an object in the middle distance (e.g. unique looking tree, rock, or other feature), and use this object as a "sight guide" for transect establishment along the desired azimuth.
4. Use the meter tape to measure exactly 3 meters from *S* toward the selected "sight guide," and anchor the end of the meter tape to the ground with a chaining pin.

   This step creates a 3 meter gap between *S* and the start of the individual transect (as in **Figure 1**), which:

- Minimizes trampling near the centroid where diversity measurements may also take place; and
- Reduces the chance that a piece of CDW close to *S* will be tallied on more than one transect.

5. Continue walking toward the "sight guide" and begin extending the meter tape to the maximum distance determined in SOP A.1. Place a chaining pin every 10 m to accurately mark the transect, and begin tallying and measuring qualifying CDW particles according to **step (6)** below.
   a. In extremely dense understory conditions, in which line of sight is obscured beyond more than several meters, it will be very difficult to keep the tape straight. Do your best in these conditions, but do not spend too much time if it appears that minor deviations from a relatively straight line cannot be removed.
   b. If understory vegetation severely limits accurately setting up the transect tape consider the following strategies:
      1. Mark start points of transect for future reference, if allowed by site host.
         a) Mark logs or branches that indicate the beginning of the transect with marking that cannot be mistaken for CDW tags.
         b) Establish a marker at the end of the transect.
      2. Work in shorter transect segments, rather than trying to establish the entire transect tape from beginning to end.
         a) Walk the transect tape out until you come across an obstruction.
         b) Use a highly visible marker to indicate the end of the transect segment. If allowed by the site host, these markers should be kept in place to indicate intermediate points along the transect.
      3. Pace a transect out using a calibrated compass and/or rangefinder depending on the line of sight situation. It is critical that logDistance and azimuth are carefully and accurately tracked if a transect is paced out without the aid of a transect tape.
         a) If line of sight *__can be maintained__* with the beginning of the transect:
            (1) Walk the transect while maintaining the correct azimuth towards the transect end. If a qualifying particle is encountered, use the TruPulse rangefinder to determine the logDistance from the beginning of the transect, or extend the transect tape to the qualifying particle to record logDistance.
         b) If line of sight *__cannot be maintained__* with the beginning of the transect:
            (1) Extend the transect tape as far as possible and survey the transect.
            (2) Upon encountering a dense, impenetrable vegetation obstacle, two technicians working together can "triangulate" around the obstacle by using the rangefinder and a compass to navigate around the obstacle and re-align with the correct

transect line and bearing. Take note of the distance at which this occurred and continue pacing the transect.

6. As the transect is extended outward from *S*, begin surveying the transect for qualifying pieces of CDW ≥ 2 cm diameter AND ≥ 1 m length with central axes that intersect the transect (see examples in **Figure 1**).
   a. Assess qualifying diameter and length with respect to the point at which the central axis of the piece of CDW intersects the transect (**Figure 2**).
      - In **Figure 2**, the length of the central axis is measured from diameter “breakpoints” because bulk density is calculated separately for 2-5 cm, 5-10 cm, and > 10 cm diameter pieces, and thus length measurements must be assignable to these same diameter categories.
      - Diameter is measured perpendicular to where the transect crosses the central axis of the particle; if the particle is bent, the measurement location will NOT be where the transect crosses the particle itself (**Figure 2**).

      *** **Note:** The above point is the trickiest conceptual part of successfully implementing CDW measurement. Check with someone experienced with this protocol if you are unsure how to proceed.

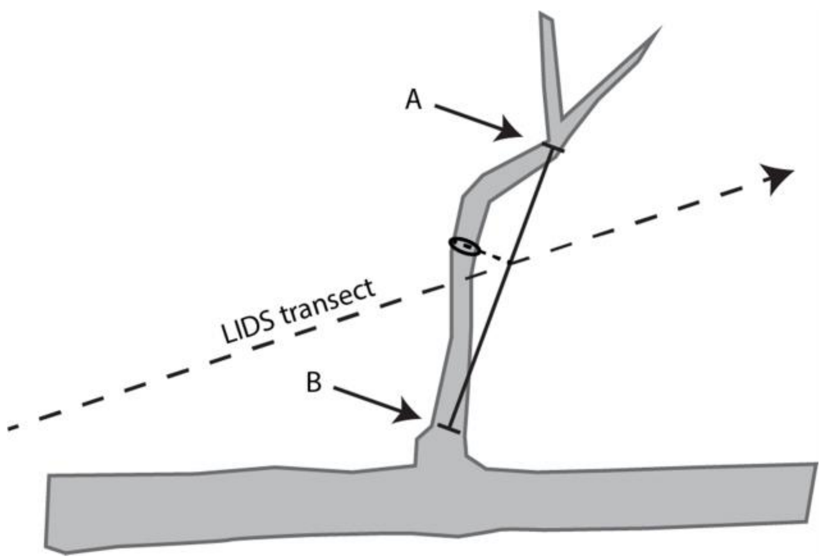

Figure 2. A LIDS transect (dashed line) intersecting a CDW particle that is tallied within the 5-10 cm diameter size class. The piece of CDW is attached to a larger piece of CDW ≥ 10 cm diameter, but is not tallied within the larger size class. Above arrow A the diameter is < 5 cm, and below arrow B the diameter is > 10 cm; the central axis (black line) is delineated along the portion of the CDW piece that is > 5 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.

7. When a potentially qualifying piece of CDW intersects the transcept:
   a. Use Appendix E to determine whether the piece of CDW should be tallied. Particles of CDW are tallied in proportion to their cross-sectional area, which is difficult to measure directly. Appendix E provides round diameter equivalents (RD_E).

      Example 1: Assuming a volume factor of F=8, pieces of CDW 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.

   b. If the log should be tallied, or it is unclear whether the log should be tallied (e.g. the diameter of a log falls between two rows of Appendix E), measure and record the required log attributes listed in **Table 7** below on the "Field Tally Datasheet".
      - Determining whether highly decomposed logs that have begun to collapse under their own weight qualify for measurement may be tricky. This is because one must determine the round diameter circular equivalent of an ellipse.
      - To be conservative, assess the widest diameter and use to determine qualification for the tally.

   c. Forked particles of CDW present more complex cases, and are tallied according to SOP B.2.

