Watershed 1 and 3 Sampling Protocols for Understory Vegetation and Trees

Brief History of Studies in Watersheds 1 and 3, H.J. Andrews Experimental Forest

There has been a long history of geomorphic, hydrological, and ecological studies in experimental Watersheds 1 and 3 (WS1, WS3), and the neighboring old-growth basin, Watershed 2 (WS2). These include studies of sediment yield, water chemistry, and flow following whole-basin logging of WS1 and patch-cut logging of WS3 and long-term studies of forest succession. The latter, initiated in 1962, are among the longest-running studies of secondary succession in forests of North America. They based on a series of ~190 understory quadrats and tree plots. Understory quadrats were established in 1962, prior to logging, and have been sampled periodically following logging and burning. They have been used to examine how community composition prior to disturbance, disturbance severity, and overstory development contribute to the long-term dynamics of the understory (Dyrness 1973; Halpern 1988, 1989; Halpern & Franklin 1990; Halpern & Spies 1995; Dovciak & Halpern 2010, Halpern & Lutz 2013). Overstory plots were installed in 1979/1980 and have been used to characterize the early stages of forest structural development, including the recruitment (ingrowth), growth, and mortality of conifers and hardwoods (Acker et al. 2002; Lutz & Halpern 2006). Both watersheds were last sampled in 2017 and were revisited in 2019 to assess tree mortality following a major winter storm (snow-down) event. This summer's sampling will focus on WS1, which burned during the September 2020 Holiday Farm Fire (as did WS2 and WS9). We will resample understory and tree plots to assess the severity of fire effects and to characterize initial responses to fire. If time allows, plots in WS3 (unburned), will also be sampled.

General Notes

Each day, check that your compass is set with the correct magnetic declination for HJA: 14.4 deg E. Consult the following reference documents before heading to the field:

WS1-3_plot_checkoff_list. This list is used to track progress. Dates of sampling are recorded as plots are completed (end of each day). Not all plots on a transect are sampled. This list indicates which plots are skipped and why (e.g., the plot intersects a road, outcrop, or stream or it is too unstable to sample).

WS1-3_Access points and plot conditions. This document needs to be carried in the field at all times. It contains driving directions to watershed entry points, details on accessing transects, notes on transect monumentation, and a running history of the physical conditions of plots. It also includes other useful information, e.g., presence of poison oak in or adjacent to a plot**. Notes from 2017 or 2019 that are critical to this summer's sampling are highlighted in yellow**. These include details on missing corner posts, missing center-point rebars or plot-identifier tags, and recent winter storm damage.

WS1-3_Tags needed. This document, based on field notes from 2017 and 2019, lists (1) tree tags that need to be carried to specific plots to replace "temporary tags" and (2) plots in which center-post rebar or plot-identifier tags were missing in 2019. **This summer we will add a new plot-identifier tag to the center post of each plot, whether the original was missing or not.** Some tags are getting old or damaged and others may have been consumed by fire.

Sampling Design

Plot distributions. Plots are spaced 30 m apart along each transect (see illustration for WS1 in **Fig. 1**). Distances are slope corrected, thus walking distances between plots increase on steeper slopes. In WS1, transects are oriented parallel along a bearing of 200 degrees (except for Transect 6 which has multiple bearings; see the annotated map in the Appendix of this document). The corresponding annotated map for WS3 contains transect bearings for the harvest units in WS3 (these vary from transect to transect).

Plots are numbered from the N to the S ridge, **except for Transect 4** which is numbered from the S to the N (**Fig. 1**). Tall T-posts with tags are installed near transect start and/or end points as detailed in the document, **WS1-3_Access points and plot conditions**. These are not set in a precise location on the transect line, but serve as a signpost that you are adjacent to a transect.

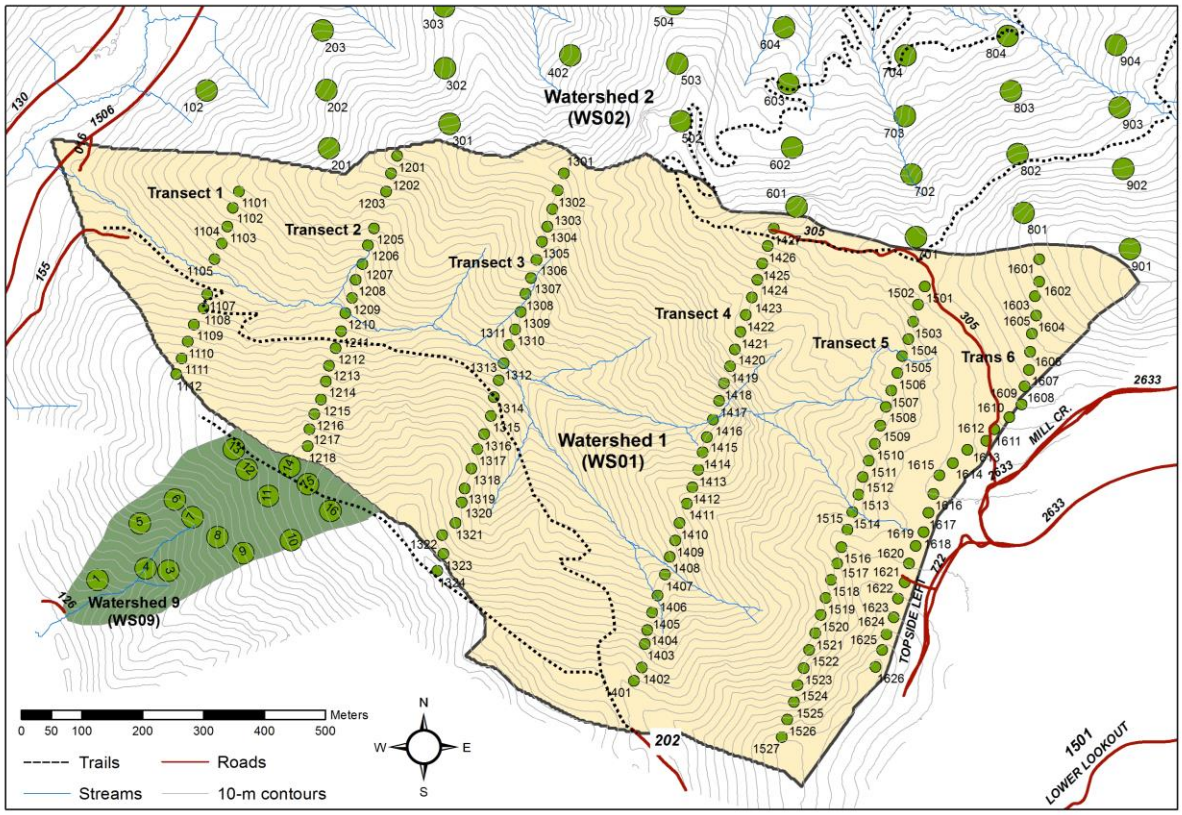


Fig. 1. Map of WS1 showing access roads (red lines), primary trails (black dotted lines), transects and numbered plots. Plot identifiers on this map are a combination of WS # (1), Transect # (1-6), and Plot # (two digits). See annotated map in the Appendix for trails and other navigational notes.

Tree plots. Tree plots are circular, 250 m^2 in area, with an 8.92 m radius (**not** slope corrected; **Fig. 2**). Plot center is marked with a steel reinforcing bar (rebar). Red/blue flagging is hung above or on the rebar to make it more apparent. At the base of the rebar is an aluminum tag with the transect and plot # (e.g., "1 / 4" = Transect 1, Plot 4). The tag may be buried by litter and may require excavation. For some

plots, the rebar and/or tag were noted as missing in 2019: see the plot-conditions section of **WS1-3_Access points and plot conditions** and the **WS1-3_Tags needed** form. In severely burned plots, the center-point tag and wire may have been consumed by fire. **We will add a new center-point tag to each plot this summer, whether the tag is missing or not.** If the rebar or tag is missing, please comment as such at the top of the **WS1-3 understory quadrats** form.

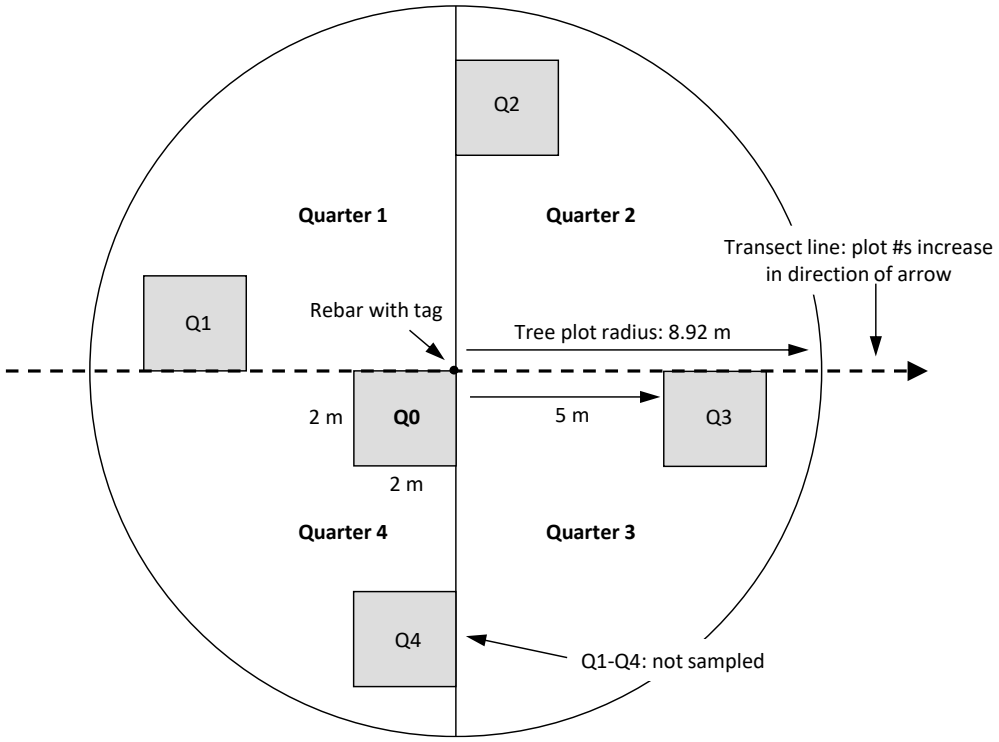


Fig. 2. Layout of the 8.92 m radius circular tree plot with nested 2 x 2 m understory quadrats (Q0-Q4). **Only the central quadrat (Q0) is sampled.** Within the tree plot, trees are located by **Quarter** (1-4). Quarters are numbered relative to the direction of the transect line, with the latter defined by the order of plots. From plot center, as you face the direction increasing plot #'s, **Quarter 1** is behind you and to the left, with subsequent quarters numbered in a clockwise direction. The central understory quadrat (**Q0)** is behind you and to the right, in **Quarter 4** of the tree plot.