Table 7. Log attributes recorded during CDW LIDS tallies.

Datasheet 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
logDiameter	Diameter of the CDW piece perpendicular to the log central axis at the point where the transect intersects the central axis (**Figure 2**); nearest 0.5 cm	Calipers
minorLogDiameter	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 2**)	Length of the CDW piece central axis; nearest 0.1 m	Meter tape or TruPulse 360 (**SD** mode)
taxonID	Species, genus, family or 'unknown hardwood' (code: 'HARSPP')/'unknown softwood' (code: 'SOFSPP') – in that order of preference.	Visual inspection of remaining leaves, bark, and surrounding live species; use field guide when helpful
identification Qualifier (idQ)	See **Table 8** for idQ codes and descriptions.	Visual inspection

Datasheet Field	Recorded Data	Method
decayClass	Record for logs ≥ 10 cm diameter only. See **Table 9** for decayClass categories and descriptions.	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.

8. Record the **logID**:
   a. <u>For logs ≥ 10 cm diameter:</u>
      - Mark with a numbered, red aluminum tag, and record the tag number in the **logID** field.
      - It is helpful to 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, place the tag where it is likely to stay in the log.
      - For CDW particles with multiple qualifying branches, place the tag on the first branch that qualifies along the transect.

   b. For logs < 10 cm diameter:
      - **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.

9. Assess and record the following **decayClass** characteristics:
   - **presenceLeaves** (or needles): 'Y' or 'N'
   - **presenceTwigs**: 'Y' or 'N'. Twigs are < 2 cm diameter woody structures attached to the main log to be tallied.
   - **presenceBranches**: 'Y' or 'N'. Branches are ≥ 2 cm diameter woody structures attached to the main log to be tallied.
   - **coverBarkBranches**: The % cover of bark on any branches; assign from the following categories: <5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, >95%.
   - **coverBarkLog**: The % cover of bark on the main log to be tallied. Use the same % cover categories as above.
   - **handBreakableLog**: 'Y' or 'N'. Pieces of the log (not bark) can be broken apart by hand.
   - **holdsShapeLog**: '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**: Since there is no remarks column, use the next available row of the datasheet.

10. Continue tallying logs that intersect the transect until the limiting distance associated with the largest diameter logs present at the site is reached (Appendix E).
    - If no qualifying CDW particles are encountered on a given LIDS transect:

- o Record the **plotID** and **lidsAzimuth**
- o Record `targetTaxaPresent = N` in the **taxonID** field.

11. Repeat Steps 2-9 for the second and third LIDS transects.

12. Continue sampling at the next plotID on the LIDS Angle List.

Table 8. Identification qualifer 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 9. Decay classes for CDW pieces (modified from classes defined by the U.S. Forest Service).

decay Class	Shape	Bark	Wood Texture	Twigs	Branches
1	Sound, freshly fallen, round.	Intact, fresh.	Intact, no rot	Present. 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	Present. Larger diameter twigs may be present.	Present. Branches are present but have begun to lose 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, those remaining are stubs with little to no 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 apart with hands is difficult	Absent. ,	Heartwood rotten; 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 remains; log does not retain shape and can be broken apart with hands; majority of log not incorporated into litter layer of soil	Absent.	Soft, powdery when dry	Absent.	Absent.

B.2 Tallying and Measuring Forked CDW Particles

When a transect intersects a particle of CDW that is forked, there are multiple scenarious that are possible, and each requires a unique strategy to ensure that logs are tallied consistently.

SOP B.2.1 Transect intersects particle below fork, or on one fork only

1. Similar to a single bole CDW particle, the decision to tally (or not) is based on the round diameter equivalent (RD_E) at the single point at which the particle intersects the transect.
    - The RD_E is measured perpendicular to the particle's central axis at the point where the the transect intersects the particle's central axis.
    - The length of the central axis is measured for the longest fork, regardless of whether the transect intersects that fork or not. That is, consider the entire particle – ***while paying attention to any diameter class breakpoints*** – when measuring log-level attributes.

2. Consult Appendix E.1 to determine whether the log should be tallied (**Table 17** or **Table 18**).

3. Record required diameter(s) and log-level attributes on one row of the datasheet, as specified in **Table 7**.

SOP B.2.2 Transect intersects 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. Measure the RD_E for each fork to determine whether the fork should be tallied.

3. Record required diameter(s) and log-level attributes on multiple rows of the data sheet as specified in **Table 7** (one row per fork).
    - Pay attention to diameter class breakpoints when determining **logLength** and the shape of the particle's central axis.

For compound splits with > 2 forks:

1. Consider connected forks originating from a common central axis AND that are in the same diameter class together as one CDW particle. Subsequent steps assume a CDW particle of this nature.

2. Determine whether to tally forked CDW particles based on a single round diameter equivalent (RD_E).
    - The diameter of each fork that intersects the transect can be combined into a single RD_E using Appendix E.2 (**Table 19**).

3. For the largest fork, record required diameter(s) as well as log-level attributes as specified in **Table 7** in one row of the datasheet.
    - Record diameter data for additional forks on subsequent rows of the datasheet using the same **logID;** there is no need to repeat log-level data on these rows.
    - Pay attention to diameter class breakpoints when determining **logLength** and the shape of the particle's central axis.

Example:
The transect crosses the main bole of a downed tree (main bole diameter = 25 cm @ intersect point), then crosses two forks of a connected branch (8 cm diameter and 5.5 cm diameter @ intersect points). The connected branch is 9.5 cm diameter where it emerges from the main bole.

Here, the main bole that is intersected is considered independently from the forked branch because it is in a different diameter class; the RD_E = 25 is used with **Table 17** *or* **Table 18** *to determine whether to tally and further measure the main bole.*

For the two forks of the connected branch that also intersect the transect, given the input intersect diameters above, the RD_E = 10 cm (from **Table 19***). The RD_E = 10 value is used with* **Table 17** *or* **Table 18** *to determine whether to tally and further measure the forked branch. 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.*

SOP B.2.3 Transect intersects 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 particle.
2. Determine whether to tally forked CDW particles based on a single round diameter equivalent (RD_E).
    - The diameter of each fork that intersects the transect can be combined into a single RD_E using Appendix E.2 (**Table 19**).
3. If the CDW particle qualifies based on the RD_E, record required diameter(s) for the largest fork, as well as log-level attributes as specified in **Table 7**, in one row of the datasheet.
    - Record diameter data for additional forks on subsequent rows of the datasheet using the same **logID**.
    - Pay attention to diameter class breakpoints when determining **logLength** and the shape of the particle's central axis.

B.3 Troubleshooting

Table 10. Troubleshooting common issues encountered when tallying and measuring CDW in the field.

<table>
<tr><th>Issue description</th><th>Action</th></tr>
<tr><td>< 5 pieces of CDW were tallied at > 20% of the sampled plotIDs</td><td rowspan="3">• Issue a problem ticket to procure a different volume factor (F) for sampling CDW at the site.
• Record the new F value at the top of each new datasheet.</td></tr>
<tr><td>Zero pieces of CDW were tallied at > 1 of the sampled plotIDs</td></tr>
<tr><td>> 20 pieces of CDW were tallied at > 20% of the sampled plotIDs</td></tr>
<tr><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, etc.).
Note: transitions between habitat/land cover (e.g. from forest to agricultural field) along a transect do not meet the definition of a physical barrier.</td><td>• At the boundary, turn 180˚, reflect the transect back onto itself, and continue walking back toward the transect origin, tallying until the total distance traveled equals the distance originally desired for the transect (Gregoire and Monkevich 1994).
• Record “reflection at X meters” in your field notebook.</td></tr>
<tr><td>Cannot identify log to species, genus, or family rank.</td><td>• Determine whether log is “softwood spp.” Or “hardwood spp.” on field data sheet.
• In the taxonID field on the datasheet, record either ‘2plant-S’ (unknown softwood) or ‘2plant-H’ (unknown hardwood).</td></tr>
<tr><td>Particle has an irregular base e.g. a stem base that is wider than the rest of the trunk</td><td>• Move diameter measurement point to the nearest “regular” point on the log i.e. the first point at which the diameter stops changing</td></tr>
<tr><td>Particle is tallied on more than one transect; that is, when plots are relatively dense, a particle intersects two transects that originate from different plots.</td><td>• 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]’</td></tr>
</table>

SOP C Bulk Density Sampling in the Field

C.1 General sampling strategy

Bulk density will be sampled twice at each site, and the second sampling will be 5 y after the first sampling event. 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 saws are alternatives.
- Cut cross-sectional disk samples at least 1 m in from the end of the log; and
- To repeat sample the same logs across both sampling bouts.
- Preferentially sample logs > 3 m length, due to the fact that two disks can be cut from the same log at a 5 y interval while still cutting each disk 1 m in from the end of the log at each sampling event.
- 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 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 particle.
- The most common CDW taxa for a site should be targeted first. Note that ideal sample sizes may not be achievable for relatively rare taxa. The amount of time spent searching for rare CDW taxa will vary by domain; additional guidance should be sought from staff scientists regarding rare CDW taxa bulk density sampling.

Cutting cross-sectional disk samples from CDW pieces for bulk-density estimation is carried out in and around Tower plots and Distributed plots, although logs that intersect LIDS transects within a given plot should not be sampled (**Figure 1**). Because sampling involves cutting and removing a small section of downed log, individual site hosts may impose additional restrictions on where within a site it is allowed to perform the sampling. Be sure to check with the Field Operations Manager regarding potential sampling restrictions.

Additional restrictions for bulk-density sampling include:

- 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 particles 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.***

For estimation of bulk-density, the goal is to sample logs for each unique combination of diameter class (2-5 cm, 5-10 cm, and ≥ 10 cm), decay class, and taxonID (target sample sizes are listed in **Table 11**). For highly decayed logs, the taxonID resolution may be at the family level or “unknown hardwood” / “unknown softwood” for some sites. Because larger diameter logs are typically more rare, and also contribute the majority of the CDW biomass, the largest diameter logs are preferentially selected for bulk-density sampling (Keller et al. 2004) (**Table 11**). Sample sizes listed in **Table 11** may be achieved over <u>up to two field seasons</u>; however, completing sampling in one field season is ideal.

Table 11. Example of desired 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, but all taxon by decayClass combinations present should be sampled.

taxonID	decayClass	diameterClass	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:

- 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 criteria before sampling smaller length logs in any given plot.
- Once the desired sample size is achieved for a given taxonID by decayClass by diameterClass combination, stop searching for that combination in other plots.
- It is acceptable to meet the desired sample size for a given combination in only one plot.
- It may not be possible to achieve the desired sample size for rare taxa; moreover, it may be difficult to achieve the desired sample size for the “unknown hardwood” and “unknown softwood” taxonIDs if most logs are identifiable to higher taxonomic resolution.
- Achieving the desired sample size for all decayClasses may not be possible if particles in some decayClasses are rare – i.e., the distribution of CDW particles is not uniform across decayClasses. For example, a recently logged site will not have highly decayed CDW. Do your best given site conditions and the prescribed search area around the plot centroids.
- Within the ≥ 10 cm diameterClass, seek out and sample the largest diameter CDW pieces (e.g. diameter ≥ 30 cm), and then populate the rest of the desired sample with randomly selected CDW pieces.

C.2 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 critical components to determining CDW bulk density. To quantify uncertainty in bulk density measurements, QA must also be performed on these field measurements. Field QA consists of selecting 10% of sampled disks for re-measurement by the technician who did not perform the original measurements. To record QA data:

- Record **qaSample** = 'Y' on the Field Bulk Density Disk and Disk Subsample Datasheet (RD[05])
- When not recording QA data, record **qaSample** = 'N'.

Before performing any of the steps below, be sure you are permitted to obtain CDW bulk-density samples from the intended sampling area, and determine whether chainsaw sampling is a permitted activity.