Understory quadrat (Q0). The rebar serves as one corner of a central 2 x 2 m understory quadrat (**Q0**). Understory quadrats **are slope corrected**, unlike the tree plots (**Fig. 2**). Often, a second corner of Q0 on the bearing of the transect line is a 2+ m tall metal "sighting" pole. Over the decades these poles have been bent or knocked down and have been replaced by shorter PVC posts. Usually, but not always, the remaining corners of Q0 are red spray-painted PVC posts, although other markers are possible. These include: (1) white or orange PVC, (2) a nail on a log or stump spray-painted orange and/or flagged in red, or (3) an orange spray-painted dot on a rock surface. Because Q0 is slope corrected, its shape will change as the slope or direction of the slope changes. It is important to **avoid stepping into Q0** when you sample the larger tree plot. For this reason we sample the understory quadrat before the tree plot.

Satellite quadrats. There are four additional "satellite" quadrats (Q1-Q4), marked by short PVC, which are no longer sampled (**Fig. 2**). The edges closest to the center-point rebar are 5 m (non-slope corrected) from the rebar. These were established in 1980 to increase the intensity of understory sampling, but the increased sampling effort could not be maintained and they were dropped from the study. Over time, some of the satellite posts have fallen over or disappeared. Fallen (but not upright) satellite posts can be used to replace missing Q0 corner posts if needed (e.g., if you have run out of replacement PVC).

Quadrat maintenance and post reestablishment. As you approach Q0, try from a distance to spot the center-point rebar and PVC corners to avoid stepping into the quadrat. Depending on fire or previous tree-fall damage to the quadrat, various tasks may be necessary:

- Find the rebar and check its tag. If the rebar or tag are missing make a note in the **Comments** box at the top of the data form.
- Place a short PVC post over the rebar (exposed rebar is no longer permitted in HJA).
- Using a piece of aluminum wire, loop the **new plot-specific center-point tag** around the base of the PVC.
- Flag the PVC in red and blue. If there is a shrub/tree branch above it, add additional flagging. This will help the next crew to find plot center.
- If posts are leaning but intact, stand them vertically and tap gently with a hammer to secure them.
- Any posts that are down, damaged, or missing will need to be reset or replaced. This will require at least two people using the "quadrat poles" (2 m long for the edges; 2.83 m long for the diagonal) and/or meter tapes, as follows.
- **Center post standing and one or two other posts down.** Use the triangulation method. Place the end of a 2-m pole at the base of a standing corner post. Place the end of a second 2-m or 2.83-m pole (depending on how many corners are missing) at the base of a second standing post. *Holding the poles horizontally* (which may be well off the ground on steep terrain), move the free ends of the two poles together until they touch. From the point at which they touch, drop a small object (stone or pencil) and watch where it hits the ground. Insert the replacement post at that point. Use the same procedure to reset a second down or missing post. If a log prevents insertion of a post, use a nail for the corner, flagged heavily in red. Describe which corner(s) were reset or replaced in the **Comments** field of the **WS1-3_Understory quadrat** form.
- **If only the center-point rebar remains,** first reestablish the corner that falls along the transect line (see **Fig. 2**). From the covered rebar, this post will lie on a bearing of 20 degrees (200 minus 180 degrees) at a slope-corrected distance of 2 meters. **This bearing will differ for the northern half of Transect 6 (Plots 1-15) where the transect bearing deviates from 200 degrees** (see the annotated transect map in the Appendix, page 22; the annotated map for WS3 contains the various bearings in that watershed). Once this first PVC is reestablished, the triangulation procedure described above can be used to reset the remaining two posts.
- **If the center-point rebar is down or lost**, it can be reestablished in one of two ways: (a) using existing corners in the quadrat, as described above; or (b) by triangulation from two "reference trees". Reference trees are identified by tag # at breast height and by a #1 or #2 round metal tag at the base. The **WS1-3_Reference tree bearings & distances** table contains the bearings and non-sloped corrected distances (nearest cm) *from the tag at the base of the reference tree to the rebar*. Using two meter tapes (e.g., the linear side of a Dbh tape), two grip clips to hold the tapes to reference nails, and a compass, one person sights from each reference tree in the direction of the missing rebar. The second individual runs the two tapes along these bearings until they cross at the distances listed. The rebar is reset or added at this point and covered with a PVC post. Then the **new center-point tag** is wired around the base. Record that the original rebar was down or missing in the **Comments** box at the top of the **WS1-3_Understory quadrats** form.
- **If all posts including the rebar are missing:** use the procedures described above, in the following order: (a) use the reference trees to reestablish the rebar, then (b) use the rebar to reestablish the post on the transect line, then (c) triangulate to reestablish the two remaining posts. Add a note to the **Comments** box that all posts, including the rebar, were reestablished.
- **If all posts are missing and the reference tree tags have been consumed by fire:** consider

whether any satellite posts can be used to reset the rebar (see distances and orientations in **Fig. 2**), then follow steps (a) through (c) in the previous bullet.

- If there are no satellite posts available, the position of the rebar will need to be approximated from (a) the orientation of tree tags (all tags should face the rebar), (b) the distance to which trees are tagged from the plot center (maximum of 8.92 m along the ground surface), and (c) the positions of tagged trees by quarter (see the quarter arrangement in **Fig. 2**). Once the center-point rebar is reset, follow the steps outlined in the previous bullet(s).

Order of sampling: understory quadrats then tree plots. In each plot we will sample ground conditions and the understory vegetation before we sample the trees, to avoid damaging the ground surface and understory while sampling the trees. The following paragraphs describe the understory sampling.

Sampling Protocols – Understory Quadrats

Data form. Each plot has its own, pre-printed **WS1-3_Understory quadrats** form. A blank, **WS1-3_Understory quadrats continuation** form may be needed in some plots.

At the top of each page, record the month (MM), day (DD), and personnel (last names). Record the same information before starting a "continuation" form. Once sampling is complete, enter the page # and total number of pages for the plot (this includes the pre-printed and continuation forms; e.g., Pg. 1 of 1 or Pg. 1 of 2 and Pg. 2 of 2). This will ensure that all pages are accounted for.

Missing reference tags. Check the integrity of the round metal tags at the bases of reference trees. Tagged trees that serve reference trees are listed on the form, **WS1-3_Reference tree bearings & distances**. If the tags are intact, place a check mark in the space provided at the top of the data form: "**Reference tag distance, bearing to rebar √ ". If one or both trees are down or disturbed, or if the tags are missing, select new reference tree(s) and move or install new reference tag(s). If new trees are selected, they should be vigorous, close to plot center, and located such that the two bearings form an approximate right angle at the rebar (which is now covered). Nail the pre-numbered #1 or #2 tags at the base of each tree with the tag facing the rebar. As described above, use a meter tape and compass to determine the non-slope corrected distance (to the nearest cm) and bearing (in degrees) *from the nail to the rebar*. Record the new reference tree Tag #s, distances (m), and bearings (deg) at the top of the data form:

"#1 = Tag# _____, ___ . ___ (m), ____ (deg) #2 = Tag# _____, ___ . ___ (m), ____ (deg)".

Add a note in the **Comments** box that the Reference trees have been updated.

Marking the edges and mid line of Q0. To mark the perimeter of the quadrat, place 2-m PVC poles along each edge and place the 2.83-m diagonal pole down the middle of the quadrat to split it into halves. It is best if the split is done up- and down-slope. Two observers will estimate cover in their respective halves of the quadrat, preferably standing at opposite, side-slope positions. If the quadrat is split horizontally, it is difficult for the observer standing upslope of the quadrat to see down into it.

Three 3 types of cover or biomass-related measurements are made in each quadrat, as follows.

1. Canopy Cover (≥2 m tall)

The first set of cover estimates are of species in the canopy layer. For this study, these are **woody plants (conifers, hardwoods, or tall shrubs) that are ≥2 m tall.** Cover is estimated by two methods.

1a. Truck-mirror densiometer (Fig. 3). This method captures a wide view of the canopy and it does not distinguish among conifers, hardwoods or tall shrubs. The densiometer is a convex mirror with a 10 x 10 grid (100 squares) divided into 4 quadrants (NW, NE, SE, and SW). Each quadrant has 25 cells. The mirror

sits on 1-m-tall PVC pole on a swivel that allows it to be leveled. Insert the post into the ground touching the covered center-point rebar[1]. The mirror should sit at ~1 m above the ground surface. Using a compass, rotate the mirror so its center line runs N/S (see quadrant markings on the mirror. Then place a leveling "bubble" in the center and use it to level the mirror.

Cover is estimated for each of the four quadrants. When reading cover, your eye should be ~20 cm above the mirror (see **Fig. 3**) over the quadrant that is diagonal to quadrant being read—e.g., over the NW quadrant to read the SE quadrant (and vice versa). Use one eye and close the other. As needed, lean around the densiometer pole to make readings rather than stepping into Q0.