1. Make a table in your field notebook similar to **Table 11** to help target the sampling effort for CDW bulk density sampling. Tally each sampled log in the table to track sampling progress across taxa and decayClasses.
2. The most common CDW taxa for a site should be targeted first. 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 pieces of CDW that qualify for bulk density sampling:
   - For CDW < 10 cm diameter: Pieces must be ≥ 1 m length
   - For CDW ≥ 10 cm diameter:
     - Pieces 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 will be a major contribution to this field of ecology.
   - If you are sampling within an established NEON plot, use the LIDS Angle List to ensure that you do NOT select CDW pieces for bulk-density sampling that intersect the LIDS transects. If you are unsure, be conservative and do NOT sample the piece in question.

4. Record required log-level data in the Field Bulk Density Log Datasheet (RD[05]):
   a. Record 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.
      - *For logs ≥ 10 cm diameter AND ≥ 3 m length that will be repeat sampled:*
        - Affix a red, numbered tag to the middle of the log, and record the number in the **logID** field.
      - *For logs not meeting these criteria:*
        - **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.

   b. Record the following for all logs:
      - **plotID**: The plotID in which the cross-sectional disk is sampled. If the log does not lie within a plot, record the nearest plotID.
      - **taxonID**: The finest resolution taxonID to which the log can be assigned (*Genus species → Genus → Family → "unknown hardwood"/ "unknown softwood")*. *Genus-species* or *Genus rank identifications* should be possible for logs in decayClass 1-3, higher levels for decayClasses 4 and 5.
      - **idQ**: Any relevant identificationQualifiers (see **Table 8** in SOP B)
      - **decayClass**: Categories 1-5 (see **Table 9** in SOP B)

   c. **For logs ≥ 10 cm diameter:**
      - **presenceLeaves** (or needles): 'Y' or 'N'
      - **presenceTwigs**: '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.
      - **presenceBranches**: '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.
      - **coverBarkBranches**: The % cover of bark on any branches; assign from the following categories: <5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, >95%.
      - **coverBarkLog**: 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.
      - **handBreakableLog**: 'Y' or 'N'. Pieces of the log can be broken apart by hand (bark does not count).
      - **holdsShapeLog**: '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.
   d. **For logs ≥ 10 cm diameter AND ≥ 3 m length** that will be re-located for repeat sampling:
      - **logDistance**: The distance to the nearest plot centroid, nearest 0.1 m

- **logAzimuth**: The azimuth relative to True North, measured from the log facing toward the nearest plot centroid.
  Note:
  - If the nearest plot centroid is not visible from the log, GPS coordinates may be recorded to enable re-finding the log (UTM format with easting / northing is easiest to use in the field).
  - Record coordinates on the next blank row of the datasheet, and then enter into the **remarks** field during data entry.

5. Prepare a label for the disk (or disks) that will be cut from the selected log. Use a pre-cut piece of 'Rite-in-the-Rain' type paper, and write with a sharpie.
   - **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 4.a above
     - **diskID**: A technician assigned numeric identifier for the disk – either '1' or '2'; diskID = 2 is only used for logs ≥ 5 m length.

6. 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 12** below, and see **Figure 3** below for example information.
   - **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 approx. 10 cm apart in the rotten log.
     - Keep the chain at the highest speed when cutting to make a clean cut and prevent rotten material from being thrown by the saw.
     - When both cuts are complete, simply scoop out the "disk" between the cuts by hand into a plastic garbage bag.
     - Thoroughly mix the sample by hand.
   - Record on the Field Bulk Density Disk and Disk Subsample Datasheet the same data recorded on the label in step (5):
     - **plotID**
     - **logID**
     - **diskID**

Table 12. Guidelines for cutting cross-sectional disks from CDW with different diameter and decayClass combinations

	≥ 10 cm diameter log	< 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 4-5	• 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

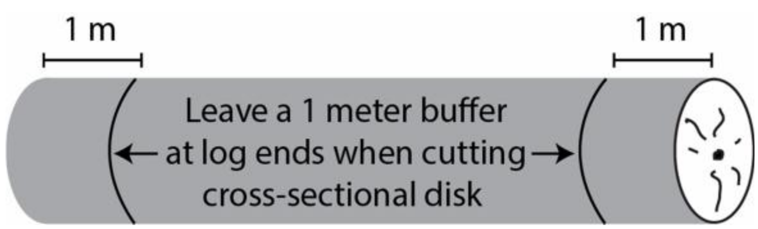

Figure 3. A 1 m buffer should be left on either end of a ≥ 10 cm diameter CDW piece when cutting a cross-sectional disk for bulk-density sampling. The log depicted is > 5m length and is sampled from both ends at each of the two sampling timepoints. Qualifying logs < 5m length are only sampled at one end.

7. Measure the required dimensions of the cross-sectional disk, and record on the Field Bulk Density Disk and Disk Subsample Datasheet (RD[05]).
   a. **For disks with structural integrity that hold their shape:**
      1. *For disks ≥ 10 cm diameter:*
         - Measure diameter with a Lufkin DBH tape. Record to the nearest 0.5 cm:
           - **diameter**: The diameter of the cross-sectional disk
           - **90diameter**: 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**: Technician selected representative intermediate disk height
           - **bDiskHeight**: Technician selected representative intermediate disk height
      2. *For disks < 10 cm diameter:*
         - Measure diameter with calipers. Record to the nearest 0.1 cm:
           - **diameter**: The maximum disk diameter; i.e., the major ellipse axis
           - **90diameter**: 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
           - **minDiskHeight**: The minimum disk height
           - **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:

1. *For "disks" ≥ 10 cm diameter:*
    - Measure diameters on both faces of the remaining cut log using calipers (**Figure 4**). 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
        - **90diameter**: 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 4**). 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
        - **minDiskHeight**: The minimum disk height
        - **aDiskHeight**: Technician selected representative intermediate disk height
        - **bDiskHeight**: Technician selected representative intermediate disk height

2. *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.
    - 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

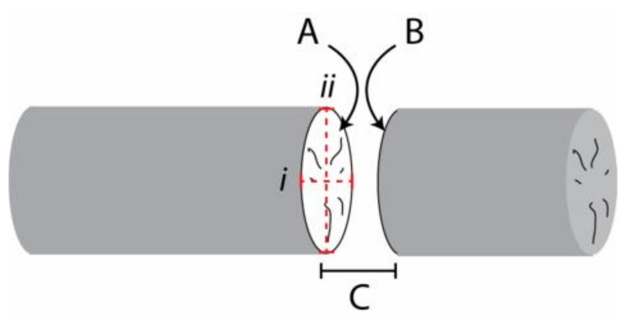

Figure 4. Measurements required for the space from which a crumbly "disk" was extracted by hand from a highly decayed log. Freshly cut surfaces are indicated by A and B, and C shows the height of the "disk." Highly decayed logs are often collapsed under their own weight, and show elliptical cross-sections (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* ; **90dameter** is typically the average of A.*ii* and B.*ii*

8. Measure the fresh mass of the entire cross-sectional disk sample using a portable electronic scale.
   - Break up large pieces that exceed the scale limits, or that are unwieldy, with a hatchet and weigh one at a time.
   - Use an upside-down plastic frisbee (or other plastic container equivalent) as a weigh boat, and tare before each weighing.
   - Record on the Field Bulk Density Disk and Disk Subsample Datasheet (RD[05]):
     - **diskFreshMass**; nearest 1 g

9. Cut an approx. 100 g subsample from the disk to take back to the laboratory and determine the fresh:dry mass ratio (see **Figure 5** below for subsampling guidelines). Use either the hatchet or the chainsaw. Skip this step if the entire disk has a fresh mass < 100 grams.
   - If decay throughout the disk appears non-uniform, i.e. a portion of the disk is more decayed than the rest, generate up to two subsamples that weigh approx. 100 g total, with volume of the two subsamples roughly proportional to the affected areas of the disk.
     - Create a second label for the second subsample, with sample information as in step 5.
     - Add **numericID** to each label. This is either '1' or '2'.
   - **For "disks" lacking structural integrity that do NOT hold their shape**:
     - Subsample approx. 100 g of well mixed sample by hand from the plastic bag into the frisbee (which should be tared and sitting on the scale).

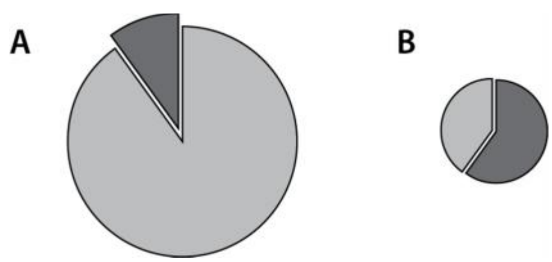

Figure 5. Creating wedge-shaped subsamples from cross-sectional disks from relatively large disks (A), and relatively small disks (B). In both A and B, the dark grey area is approx. 100 g, and the light grey is discarded.

10. Weigh the subsample created in step 9, and determine the fresh mass. Always tare the scale first if using the frisbee as a weigh boat. Record on the Field Bulk Density Disk and Disk Subsample Datasheet (RD[05]):
    - **numericID**: A numeric identifier for the wedge-shaped subsample; either '1' or '2'.
    - **sampleFreshMass**: Fresh mass of the disk subsample; nearest 1 g

11. Place the subsample into a muslin bag with its associated label, and tie the bag.

12. Return to step 3.

C.3 Post-field sampling tasks

1. Place cross-sectional disks, or subsamples of disks, into the 105 ˚C drying oven(s).
   - Track drying progress with the Lab Bulk Density Drying QC Datasheet (see SOP D.1 for details).
2. Perform chainsaw maintenance:
   - Sharpen chain if necessary. Keep in mind that during sampling of downed logs, the chain makes frequent contact with the ground and dulls quickly. That said, 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.
   - 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.

C.4 Repeat bulk-density sampling in the field (Bout 2)

The process of cutting, measuring, weighing, and subsampling cross-sectional disks from selected logs is identical to that described in SOP C.1 for Bout 1 sampling. However, the process of selecting logs for sampling is different: Only those logs ≥ 10 cm that were tagged with a red, aluminum tag in Bout 1 are re-sampled in Bout 2. For these logs that are re-sampled, cut cross-sectional disks per log according to the following strategy (see **Figure 6**):

- **For all logs:**
  - Use the disk sampling guidelines in **Table 12**.
- **For logs ≥ 3 m length** (that were ≥ 5 m length in Bout 1)(**Figure 6**A):
  - Cut two cross-sectional disk samples, 1 meter in from each end of the log.
- **For < 3 m length** (that were < 5 m length in Bout 1)(**Figure 6**B):
  - Cut one cross-sectional disk sample, 1 meter in from either end of the log.
  - For logs exactly 2 m long, cut the disk from the center of the log.

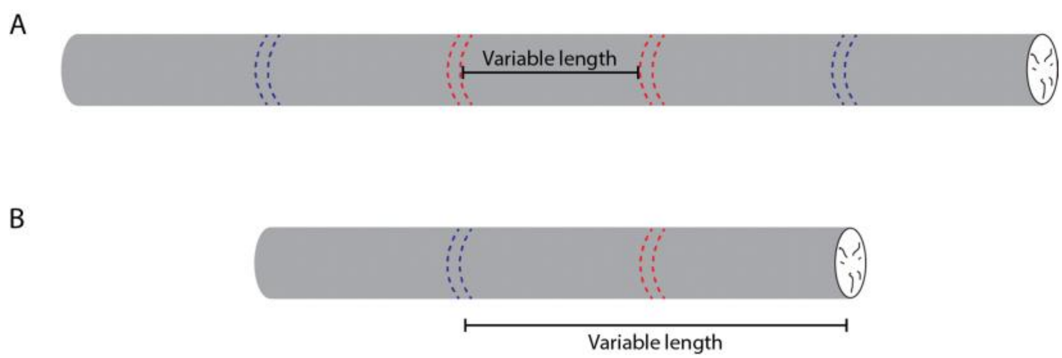

Figure 6. Strategy for generating cross-sectional disks from logs re-sampled for bulk density in Bout 2. (A) Logs ≥ 5 m length in Bout 1 and ≥ 3 m length in Bout 2; (B) Logs < 5 m length in Bout 1 and < 3 m length in Bout 2. Pairs of blue dashed lines represent Bout 1 disks, and pairs of red dashed lines indicate Bout 2 disks.