Each of the 25 grid cells in a quadrant is scored for canopy cover on a scale of 0 to 4, where 0 = open sky (<12.5% of the cell covered), 1 = ~25% of the cell covered, 2 = ~50% of the cell covered, 3 = ~75% of the cell covered, and 4 = ~100% of the cell covered. Cover can be foliage, branch, or tree bole but it has to be at least 2 m above the ground surface.

Estimate canopy cover in each grid cell and sum the values as you move from one cell to the next. If the canopy is mostly closed, it is easier to tally units of **open sky** (0 to 4), then to subtract the total from 100. Once you are done with a quadrant, reposition yourself to read the next quadrant. Be sure to record each value in the appropriate quadrant on the data form.

Fig. 3. Technique for sighting with the truck-mirror densiometer. The reading eye should be ~20 cm above the mirror, over the quadrant that is diagonal to the quadrat being read (e.g., over the NW quadrant to read cover in the SE quadrat). Use one eye and close the other.

1b. Growth-form (GF) cover %. A second set of canopy measurements, **Growth-form (GF) cover**

[1] There is one exception: in WS1, transect 5, plot 8, place the pole adjacent to the NE corner post.

(%), is recorded on the line below the truck-mirror densiometer measurements. These are visual estimates of cover of **woody growth forms ≥2 m tall.** Cover is estimated as the **vertical projection** into the quadrat—a much narrower view of the canopy than that obtained from the truck mirror. Don't try to resolve small spaces in the canopy between branches or leaves. Instead, view canopy cover as larger polygons, ignoring these spaces.

Separate estimates are made for **Conifer (C)**, **Hardwood (Hw)**, **Tall shrub (S),** and **Total** canopy cover. **Table 1** shows the classification of species by growth form, as does the **WS1-3_Species names & codes** table and the **Species cover** section of the data form. **Total** cover ignores the growth forms: it is any cover ≥2 m tall.

Canopy cover for each growth form or for **Total** cannot exceed 100%. **Total** should equal or exceed the maximum of **Conifer**, **Hardwood** and **Tall shrub**. Record "0%" if there is no cover for a growth form.

Table 1. Designation of species as tall shrubs, hardwood trees, or conifers. Species present at the last measurement (2017) are shown; other species may be present (see table of species names and codes). All other species are considered herbs. Species names and codes are from the USDA Plants database.

Tall shrubs	ACCI	*Acer circinatum*	TODI	*Toxicodendron diversilobum*
	AMAL2	*Amelanchier alnifolia*	RHMA3	*Rhododendron macrophyllum*
	ARCO3	*Arctostaphylos columbiana*	ROGY	*Rosa gymnocarpa*
	CEIN3	*Ceanothus integerrimus*	RULE	*Rubus leucodermis*
	COCOC	*Corylus cornuta* var. *californica*	RUPA	*Rubus parviflorus*
	CYSC4	*Cytisus scoparius*	VAME	*Vaccinium membranaceum*
	HODI	*Holodiscus discolor*	VAPA	*Vaccinium parvifolium*
	OECE	*Oemleria cerasiformis*		
Hardwoods	ACMA3	*Acer macrophyllum*	CONU4	*Cornus nuttallii*
	ALRU2	*Alnus rubra*	PREM	*Prunus emarginata*
	ARME	*Arbutus menziesii*	FRPU7	*Frangula purshiana*
	CHCH7	*Chrysolepis chrysophylla*		
Conifers	CADE27	*Calocedrus decurrens*	THPL	*Thuja plicata*
	PSME	*Pseudotsuga menziesii*	TSHE	*Tsuga heterophylla*
	TABR2	*Taxus brevifolia*		

2. Substrates, Burn Severity, and Growth-form (GF) Totals

The second section of the data form is used to assess forest-floor substrates, burn severity, and total cover of plant growth forms irrespective of height.

2a. Substrates. These include:

- **Bare**: Bare ground/mineral soil, regardless of cause (e.g., sparse litter, erosion, or exposure by fire). **If recent "needle rain" from fire-killed or scorched trees covers fire-exposed mineral soil, the cover should be recorded as Litter.**
- **Stone**: Rock ≥7 cm in width (or smaller pieces if they form a contiguous surface)
- **Log**: Pieces of wood (branches, boles, root wads, or bark ≥10 cm in the smallest dimension). Smaller pieces that form a contiguous surface ≥10 cm wide also qualify.
- **Stump**: Stump of a cut tree, if upright (otherwise Log)
- **Butt**: Live tree base irrespective of species if ≥1% cover
- **Snag**: Dead tree base if ≥1% cover
- **Litter**: Old needles, recent "needle rain" from fire-killed or scorched trees, deciduous leaves, or fine woody debris (<10 cm wide). It is often easiest to compute **Litter** as the difference between 100 and the sum of the previous categories. However, see the exception below.

Notes and exceptions:

- If **Bare** ground is not visible under a plant, consider the cover as **Litter**
- Substrate cover values typically sum to 100%. However, they can exceed 100% if a **Log** is elevated over the quadrat, or if its diameter is large enough to project **Log** cover over **Litte**r or **Bare** ground. If the sum exceeds 100%, explain why in the **Comments** box using the following as an example: "10% of Log cover is elevated"

2b. Burn severity. Estimate the percentage of ground surface burned by the 2020 fire. Cover is estimated for each of two categories of burn severity:

- **Black**: Corresponds to **lower severity** fire. Pre-fire litter or logs have not been consumed by fire but are charred or blackened; mineral soil has not been exposed by consumption of the litter/duff layer.
- **White:** Corresponds to **higher severity** fire. Pre-fire litter or logs have been consumed by fire, leaving white ash or exposed mineral soil which can be reddish in color. Mineral soil that has not been burned will be darker in color.

Note: Recent "needle rain" from fire-killed or scorched trees, which should be included in the estimate of **Litter** cover (in **Section 2a**, above), may obscure evidence of burning. However, it should be possible to determine if these needles sit on top of the original (pre-fire) litter layer, on charred/blackened litter or logs (**Black**), or on white ash/fire-exposed mineral soil (**White**).

If there is no evidence of **Black** or **White,** record 0%. The sum of **Black** and **White** cannot exceed 100%, but it can be lower, depending on how much of the quadrat burned.

Additional observations about fire effects should be noted in the **Comments** box (e.g., "Q0 has 25% cover of soil depressions/concavities due to tree-root burnout). Fire effects on tagged trees (bark char, canopy scorch) will be recorded as part of the tree measurement protocol.

2c. Growth-form totals. This third section of the data form is used to assess the cover of all plant growth forms, **irrespective of height**. Cover is estimated as a vertical projection for each of four groups:

- **Moss** (includes mosses and liverworts). Use the vertical projection of cover even if mosses/liverworts are growing on the sides of logs or stumps. This vertical projection will be much lower than the surface area covered.
- **Tree** (does not distinguish between hardwoods or conifers). Includes tree cover <2 m tall. This corresponds to species coded as **T** in the **Species cover** section of the data form. See **Table 1** for the full list of tree species.
- **Tall shrub.** This corresponds to species coded as **S** in the **Species cover** section of the data form. See **Table 1** for the full list of tall shrub species.
- Because stems of any height are included, this value should equal or exceed the tall shrub value recorded in "**Section 1b. Canopy cover (≥2 m)".**
- **Herbs** (graminoids, ferns, herbs, subshrubs, and low shrubs). This corresponds to species coded as **H** in the **Species cover** section of the data form. For this study, the low shrubs *Gaultheria shallon* and *Mahonia nervosa* are classified as herbs. For a full list see **WS1-3_Species names & codes.**

3. Species Cover, Height, and Biomass-related Measures

This final section of the data form is used for species-level data: **Cover**, **Height** and other **Biomass-related measures**. Species found at the last measurement (2017) are listed. Some may no longer be present and new species may have colonized, so it is critical to search the entire quadrat for additional species. There are blank lines to add new species and if necessary, a blank **WS1-3_Understory quadrats_continuation** form can be used.

Order in which species are assessed. Rather than work from the existing list of species (which is alphabetized), it is easier to assess cover by layer: tree species, then tall shrub species, then low woody or herbaceous species. Within each layer, begin with species that account for the most cover, then follow with the less abundant species. End by searching for species that have not been accounted for or for new species. **It is important to search through the entire quadrat, under the foliage of larger species, and for species overhanging the edges—including high above the quadrat. Small sprouts or seedlings may be overlooked unless you get close to the ground.**

Species full name and code. For new species, record the full name in addition to the code; full names will allow us to correct erroneous codes. It is ok to abbreviate the names of common species. We are following the nomenclature and coding of the USDA Plants database. The **WS1-3_Species names & codes** form lists all species present in 2017, plus a number of ruderal species that may have colonized post-fire**.** If a species is found that is not on the list, enter its name and assign it a code but verify these from the USDA Plants database: https://plants.sc.egov.usda.gov

Unknown species. If a plant can be identified to genus only, record the first 5 letters of the genus. If only its family is known (e.g., Liliaceae or Poaceae), record the first 6 letters (LILIAC or POACEA). If a plant cannot be identified, record a short descriptive name (e.g., "Hairy-stem grass") and unknown code "UNKN#" (where # is a unique number **for the quadrat**). Make a sketch and describe it in the **Comments** box (e.g., "UNKN# = hairy-stemmed grass w/ long awns") or on the back of the data form, noting as such in the **Comments** box so we know to look there. Please take a photo if possible, then rename the image as UNKN# _transect-plot identifier_date (e.g., UNKN1_1-17_6July). If possible, collect a voucher specimen from outside the quadrat, place it in a Ziploc bag, and label the bag with a sharpie, noting collector's name, date, UNKN#, and transect/plot # (in WS3 also include the harvest unit #).

LC (line count). LC = 1 designates the first record (data line) of a species in a quadrat—the line on which cover is recorded. If additional lines are needed to record stem diameters (see below), increment the LC value by one (e.g., 2, 3, etc.).