SOP D Processing Bulk Density Samples in the Laboratory

Bulk-density samples from SOP C are dried to constant weight in the laboratory, and the weight of the dried wood samples is recorded so that bulk-density can be calculated for each diameter class (2-5 cm, 5-10 cm, ≥ 10 cm) by decay class by taxon combination within each site.

D.1 Weighing and recording sample dry mass

1. Label muslin bags containing bulk density samples with the **ovenInDate** and time the samples are placed in the drying oven.

   Critical step: Labeling envelopes allows assessment of how long different batches of wood samples have been in the oven, especially when samples generated from multiple days occupy the same oven. To create a label, wrap a piece of lab tape around the drawstrings, and write with a sharpie.

2. Place labeled muslin bags into a 105 ˚C drying oven until samples are dried to a constant weight. Drying may take up to 5 days (120 h) or longer.
3. Check the drying progress using the “Drying QC” datasheet.
   a. Choose 5 muslin bags per sampling date to monitor for drying time. If there are different size classes of sample (e.g. wedges from larger logs vs. cylinders of various sizes from smaller logs), choose 5 samples per size class and perform the steps below separately for each size class.
   b. Record the weight 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 weight of the bag + the sample inside.
   c. At each timepoint that drying is checked, calculate the difference in weight between the last two timepoints for each envelope + sample(s).
   d. Samples are dry when the average weight difference between the last two timepoints equals zero (averaged across all 5 bags, to within ± 0.5 g).
4. Remove dried bulk-density samples from the drying ovens, let cool, and weigh as soon as possible.
   - Oven-dried wood will readily absorb water from the air, particularly in humid environments. Weigh samples in small batches soon after removal from the oven to prevent this problem.
   - ***If not weighing samples the same day they are removed from the oven***, record **ovenOutDate** and time on the tape label, and place in temporary storage. Samples not weighed on the same day they are removed from the oven must be returned to a 105 ˚C drying-oven for 24 h prior to weighing.

5. Weigh biomass from each individual disk sample or wedge-shaped subsample using a mass balance (0.01 g accuracy) and a large weigh boat if necessary.
   a. Tare the balance + weigh boat prior to weighing each sample.
   b. Record mass data, metadata written on the 'Rite-in-the-Rain' sample label, and drying metadata on the Lab Bulk Density Drymass Datasheet (RD[05]):
      - **plotID**: The unique identifier for the plot (or closest plot)
      - **collectDate**: The date the wood was sampled in the field; *YYYY-MM-DD* format
      - **logID**: Either the number from the red, aluminum tag, or 'LXX' format, where 'XX' are sequential numbers assigned in the field that start over at '01' at each new plot.
      - **diskID**: A technician assigned numeric identifier for the disk – either '1' or '2'
      - **numericID**: A numeric identifier for the wedge-shaped subsample; either '1' or '2'
      - **ovenInDate / Time**: The date and time the sample was placed in the oven; *YYYY-MM-DD* and *HH:mm* 24-h format
      - **ovenOutDate / Time**: The date and time the sample was removed from the oven
      - **dryMass**: The oven dry mass, without the bag, of the sample; nearest 0.01 g

6. Return dried wood samples to temporary storage once all data have been recorded.
   - Samples may be discarded after all data and QA data (see section below) have been recorded and transcribed, successfully ingested into the NEON Cyberinfrastructure, and the data have passed through initial QA/QC algorithms.

D.2 Data Verification and QA

To quantify uncertainty associated with weighing dried wood samples, a portion of dried samples are re-weighed by a different technician than the person who originally weighed the biomass.

1. Select 10% of dried, previously weighed samples for re-weighing by a different technician than he/she who performed the initial weighing.
   - If QA weighing does not take place on the same day as the initial weighing, return samples targeted for QA to a 105 ˚C drying oven for 24 h prior to re-weighing.
2. For all QA records, find the existing sample record on the Lab Drymass Datasheet and record:
   - **qaDryMass**, nearest 0.01 g
3. Return wood samples to temporary storage until all data have been successfully entered to the NEON database. Once data have been successfully entered and QC checked at NEON headquarters, samples may be discarded.

D.3 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

The importance of thorough, accurate data transcription cannot be overstated; the value of the efforts in the field is only manifested once the data are properly entered for delivery to NEON's end user community.

As a best practice, field data collected on paper datasheets should be digitally transcribed within 7 days of collection or the end of a sampling bout (where applicable). However, given logistical constraints, the maximum timeline for entering data is within 14 days of collection or the end of a sampling bout (where applicable).

Before entering data, all personnel ***MUST*** read RD[04] for complete instructions regarding manual data transcription. Prior to entering data via a web user interface (webUI), each technician shall enter a plot (or subplot) of data from one bout into the protocol-specific webUI housed on the Training portal, as described in RD[04].

Protocol-specific instructions and the associated data ingest workbook for entering Coarse Downed Wood data can be found on the NEON intranet.

SOP F Sample Shipment

This protocol does not generate any samples that require shipment to external facilities for analysis or archive.

8 REFERENCES

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Valentine, H. T., J. H. Gove, M. J. Ducey, T. G. Gregoire, and M. S. Williams. 2008. Estimating the carbon in coarse woody debris with perpendicular distance sampling. Pages 73-87 *in* C. M. Hoover, editor. Field Measurements for Forest Carbon Monitoring. Springer Science, New York.

Warren, W. G., and P. F. Olsen. 1964. A line intersect technique for assessing logging waste. Forest Science **10**:267-276.

APPENDIX A DATASHEETS

The following datasheets and ingest documents are associated with this protocol:

Table 13. Datasheets associated with this protocol

NEON Doc. #	Title
NEON.DOC.002121	Datasheets for TOS Protocol and Procedure: Coarse Downed Wood
NEON.DOC.001921	NEON Raw Data Ingest Workbook for TOS Coarse Downed Wood: Field Tally Data
NEON.DOC.001922	NEON Raw Data Ingest Workbook for TOS Coarse Downed Wood: Bulk Density Field and Lab Data

These datasheets can be found in Agile or the NEON Document Warehouse.