Cover (%). Species cover (%) is estimated as a vertical projection into the quadrat. It includes foliar and stem cover whether the species is rooted in or out of the quadrat. Don't try to resolve small gaps between stems or leaves. Instead, view cover as the larger polygon ignoring these spaces. The minimum cover value to record is 0.1%. If it is less than that, still record 0.1%. Maximum cover is 100%.

Estimating cover requires two observers. Divide the quadrat in half (two, 1 x 2 m quadrats). This works best if each observer stands side-slope of the quadrat with the dividing pole oriented up and down slope through the center. Cover estimates from each half of the quadrat can be combined in one of two ways:

- For species that occupy a large portion (>50%) of the 2 x 2 m quadrat, estimate cover in each half then average the two values.
- For species that occupy a small area, estimate the physical dimensions of plants then convert to cover. **Table 2** lists conventions to convert from physical dimensions to % cover in the 2 x 2 quadrat.

Table 2. Converting plant dimensions to % cover in the 2 x 2 m quadrat.

Plant dimension	Cover (%)
Fist with knuckles folded under (10 x 10 cm)	0.2 - 0.3
Sheet of 8.5 x 11" paper (or a standard clipboard)	1.5
50 x 50 cm (1/16 of the 2 x 2 m quadrat)	6.2
1 x 1 m (one quarter of the 2 x 2 m quadrat)	25.0

Height (cm). Height is estimated in centimeters for **all herb and tall shrub species, but not for tree species.** PVC height **p**oles are marked in 10-cm increments, but centimeter precision can be estimated (see below). Height is used to characterize the vertical distribution of non-tree species. For species with

erect stems, height is modal height—the most common stem height in the quadrat. For species with only a basal rosette of leaves or with a creeping form, height is height of the foliar surface off the ground (e.g., 2 or 3 cm). For tall shrubs which often lean, height is estimated as **stem length**. The precision of estimates will vary with height. For modal heights of <1 m, estimate to the nearest 5 cm. For modal heights between 1 and 2 m, estimate to the nearest 10 cm. For modal heights >2 m tall, estimate to the nearest 50 cm**. It is most efficient if a species' height is estimated right after its cover. This way the height estimated won't be forgotten.**

Biomass-related measurements. For a subset of species (see **Table 3**), one or more additional measurements are made **if the species is rooted in the plot**. These measurements allow us to estimate above-ground biomass using equations developed earlier. Underscore lines ("__. _" or "___") on the data form prompt the observer for the relevant measurement for a species—if it has stems rooted in the plot. If it is rooted outside the plot, these measurements are not taken, but a check-mark (√) is entered in the "**Rooted out**?" column. This way we know that the measurement was not overlooked. Presence in/out of a quadrat is based on the center of the stem where it enters the forest floor. Details on which species require biomass-related measurements follow below.

Table 3. Species that require individual stem-based measures to estimate biomass.

Stem measurement	Species	Note
Dba	• All tall shrub species except *Rubus parviflorus* (RUPA) • Tree seedlings without tags • Small trees (saplings) with tags on wires/zip-ties	See **Table 1** for full list of tall shrub species
Dba and # of stems per dba	*Pteridium aquilinum* (PTAQ)	
Dba & height	*Xerophyllum tenax* (XETE)	See text for details on measurements
Frond length & # of fronds per length	*Adiantum pedatum* (ADPE), *Athyrium filix-femina* (ATFI), and *Blechnum spicant* (BLSP)	

Dba is measured for each **live stem** of: all **tall shrub species** (except RUPA), all **tree** s**eedlings or sapling** without a tag or with a tag on a wire or zip-tie, and *Pteridium aquilinum* (PTAQ). Dba is also measured for each **clump** of *Xerophyllum tenax* (XETE).

For tall shrubs, measure diameter at the base at the ground surface. For trees, measure diameter at the base but above any butt swell. Dba is measured using a plastic caliper or short strip of diameter tape. **Measure to the nearest 0.1 cm.** If a caliper is used on an oval-shaped stem, take two measurements perpendicular to each other and record the average. For larger oval-shaped stems, the short strip of diameter tape is usually more accurate.

Note: In the few quadrats containing poison oak (*Toxicodendron diversilobum*, TODI), diameters can be estimated from a distance!

For each species requiring a diameter, the first Dba measurement is recorded on the **Cover** line (LC = 1). Subsequent measurements of the same species are recorded on separate lines. For each additional line, enter the species name and code and increment the LC value by one. However, where there are multiple stems of the same diameter, a count can be recorded in the **No. stems** column. This reduces the number of data lines. If a count is not recorded for a species, it is assumed to be "1".

Note: This counting procedure should not be used for trees with tags; instead, each **Dba** is recorded on a separate line and the tag # is recorded in the last column (**Tree tag #**).

For *Xerophyllum tenax* (XETE, beargrass), **each ramet** (clump of leaves) gets measured for basal diameter (**Dba in cm**) and height. Leaves are gathered, compressed, and measured for basal diameter using a short strip of diameter tape. Leaves are then pulled up until fully extended, then measured for **Height**. If there are multiple clumps, pairs of Dba and Ht measurements are recorded on separate lines.

Dbh is measured for trees **with nailed tags**. **Measure to the nearest 0.1 cm** just above the nail. Each Dbh is recorded on a separate line. As with Dba, the first Dbh is recorded on the Cover line (LC = 1) unless there is already a Dba measurement. If there is, Dbh is recorded on a second line (LC = 2). **Tree tag #** is recorded in last column. If a tree doesn't have a tag, but it should (i.e., it is taller than 1.37 m), it may have lost its tag or it may be "ingrowth" (a tree that has attained 1.37 m height since the last measurement). Add a note about the lack of a tag in the **Comments** box. The tag can be added when trees are sampled in the larger plot (including any in Q0).

Length of fronds is recorded for three relatively uncommon **fern species:** *Adiantum pedatum* (ADPE, maidenhair fern), *Athyrium filix-femina* (ATFI, ladyfern), and *Blechnum spicant* (BLSP, deer fern). **Frond length is measured to the nearest cm**. For maidenhair fern, the leaflets (or pinnules) are not extended before measuring the length. Because there are often multiple fronds of similar length in a clump, record **Length** and **No. stems** of a given length. If there are multiple clumps with differing lengths, record the data on separate lines. Note that although fronds are counted and measured for length, a **modal height** for the species is also recorded.

Before leaving the quadrat recheck the data form. It is best if the person who did not record the data checks the work of the recorder. Check the following:

- Have **Reference tags** been checked?
- **1b. Canopy Cover (≥2 m tall):** Is the value for Total cover equal to or greater than the maximum of Conifer, Hardwood and Tall shrub cover?
- **2a. Substrates:** Do cover values sum to 100% (assuming no overlap of substrates)?
- **2b. Burn severity:** Is there a value recorded for Black and White (or 0% in their absence)?
- **2c. Growth-form Totals:** Is there consistency between each growth form total and the sum of individual species cover values? If there is foliar overlap among species within a growth form, the sum of species values should exceed the growth-form total. If there is no overlap among species, the sum should equal the growth-form total. If comparisons of species' sums vs. growth-form totals suggest a discrepancy, adjust species' value(s) or growth-form totals accordingly to reconcile any differences.
- **1b. Canopy Cover (≥2 m tall) vs. 2c. Growth Form Totals:** Is the value for Total tall shrub cover in **2c** greater than or equal to the value in **1b**? Is the value for Total tree in **2c** greater than or equal to the values for Conifer or Hardwood in **1b**?
- **Section 3. Species Cover:** Are all species from the previous measurement accounted for? **If a species is not found, place a strikeout line through the name/code to indicate that you have looked for it.**
- Are full names and codes entered for all species?
- Does each species have a cover and modal height value on the LC = 1 line **and only that line**?
- For species requiring multiple line counts, is the series of LC values complete with no skips or duplicate numbers)?
- Is a page number recorded at the top of each page?

Sampling Protocols – Tree Plots

Data history. Each plot has its own set of data forms. Data derive from two sources: (1) a remeasurement of all trees in 2017, and (2) an assessment of survival/mortality of larger (≥5 cm dbh) trees in 2019. In 2019, diameters were not measured and smaller trees (<5 cm dbh) were not assessed for survival/mortality. As result, except for diameters (2017), the recency of data varies by individual:

- Status codes (live, dead, or missing) for larger trees (≥5 cm dbh) are from 2019
- Status codes for smaller trees (<5 cm dbh or dba trees) are from 2017
- Vigor codes, which apply only to live trees, are from 2017

Which trees are listed? The data form lists all trees that were **alive in 2019** and all trees that **died or were missing in 2017 or 2019**. It does not list trees that died earlier so you may encounter dead trees or tags of dead trees that are not recorded on the forms. Species considered trees (hardwood or conifer) are listed in **Table 1**.

Order of tags. Trees are listed sequentially by plot quarter (column **Q** on the data form) then by tag #. See **Fig. 2** for the arrangement of plot quarters.

Comments. Be sure to read the comment associated with each tree. It may include instructions to resolve past discrepancies, e.g., the presence of duplicate tag #s or the need to replace a temporary tag with a permanent one (e.g., the comment "needs new tag" abbreviated as "NNT"). Permanent tags will be provided daily to replace temporary tags (see the plot and tag list on **WS1-3 Tags needed** form).

Page headers and footers. At the top of each page, record the month (MM), day (DD), and personnel (last names). **After completing measurements, enter all page #s at the bottom of form (e.g., Pg. 1 of 5, Pg. 2 of 5, … Pg. 5 of 5).** This will ensure that all pre-printed pages are accounted for. Ingrowth pages are numbered as a separate series for each plot (e.g., Pg. 1 of 1, Pg. 1 of 2).