APPENDIX B QUICK REFERENCES

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

Table 14. Limiting distances (D_{lim}) for fixed round diameters (RD) across various LIDS volume factors (F, m^3 ha^{-1}) for a three-segment transect. Double-lines indicate boundaries between diameter size classes.

	D_{lim} (m)				
RD (cm)	**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		185	148	99	74
70			202	134	101
80				175	132
90				222	167
100					206

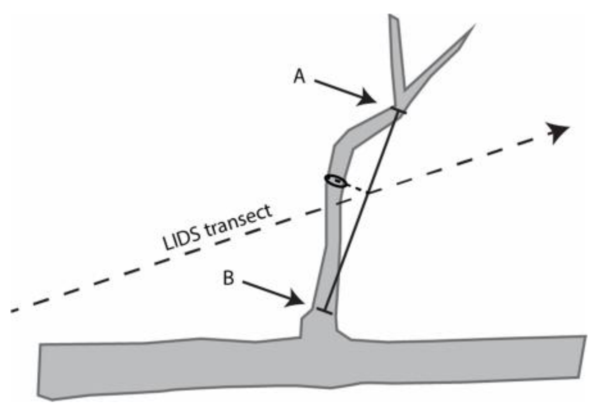
Table 15. Minimum round diameters (RD_{min}) for fixed distances (D) for various LIDS volume factors (F, m^3 ha^{-1}) for a three-segment transect. Diameters of logs larger than those listed in the table are tallied at any distance.

	RD_{min} (cm)				
D (m)	**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

Table 16. The round diameters of split CDW pieces (RD_{INPUTS}), and corresponding calculated equivalent round diameters (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
1, 3	3.2	3, 16	16.3	7, 10	12.2
1, 4	4.1	3, 18	18.2	7, 12	13.9
1, 5	5.1	3, 20	20.2	7, 14	15.7
1, 6	6.1	4, 5	6.4	7, 16	17.5
1, 7	7.1	4, 6	7.2	7, 18	19.3
1, 8	8.1	4, 7	8.1	7, 20	21.2
1, 9	9.1	4, 8	8.9	8, 9	12.0
1, 10	10.0	4, 9	9.8	8, 10	12.8
1, 12	12.0	4, 10	10.8	8, 12	14.4
1, 14	14.0	4, 12	12.6	8, 14	16.1
1, 16	16.0	4, 14	14.6	8, 16	17.9
1, 18	18.0	4, 16	16.5	8, 18	19.7
1, 20	20.0	4, 18	18.4	8, 20	21.5
2, 3	3.6	4, 20	20.4	9, 10	13.5
2, 4	4.5	5, 6	7.8	9, 12	15.0
2, 5	5.4	5, 7	8.6	9, 14	16.6
2, 6	6.3	5, 8	9.4	9, 16	18.4
2, 7	7.3	5, 9	10.3	9, 18	20.1
2, 8	8.2	5, 10	11.2	9, 20	21.9
2, 9	9.2	5, 12	13.0	10, 12	15.6
2, 10	10.2	5, 14	14.9	10, 14	17.2
2, 12	12.2	5, 16	16.8	10, 16	18.9
2, 14	14.1	5, 18	18.7	10, 18	20.6
2, 16	16.1	5, 20	20.6	10, 20	22.4
2, 18	18.1	6, 7	9.2	12, 14	18.4
2, 20	20.1	6, 8	10.0	12, 16	20.0
3, 4	5.0	6, 9	10.8	12, 18	21.6
3, 5	5.8	6, 10	11.7	12, 20	23.3
3, 6	6.7	6, 12	13.4	14, 16	21.3
3, 7	7.6	6, 14	15.2	14, 18	22.8
3, 8	8.5	6, 16	17.1	14, 20	24.4
3, 9	9.5	6, 18	19.0	16, 18	24.1
3, 10	10.4	6, 20	20.9	16, 20	25.6
3, 12	12.4	7, 8	10.6	18, 20	26.9

Bark Cover Percentage Classes
<5%
5 – 10%
10 – 25%
25 – 50%
50 – 75%
75 – 95%
>95%



A LIDS transect (dashed line) intersecting a CDW particle that is tallied within the 5-10 cm diameter size class. The piece of CDW is attached to a larger piece of CDW ≥ 10 cm diameter, but is not tallied within the larger size class. Above arrow A the diameter is < 5 cm, and below arrow B the diameter is > 10 cm; the central axis (black line) is delineated along the portion of the CDW piece that is > 5 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.

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 in **Table 14** below put coarse bounds on the northern hemisphere winter season, and are derived from MODIS-EVI phenology data, averaged from 2001-2009. The 'Approximate Start Date' field corresponds to the average date of greenup, and thus presumably, the end of winter and associated storm activity. The 'Approximate End Date' field corresponds to the average date by which greenness has returned to baseline 'winter' levels, and by which winter storms have presumably begun. Dates are provided in 'Day-of-Year' format; **Table 15** provides conversion to 'MM-DD' format.

The dates in **Table 14** 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. For example, the hurricane season in the Southeastern U.S. and Puerto Rico is not meaningfully captured by this 'winter' window, and is therefore noted specially. Moreover, not all sites for which dates are listed below produce CDW; be sure to follow provided guidelines to determine whether the protocol should be implemented.