Plot perimeter. As you sample you may need to determine if an untagged tree is in or out of the plot. Plot radius is 8.92 m (not slope corrected). Previously, blue flagging was used to mark the plot boundary; some flagging may remain. We used the following convention to flag trees at the boundary: if the tree was out, flagging was placed on a branch facing plot center (designating that the bole is out). If a tree was in, flagging was placed on a branch facing away from the plot center (i.e., the bole is in). "In" vs. "out" is based on the center of the bole where it meets the ground surface.

Breast height definition. 1.37 m from the ground on the side-slope (not above or below the tree).

Hardwoods with multiple stems from a base. Hardwood stems arising from a common base should be tagged individually if they are ≥1.37 m tall.

Resprouting or fire-damaged trees. If there is no live foliage above 1.37 m the tree is considered "dead" even if it is re-sprouting from the base. Any new shoots arising from the base of a hardwood that exceed 1.37 m in height are considered "ingrowth" and are given a new tag (see details below).

Correcting quarter #s (Q) or species codes. Any such corrections should be done as follows: cross out the incorrect data, pencil the correct data adjacent to it, circle the change, and note the correction in the **Comments** column.

Strategies for sampling efficiency, accuracy and data continuity:

- **Observer and recorder should work in close proximity.** This makes it easier to track whether trees have or have not been measured and to assess fire effects more accurately (crown scorch). It also makes it easier for the recorder to hear the observer: in general, the recorder should repeat each measurement back to the observer to ensure accurate transfer of data.

- **Move systematically through the plot**. If possible, work in one quarter of the plot before moving on to the next; this minimize travel, ground disturbance, and likelihood of missing a tree. As sampling proceeds, the recorder can alert the observer to tag #s that have not yet been measured in a quarter or to trees that were missing at the last measurement.
- **Tag and nail maintenance.** Trees can outgrow their nails. **Make sure there is at least 1" of exposed nail.** If the exposed portion is less, back the nail out of the tree. First, tap the nail head to loosen the pitch, then pull the nail for a short distance with a claw hammer. If necessary, place a stick or piece of wood behind the hammer head for leverage and to protect the cambium. **If the nail doesn't move,** clip off its head with wire cutters leaving the shaft of the nail in the tree. Reattach the tag at the same height with a new nail adjacent to the old. **If a tagged tree is dead**, pound the nail/tag all the way to the bark to secure the tag (but first check that the tree is dead!).

Sampling details. Different scenarios and sets of measurements apply depending on tree status (live or dead), measurement point (MP = base, B; or breast height, H), and other factors. These scenarios are described below (#1 through #5). However, the overall objectives is to:

- Systematically re-measure and record status and vigor of all previously tagged stems
- Tag, measure, and record status and vigor of ingrowth trees (non-tagged stems $\geq$ 1.37 m tall)
- Assess fire damage on all live or recently killed trees.

1. Live trees tagged at breast height (MP = H). Measure and record the following:

- Diameter directly above the nail in the **Dbh** column, to the nearest 0.1 cm
- Status (**St**) = 1 (present and alive)
- Overall vigor (**Ov): 1** = good, **2** = fair (some loss of foliage, branches, or crown), or **3** = poor (few live needles or live branches, almost dead)
- If necessary, enter a near tag # (tag # of the largest adjacent tree) in the **Near** tag column. This can be done if the tree was difficult to find or if the previous Near tree is now dead, missing, or has poor vigor. There are no underscore lines for **Near**, but a tag # can be entered in the blank space, or an existing tag # can be crossed off and a new tag # penciled in above it. Circle any changes to make them obvious for data entry.
- If the tag is being overgrown or if there is little room on the nail for future growth, clip off the head of the nail or cut a slit above the hole in the tag and remove it from the nail (if necessary, a nail can be driven through the tag to make a new hole). Place the tag on a new nail at the same height, facing plot center. **Important note**: don't remove tags by prying with the hammer against the tree; this can damage the cambium/bark of smaller trees.
- If the tag is overgrown and can't be removed, leave it. Nail a temporary tag (flexible tag on which the same # is written) at the same height facing plot center and comment on the need for a new tag ("NNT").
- If the previous comment includes "NNT", replace the temporary tag with the new tag provided
- Assess **Bark char** and **% Canopy scorch** following the methodology on pages 17-20
- Record any unusual feature(s) of the tree in the **Comments** field. To save space, you can use the abbreviations listed in **Table 4 (**next page).

2a. Live trees with a tag wired onto a branch (MP = B), but too small to nail at breast height. Measure and record the following:

- Basal diameter (above any basal swell) in the **Dba** column, to the nearest 0.1 cm
- Status (**St**) = 1 (present and alive)
- Overall vigor (**Ov),** as described above

- **Near** tag #, if necessary, as described above
- If the wire is old or flimsy, replace it with a zip-tie set loosely on a side branch. If the wire looks like it may slip off the branch, find a more secure location on a sturdier upward arching branch.
- Record any unusual feature of the tree in the **Comments** field (see abbreviations in **Table 4)**

Table 4. Common terms and abbreviations used in the Comments field.

Term/abbreviation	Meaning
BB_DDC	Bole burned/diameter double checked; used when Dbh is smaller than the previous Dbh due to bark consumption by fire (more likely on large, thick-barked trees)
Bole scraped	Bole scraped by another tree, snag, or limb
Bole snapped	Bole snapped but alive
Broken top	Broken top
Conks	Conks present
Crook	Major crook in stem
Crushed by tree	Crushed by a tree that was alive when it fell
DDC	Diameter double checked; used when Dbh or Dba is smaller or unusually larger than the previous diameter (after rechecking the diameter)
Dead top	Dead top
Mistletoe	Dwarf mistletoe plants observed
Forked top	Forked top
Fused w/ tag # ___	Used if two tagged trees have their boles "fused". Use the linear side of the Dbh tape to estimate the diameter of each.
NFAS	Not found after search: used when a tagged tree is missing (status = 9)
NNT	Needs new tag; used when a tree tag is not found. Attach a temporary tag at the same height as the original nail (look for the old nail hole) or at a height consistent with the previous measurement or growth of similar-sized trees.
Pitching	Sheets/copious amounts of pitch running down the stem
Tagged but not listed	Used for a previously tagged tree that is not listed on the data form
Reiterated leader	An old broken top is replaced by a side branch with apical dominance
Sweeping	Major stem sweep (long curve)
Tag found/renailed	Used when a tag is found on the ground and re-nailed to a tree missing its tag
Tag replaced	Used when a temporary tag is replaced by a permanent tag
Temp tag added	Used when a temporary tag is added to a tree missing its tag
Witch's broom	Dense branching from a single point, usually caused by dwarf mistletoe

2b. Live trees with a tag wired onto a branch (MP = B), but now large enough to nail (≥5.0 cm dbh). Measure and record the following:

- First, remove the wire/zip-tie and nail the tag facing plot center at breast height (1.37 m side slope)
- Basal AND breast height diameter (**Dba** AND **Dbh**), each to the nearest 0.1 cm
- Status (**St**) = 1 (present and alive)
- Overall vigor (**Ov**), as described above
- **Near** tag #, if necessary, as described above
- Assess **Bark char** and **% Canopy scorch** following the methodology on pages 17-20
- Record any unusual features of the tree in the **Comments** field (see abbreviations in **Table 4)**

3. Tagged trees that have died since 2017 or 2019. Measure and record the following:

- **Dba** for a tree with a tag on a wire or zip-tie; **Dbh** for a tree with a nailed tag. **Because the tree is**

now dead, its diameter may be smaller than the previous diameter.

- Status (**St)** = 6 (dead)
- Overall vigor (**Ov**) remains blank
- Assess **Bark char** and **% Canopy scorch** following the methodology on pages 17-20
- In the **Comments** field:
  (a) Record the tree's physical characteristics, broken crown or bole, down or crushed (trees on the ground), bark stripped (animal damage), charred or scorched (trees affected by fire)
  (b) Record the probable cause of death using the following syntax: "**Mort = Cause**", where Cause is abbreviated as follows: suppression (Supp), mechanical (Mech), slope failure (Slide), root rot (Rot), dogwood anthracnose (Dogwood a.), animal damage (Animal), unknown (Unkn), or fire (Fire). See **Table 5** for definitions and descriptions of non-fire related causes of mortality used in previous assessments. Fire represents a new agent of mortality (see details below).

Table 5. Definitions/descriptions of non-fire related causes of mortality (Lutz & Halpern 2006).

Cause of mortality	Description
Suppression	Common in small/subordinate stems whose growth has been suppressed (manifested as minimal diameter growth since the previous measurement and minimal leader/branch growth). No sign of physical damage or pathogens.
Mechanical	Results from wind or snow loading; includes stems uprooted or snapped, and stems snapped or crushed by other uprooted or broken stems.
Slope failure	Uprooting of stems associated with slope failure.
Crushed by old-growth	Old-growth tree falling into a plot from the adjacent forest (rare event).
Pathogens (root rot or dogwood anthracnose)	Two fungal pathogens have been observed: root rot and dogwood anthracnose (*Discula destructiva*). Symptoms of root rot in conifers: gradual loss or chlorosis of needles in non-suppressed trees, absence of physical damage to boles/bark, and mortality in clumps. Although field crews could not identify fungal species, visits to infection centers in 2004 verified presence of *Armillaria ostoyae* (native pathogen). Symptoms of dogwood anthracnose (affecting *Cornus nuttallii*, CONU4): distinct brown spotting, senescence of leaves with eventual dieback of twigs/entire stems.
Animal damage	Tree with obvious signs of browsing damage and stripped bark exposing the cambium.
Unknown	Insufficient evidence to assign a cause

Ascribing mortality to the 2020 fire. Ascribing mortality to fire may be confounded by other wind-related damage that occurred prior to fire: (1) a "snow-loading" event in early 2020 that led to windthrow and (2) a strong easterly wind that drove the fire, causing windthrow (most likely along the ridgelines of WS1). As a result it may be difficult to separate wind- from fire-related mortality. **For plots that burned in 2020**, we will use the characteristics of dead trees—as outlined in **Table 6**—as criteria for deciding whether mortality was due to fire or to other causes.

Table 6. Criteria used to ascribe mortality to fire vs. other causes. **Applies only to plots that burned.**

Tree conditions	Cause of mortality
Standing, newly dead; no evidence of burning	Not fire; see Table 5 for alternatives.
Standing, newly dead; deep burning on the bole	Fire; Mort = Fire
Bole snapped, newly dead; with or without evidence of fire	Snow or wind damage; Mort = Mech
Tree down, newly dead; exposed roots that are charred	Windthrown prior to fire; Mort = Mech
Listed as MP = B in 2017 (thus, not assessed in 2019); vigor (Ov) = 1 in 2017; tree not found in 2021, tag found on the ground or missing; plot burned at high severity	Consumed by fire; Mort = Fire.

4. Tagged trees that cannot be found (missing). Before leaving a plot, check that all trees are accounted for and that all data are properly recorded. Search again in the appropriate quarters using near tag #s (if available) as clues to where the trees might be. If a tree is still missing there may be several explanations, depending on whether the plot burned or not. Consider the following:

Unburned plots:

- **Tree was missing in 2017 or 2019 and remains missing in 2021 (Status = 9).** If a previously missing tree can't be found, record Status (**St**) as "9" and add the comment: **"Still missing in 2021".**
- **Tree may have been listed in the wrong quarter # (Q) or had two tags.** Sometimes, a tree is listed in the wrong quarter # or it has two tags (a new tag replaces an old tag but both remain on the data form). If you find a tree with two tags and have data for the first, make a note in the **Comments column** for the second tag #: "**Same as tag # ___, tag removed**". Leave the remaining data columns blank for the second tag # and remove the second tag from the tree.
- **Tree is alive or dead and has dropped its tag; tree is alive but has fallen; or tree has been crushed/buried by another stem**. In the area where there are adjacent tag #s in the tag series, look for a dead or fallen tree or for a tag on the ground near an untagged tree. Check if an old nail hole exists on a candidate tree. If there is strong evidence that you have found the tree—i.e., it is alive, lacks a tag, is the right species, is in the right quarter #, the diameter is reasonable—retag it with a temporary tag inscribed with the original tag #, and take the necessary measurements. Add a comment about the tree's condition, the addition of a temporary tag, and the need for a new tag (NNT). If the candidate tree is dead (standing or down), don't retag it but follow the directions above for scenario "**3. Tagged trees that have died since the last remeasurement**". Add a comment that the tag was missing and not replaced.
- **Tree is alive, has dropped its tag, and has been mistakenly tagged as ingrowth.** Return to the area of the appropriate quarter where there are ingrowth. Consider which ingrowth share the missing tree's characteristics (species, diameter, and conditions). If you are confident that you have found the tree (same species, reasonable diameter, adjacent to previously tagged trees with tag #s close in sequence), clip the head off the nail (for Dbh trees) or clip the zip-tie (for Dba trees), remove the tag, and add a temporary tag inscribed with the original (missing) tag #. Record the appropriate data (**Dba** or **Dbh**, **St**, **Ov**) on the Tagged tree form with a comment that the tree was found without a tag, assumed to be the "missing" tree, assigned a temporary tag, and needs a new tag (NNT). Comment on any other unusual feature of the tree (see abbreviations in **Table 4**). **Be sure to cross out the erroneous entry on the Ingrowth form.**
- **Tree is missing but you are not sure why.** If, after a reasonable search, a tree is missing for the first time record Status (**St**) as "9", leave the remaining columns blank, and add the comment, "**NFAS**" (not found after search).

<u>Burned plots</u>:

- **Tree was consumed by fire.** In severely burned plots, small trees (MP = B) may have been consumed by fire, leaving no evidence. Tags may have melted or may be on the ground (see **Table 6**, last case). If you conclude that a small tree was consumed by fire, record Status (**St**) as "6", leave **Bark char** and **% Canopy scorch** blank and, depending on whether the tag was found, add the comment: **"Tree not found, likely consumed by fire; tag not found (or tag found/left on ground); Mort = Fire".** If the tag was found, leave it where you found it.
- **Tree was killed by fire; stem remains.** If you find a charred, recently killed tree without a tag (or a tag on the ground) and it is in the appropriate quarter with the appropriate characteristics, record Status (**St**) as "6", assess **Bark char** and **% Canopy scorch** following the methodology on pages 17-20 and, depending on whether the tag was found, add the comment: **"Tree likely**

found, killed by fire; tag not found (or tag found/left at tree base); Mort = Fire". If the tag was found, leave it at the base of tree.

5. Ingrowth: trees without tags but ≥ 1.37 m tall

Trees without tags that have reached the threshold height of 1.37 m (or length if leaning) are considered ingrowth. Data are recorded on the blank form, **WS1-3_Ingrowth trees**. However, first check that the tree does not have a tag wired/zip-tied in an inconspicuous location, or that its tag has not fallen to the ground. Before you tag an ingrowth tree, be sure that the tag # is not listed in the plot.

- **For a small-diameter tree requiring a wire or zip-tie on a side branch**
  (a) Wire or zip-tie the new tag onto a sturdy (upward-arching) limb facing plot center
  (b) Record quarter # (**Q**), **Tag #**, **Near tag #**, species (**Spp**), measurement point (**MP** = **B**), diameter (**Diam**), and overall vigor (**Ov**).
  (c) Comment on tree condition and/or location as needed.
- **For a larger diameter trees whose tag can be nailed at breast height**
  (a) Nail the new tag at breast height (side-slope) facing plot center
  (b) Record quarter # (**Q**), **Tag #**, **Near tag #**, species (**Spp**), measurement point (**MP** = **H**), diameter (**Diam**), and overall vigor (**Ov**).
  (c) Comment on tree condition/location as needed.

Important note: if there are no ingrowth in a plot, complete the plot header on the **WS1-3_Ingrowth trees** form and write in large letters across the page: "No ingrowth". Every plot should have an ingrowth form with a completed header; this serves as a check for missing forms. Record page #s at the bottom of the form. The numbering of Ingrowth pages is distinct from that of the Tagged tree forms.

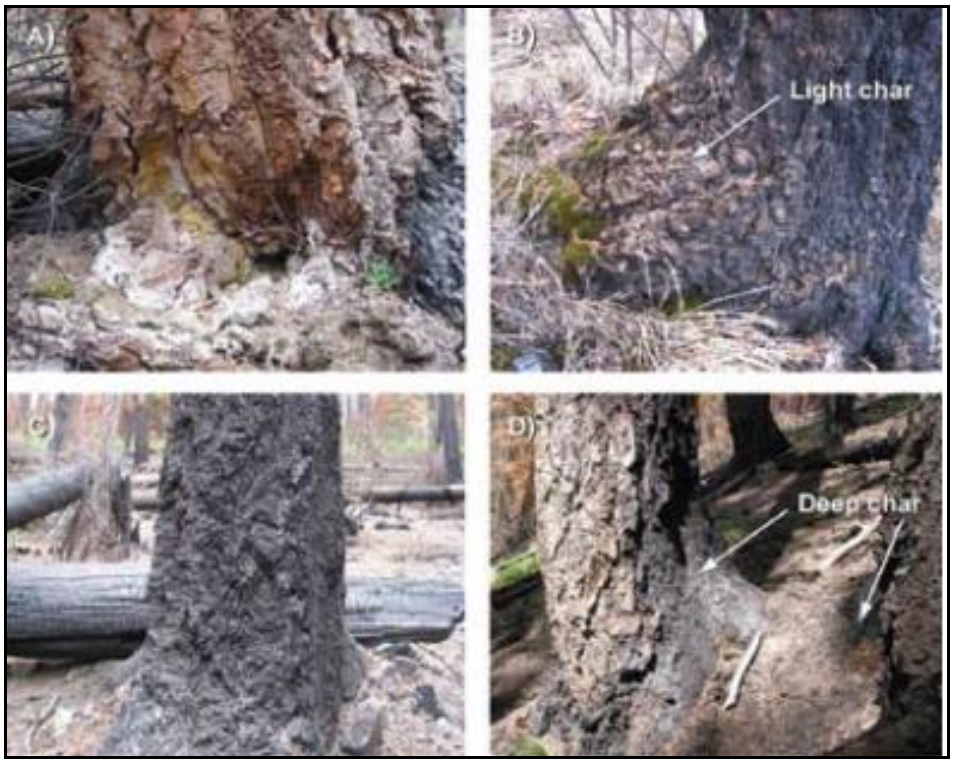
Method for Assessing Bark Char

Bark char, which serves as a proxy for cambium damage or kill, will be assessed **at ground level** in a 2.5-cm band around the bole of the tree. Degree of charring is often lighter higher on the bole than at ground level. With low-severity fire (only the duff or litter layer burned), charring may be limited to a short height on the bole (see photo, next page). However, high-severity fire may consume the original duff and litter layers, lowering the ground surface, and exposing tree roots (see photo, next page). In this situation, bark char should be assessed as close to the original ground level as possible (char on newly exposed roots should not be assessed).

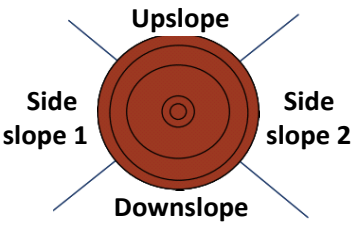
For larger trees (≥10 cm Dbh), four quadrants of the bole are rated for severity: Upslope (Up), Downslope (Down), and Side-slope 1 (S1), and Side-slope 2 (S2) (see figure below). **For smaller trees (<10 cm Dbh)**, only the Up and Down quadrants are rated; leave S1 and S2 blank.