Table 14. Estimated dates of green-up and senescence that bound the CDW sampling window

Domain	Site	Approx. Start Date	Approx. End Date
01	BART	120	300
	HARV	110	300
02	BLAN	75	310
	SCBI	85	320
	SERC	80	325
03	DSNY	Hurricane season ends	Hurricane season begins
	JERC	Hurricane season ends	Hurricane season begins
	OSBS	Hurricane season ends	Hurricane season begins
04	GUAN	Hurricane season ends	Hurricane season begins
	LAJA	Hurricane season ends	Hurricane season begins
05	STEI	120	250
	TREE	120	250
	UNDE	125	285
06	KONA	90	300
	KONZ	90	300
	KUFS	75	330
07	GRSM	90	310
	MLBS	110	310
	ORNL	90	315
08	CHOC	70	335
	DELA	60	330

Domain	Site	Approx. Start Date	Approx. End Date
	TALL	75	330
09	DCFS	120	290
	NOGP	115	290
	WOOD	120	290
10	CPER	90	350
	RMNP	120	285
	STER	90	270
11	CLBJ	60	325
	OAES	75	310
12	YELL	120	280
13	MOAB	85	300
	NIWO	140	270
14	JORN	80	320
	SRER	150	330
15	ONAQ	75	280
16	ABBY	110	300
	WREF	115	290
17	SJER	270	155 (next calendar year)
	SOAP	90	290
	TEAK	120	300
18	BARO	175	220
	TOOL	160	240
19	DEJU	130	250
	HEAL	135	245
	POKE	135	250
20	OLAA	TBD	TBD

Table 15. Day-of-year calendar for non-leap years

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	**1**
2	002	033	061	092	122	153	183	214	245	275	306	336	**2**
3	003	034	062	093	123	154	184	215	246	276	307	337	**3**
4	004	035	063	094	124	155	185	216	247	277	308	338	**4**
5	005	036	064	095	125	156	186	217	248	278	309	339	**5**
6	006	037	065	096	126	157	187	218	249	279	310	340	**6**
7	007	038	066	097	127	158	188	219	250	280	311	341	**7**
8	008	039	067	098	128	159	189	220	251	281	312	342	**8**
9	009	040	068	099	129	160	190	221	252	282	313	343	**9**
10	010	041	069	100	130	161	191	222	253	283	314	344	**10**
11	011	042	070	101	131	162	192	223	254	284	315	345	**11**
12	012	043	071	102	132	163	193	224	255	285	316	346	**12**
13	013	044	072	103	133	164	194	225	256	286	317	347	**13**
14	014	045	073	104	134	165	195	226	257	287	318	348	**14**
15	015	046	074	105	135	166	196	227	258	288	319	349	**15**
16	016	047	075	106	136	167	197	228	259	289	320	350	**16**
17	017	048	076	107	137	168	198	229	260	290	321	351	**17**
18	018	049	077	108	138	169	199	230	261	291	322	352	**18**
19	019	050	078	109	139	170	200	231	262	292	323	353	**19**
20	020	051	079	110	140	171	201	232	263	293	324	354	**20**
21	021	052	080	111	141	172	202	233	264	294	325	355	**21**
22	022	053	081	112	142	173	203	234	265	295	326	356	**22**
23	023	054	082	113	143	174	204	235	266	296	327	357	**23**
24	024	055	083	114	144	175	205	236	267	297	328	358	**24**
25	025	056	084	115	145	176	206	237	268	298	329	359	**25**
26	026	057	085	116	146	177	207	238	269	299	330	360	**26**
27	027	058	086	117	147	178	208	239	270	300	331	361	**27**
28	028	059	087	118	148	179	209	240	271	301	332	362	**28**
29	029		088	119	149	180	210	241	272	302	333	363	**29**
30	030		089	120	150	181	211	242	273	303	334	364	**30**
31	031		090		151		212	243		304		365	**31**

APPENDIX D SITE-SPECIFIC VOLUME FACTORS (F) FOR LIDS SAMPLING INFORMATION

Table 16. Site-specific volume factors for coarse downed wood tally sampling with the LIDS method

Domain Number	siteID	CDW Sampling	F	Additional information
01	BART	Yes	5	
	HARV	Yes	5	
02	BLAN		5	
	SCBI	Yes	8	
	SERC		8	
03	DSNY	Yes	15	No CDW sampling in Tower plots
	JERC	Yes	5	
	OSBS	Yes	5	Some Distributed plots may have no qualifying CDW
04	GUAN			
	LAJA			
05	STEI			
	TREE			
	UNDE	Yes	8	
06	KONA			
	KONZ			
	KUFS			
07	GRSM			
	MLBS			
	ORNL	Yes	5	
08	CHOC			
	DELA			
	TALL		5	
09	DCFS			
	NOGP			
	WOOD	No	NA	Grassland site, no qualifying CDW anticipated
10	CPER	No	NA	Grassland site, no qualifying CDW anticipated
	RMNP	Yes	8	
	STER	No	NA	Agricultural site, no qualifying CDW anticipated
11	CLBJ			
	OAES			
12	YELL	Yes	5	
13	MOAB			
	NIWO	Yes	8	
14	JORN	No		No qualifying CDW particles found in 2015 sampling.
	SRER			
15	ONAQ	Yes	15	Likely no qualifying CDW in Tower plots
16	ABBY			

Domain Number	siteID	CDW Sampling	F	Additional information
	WREF			
17	SJER			
	SOAP			
	TEAK			
18	BARO			
	TOOL			
19	DEJU			
	HEAL			
	POKE			
20	OLAA			

APPENDIX E LIMITING DISTANCE BY LOG DIAMETER GUIDELINES FOR LIDS SAMPLING

E.1 Limiting Distance by Log Diameter Tables

Use the tables below to determine the limiting distance from the transect origin for CDW particles of a given diameter (**Table 17**), or to determine the minimum diameter required to tally a CDW particle at a given distance from the transect origin (**Table 18**).

Table 17. Limiting distances (D_{lim}) for fixed round diameters (RD) across various LIDS volume factors (F, m^3 ha^{-1}) for a three-segment transect. Double-lines indicate boundaries between diameter size classes.

	D_{lim} (m)				
RD (cm)	**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		185	148	99	74
70			202	134	101
80				175	132
90				222	167
100					206

Table 18. Minimum round diameters (RD_{min}) for fixed distances (*D*) for various LIDS volume factors (*F*, m^3 ha^{-1}) for a three-segment transect. Diameters of logs larger than those listed in the table are tallied at any distance.

	RD_{min} (cm)				
D (m)	**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

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 side of the table, 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 right side of the table, a distance of 11 m falls between 10 m and 12 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.

E.2 Forked CDW and Single Round Diameter Equivalents

A CDW particle may be forked at the point at which 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 area that is made up of each fork. Equivalent RD_E values for CDW split into two forks are provided in (**Table 19**); for > 2 input forks, work in groups of two until one equivalent RD is computed.

Table 19. The round diameters of split CDW pieces (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