Four possible ratings, from **U** to **D,** correspond to increasing burn severity (see Ryan 1982):

- **Unburned (U**): not burned
- **Light (L)**: evidence of light scorching; can still identify species based on bark characteristics; bark is not completely blackened; edges of bark plates charred.
- **Moderate (M)**: bark is uniformly blackened except possibly some inner fissures; bark characteristics are still discernible.
- **Deep (D)**: fire has burned into bark but not necessarily wood; outer bark characteristics are lost.



Left: Four classes of bark char severity on Douglas-fir. (**A**) unburned, (**B**) light char, (**C**) moderate char, (**D**) deep char (photos from Hood et al. 2007).



Above: Four quadrants of the bole used to rate bark char at ground level: Upslope (U), downslope (D), Side-slope 1 (S1), and Side-slope 2 (S2). For trees <10 cm Dbh, rate only the U and D quadrants.

Left: Sharp transition between unburned (higher on the bole) and moderate bark char (ground level). Always examine the bark nearest to the ground (2.5 cm band). Here, orange piles of boring dust indicate the presence of Douglas-fir beetles.

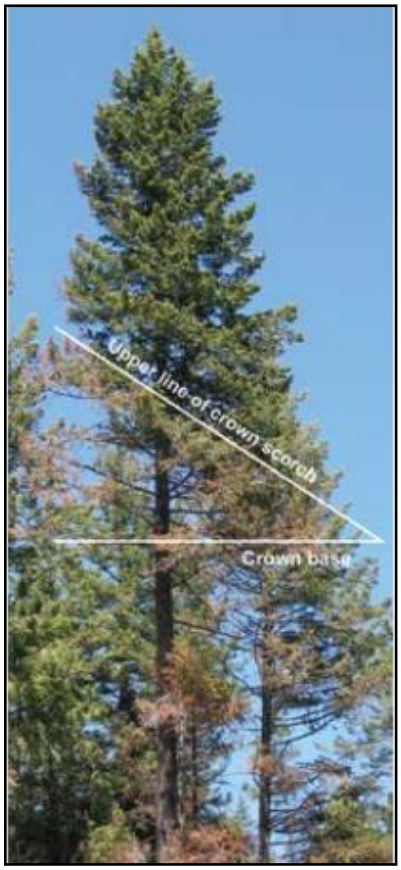
Right: Example of high severity fire that consumed the litter and duff layers, lowered the ground surface, and exposed tree roots. Bole char is assessed at the former ground surface.

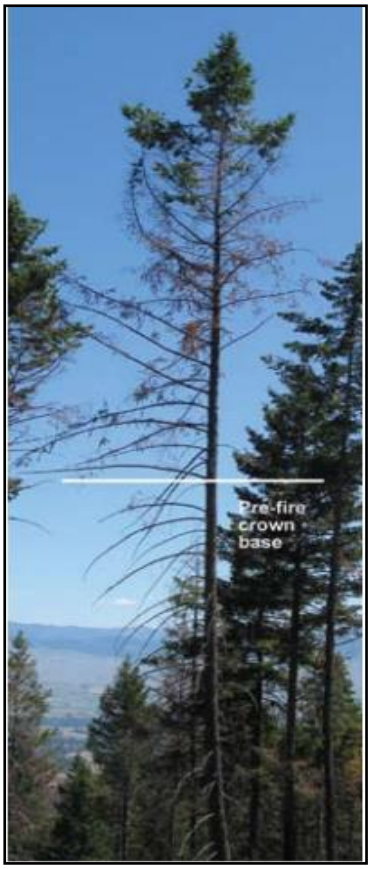
Method for Assessing Crown Volume Scorch (% Scorch)

For each tree, % crown volume scorched (**% Scorch**) is a visual estimate of % of pre-fire crown volume killed or consumed by fire. The objective is to estimate the volume of live crown killed (scorched or consumed) by direct contact with flames or convective heating. Visual examples from Hood et al. (2007) are provided below. Because scorched/blackened needles fall within a year, crown scorch should be assessed within 1 year of the fire. We are assessing crown scorch 9-10 months after burning.

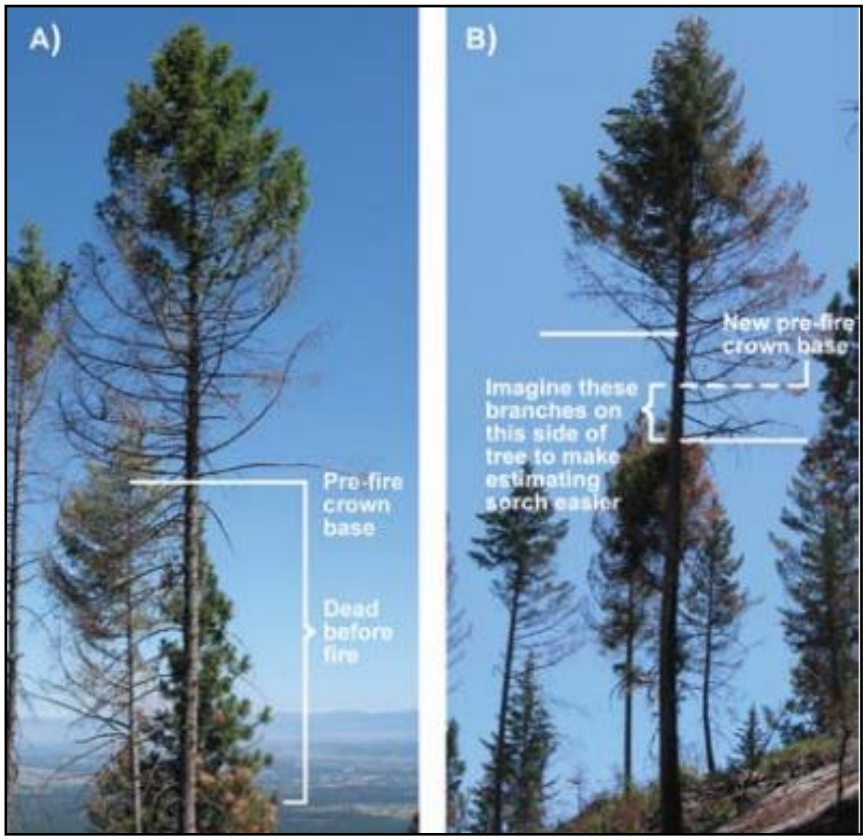
Evaluating crown scorch as you measure diameters and check for ingrowth will be challenging and time consuming. It will take at least two individuals to assess crown scorch.

- Position yourself such that the entire tree crown is visible. Optimally, the crown should be viewed at right angles to the direction of fire spread, against a blue sky. It is important to stand at a distance that allows a view of the entire crown.
- Reconstruct how the crown appeared pre-fire. Pre-fire crown volume can be estimated from the fine branch structure and needles. Branches lacking fine twigs were likely to be dead before the fire.
- Assess the overall appearance of the crown and estimate the % of crown volume killed by the fire based on your perception of the pre-fire crown. This includes areas with brown "frozen" needles and areas with blackened fine branches. Blackened twigs may have some blackened needles remaining. Binoculars may be needed to view fine twigs and buds.
- At least two individuals should assess scorch on each tree. Each should estimate the percentage of pre-fire crown volume scorched or consumed to the nearest 10%. If the observations differ by 20% or less, record the average of the two. If the observations differ by more than 20%, a consensus must be reached. This may require a reassessment of scorch from a different angle.





Left: Douglas-fir with 20% crown volume scorched. The scorch on this tree is higher on the left than on the right, shown by the diagonal line delineating uppermost scorch. This pattern of scorch is common in steep areas. **Right: Douglas-fir with 80% crown volume scorched.** Photos are from Hood et al. (2007).



Douglas-fir with 50% crown volume scorched. **(A)** The short, lower branches of this tree were dead before the fire and should not be included in the assessment. Branches that were dead prior to fire will not have fine twigs and often will be broken off. **(B)** The bases of tree crowns may not be symmetrical. It may help to "move" some lower branches to the opposite side of the crown to "even out" the crown base. Then estimate % crown volume scorch based on this new shape. Photos are from Hood et al. (2007).

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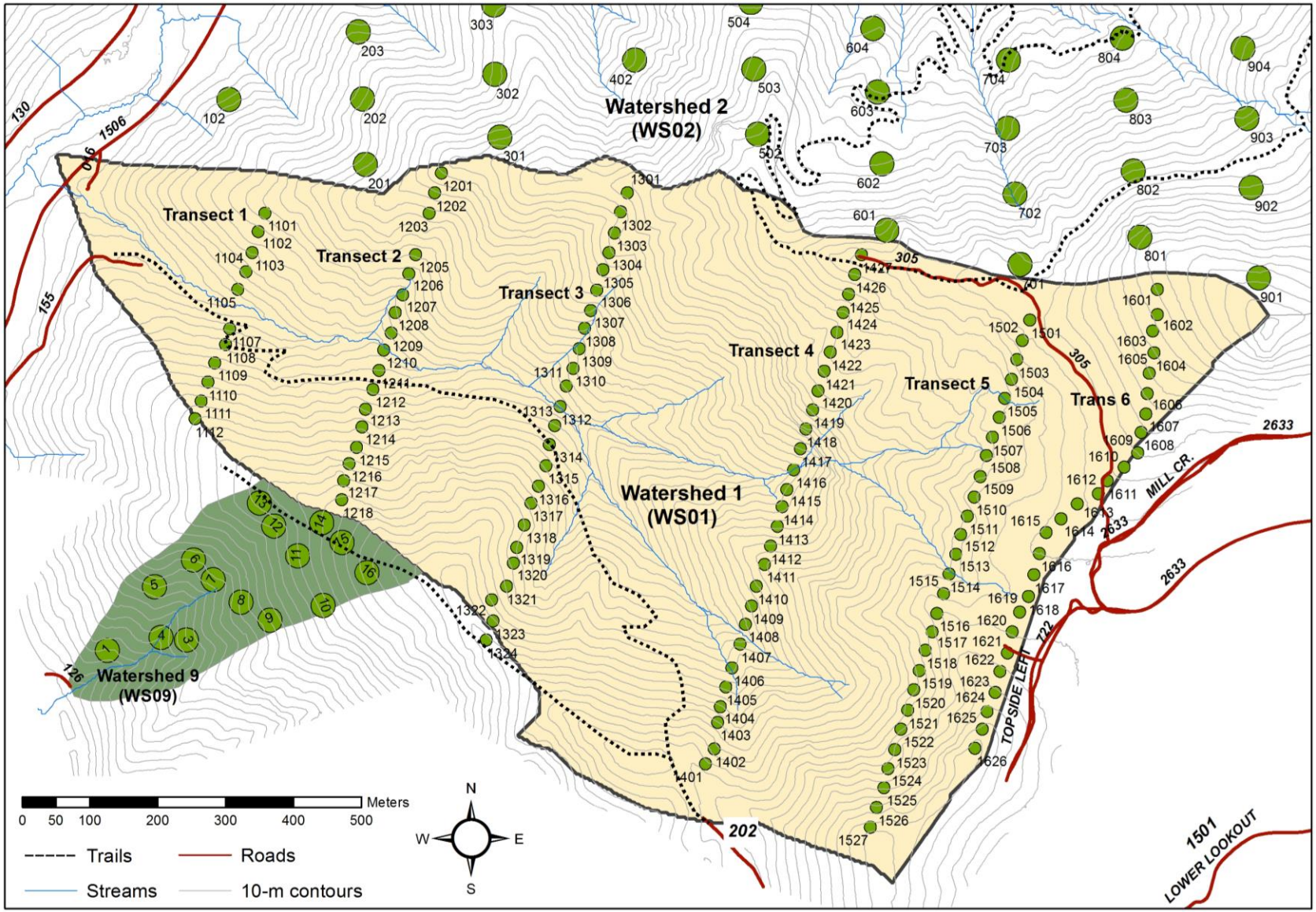
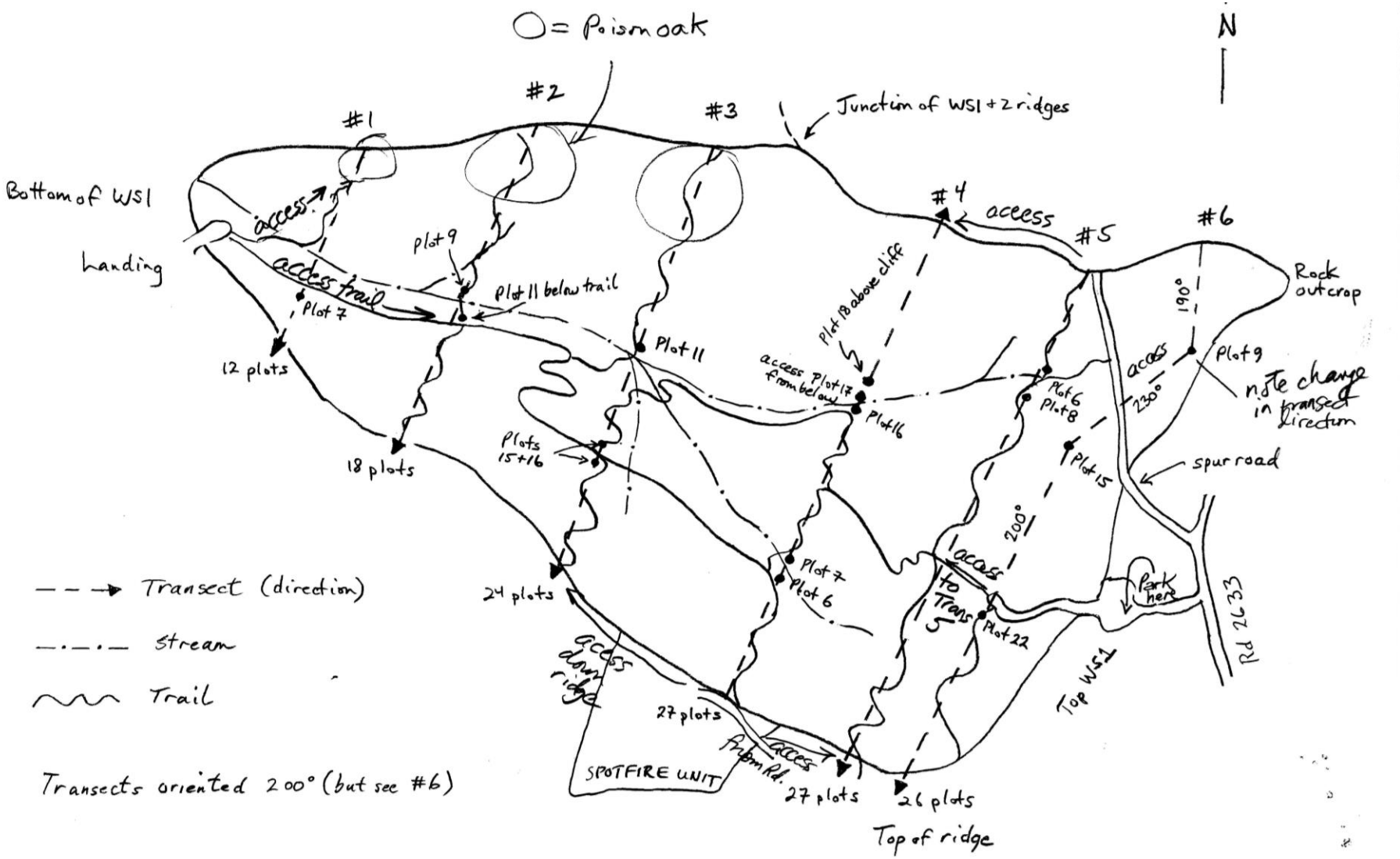
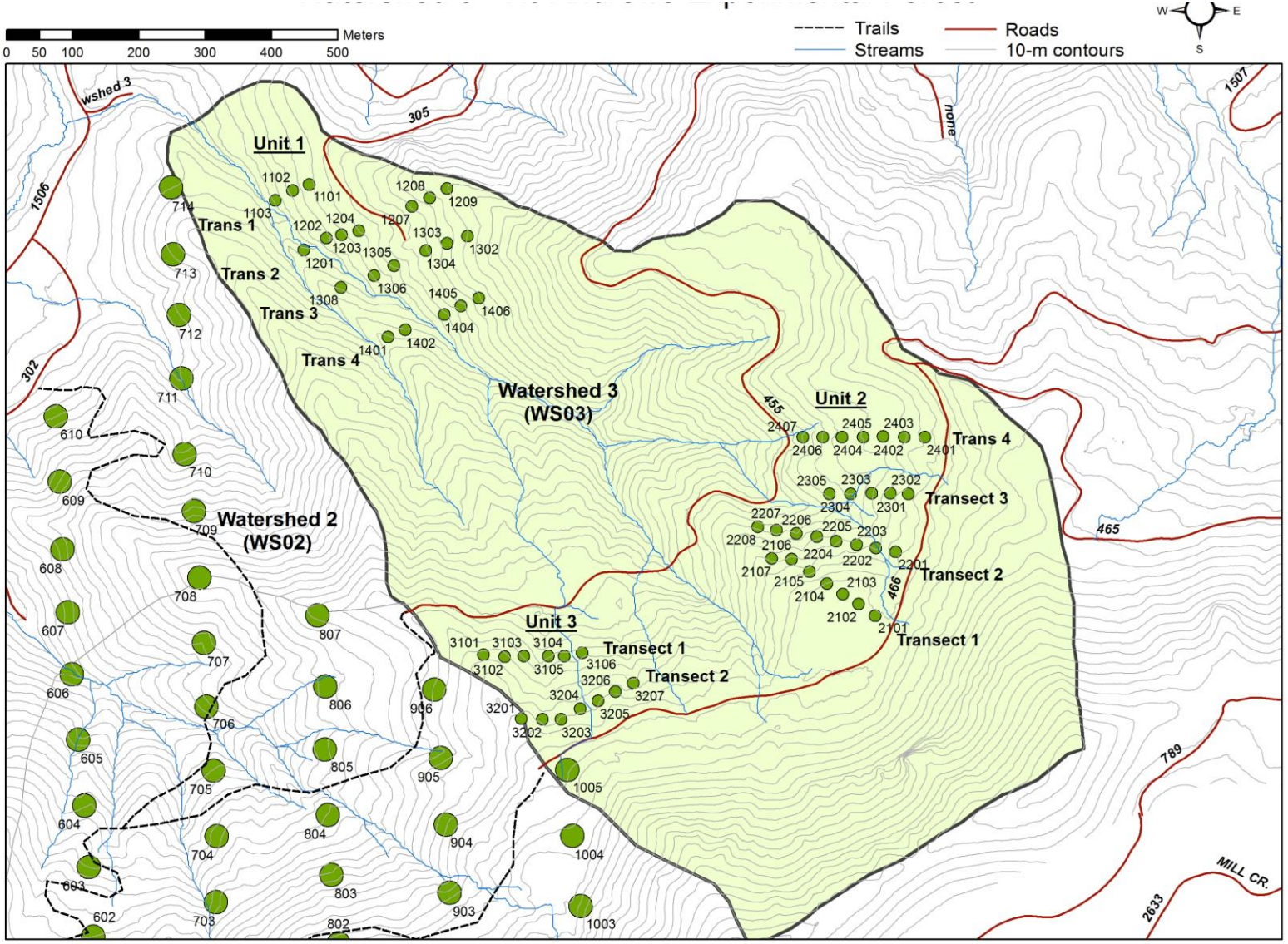
WS1. Locations of Roads, Trails, Transects, and Plots



WS1. Annotated Transect and Plot Map



WS3. Locations of Roads, Trails, Transects, and Plots



WS3. Annotated Transect and Plot Map