FiniteCarbon

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CONNECTING FORESTRY AND CARBON FINANCE

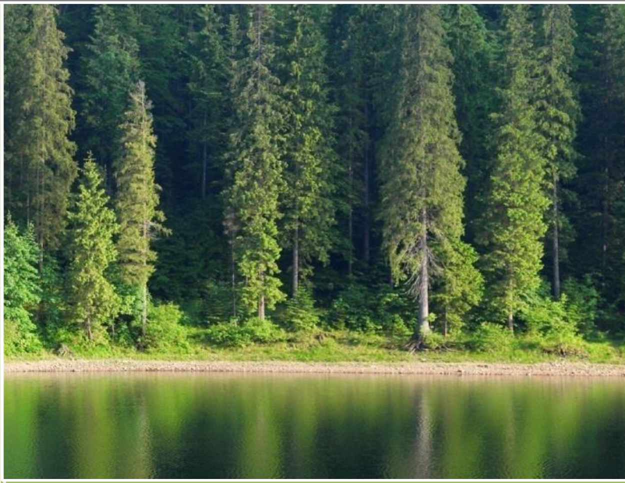
Appendix A. ACR554 Inventory and Modeling Methodology "Finite Carbon – Opal Mountain Ranch IFM"

CA EPA Air Resources Board Compliance Offset Protocol

U.S. Forests Projects: Improved Forest Management

Adopted: June 25, 2015

Initial Reporting Period: 07/30/2020 – 01/30/2021
OPR Project ID#: ACR554
ARB Project ID#: CAFR5554



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Introduction

California's Cap and Trade Regulation ("Regulation") took effect on January 1, 2012, with amendments to the Regulation effective September 1, 2012. The enforceable compliance obligation began on January 1, 2013. The Air Resources Board (ARB) has developed and implemented a compliance offset program as part of the State's Cap and Trade Program. Covered entities may use a limited number of ARB offset credits to fulfill up to 8% of their compliance obligation. Offset credits are tradable compliance instruments that represent verified greenhouse gas (GHG) emission reductions or removal enhancements made in sectors and sources not covered by the Cap and Trade Program.

The ARB U.S. Forest Projects Compliance Offset Protocol adopted on October 20, 2011 ("Forest Offset Protocol"; "Protocol"; "FOP") provides requirements and methods for quantifying the net climate benefits of activities that sequester carbon on forestland. The protocol provides offset project eligibility rules; methods to calculate an offset project's net effects on GHG emissions and removals of CO_2 from the atmosphere (removals); procedures for assessing the risk that carbon sequestered by a project may be reversed (i.e. released back to the atmosphere); and approaches for long term project monitoring and reporting. The goal of this protocol is to ensure that the net GHG reductions and GHG removal enhancements caused by an offset project are accounted for in a complete, consistent, transparent, accurate, and conservative manner and may therefore be reported as the basis for issuing ARB or registry offset credits. The protocol is built from The Climate Action Reserve's Forest Project Protocol Version 3.2. This project was developed under the updated version of the FOP adopted on June 25, 2015, and in compliance with the Regulation adopted April 1, 2019.

Finite Carbon is a forest carbon project developer specializing in the creation and monetization of forest carbon offsets. Combining unparalleled project development experience with extensive carbon market knowledge, Finite Carbon offers the most comprehensive forest carbon project development and commercialization service in the United States. With an in-house team of forest carbon experts, Finite Carbon provides all the expertise and resources for successful implementation of forest carbon inventories, project design, verification management and monetization of carbon offset.

This document is the primary appendix to the Offset Project Data Report (OPDR) for *Finite Carbon – Opal Mountain Ranch IFM* ("OMR"), assigned by the American Carbon Registry, which is an ARB approved Offset Project Registry (OPR), as Project ID: ACR554. The OPDR and all other project documentation and reports that reference carbon stocks have been prepared and submitted by Steve Dettman, SAF Certified Forester (No. 4019) and Brian Sharer, SAF Certified Forester (No. 53906) and satisfies the professional forester[1] requirements outlined in the FOP, section 7.2.

Inventory Overview

This section describes the inventory data collection specifications and is one part of the comprehensive forest carbon inventory methodology used for the project. The 'Sampling Methodology' section remains formatted as the instructive inventory specifications document provided to the contractor who performed the original project inventory. Additional footnotes have been inserted to provide clarifications and supplementary information as needed for this OPDR appendix.

The OPO, Opal Mountain Ranch LLC, commissioned the following forest inventory for this project totaling approximately 14,106.5 forested acres in central Oregon. The project boundary is defined by the boundary and strata shape files provided with this specification document.

[1] The project is located in a jurisdiction (State of Oregon) without a Professional Forester law or regulation; accordingly, oversight by a SAF Certified Forester has been employed to maintain professional standards and project quality.

The purpose of this forest inventory was to quantify the forest carbon stocks of the standing living and dead tree carbon pools in the project area for enrollment as an improved forest management carbon offset project. The procedures described herein shall also be the guiding basis for the collection of future inventory data annually and/or periodically throughout the project life. This inventory was conducted in a manner that is verifiable, facilitates modeling, and is replicable. All inventory data collected was audited for accuracy both by the primary contractor, Finite Carbon, and a third-party auditor.

Project Area Background

The Opal Mountain Ranch has been managed for recreation, grazing, and timber production over many decades. The Project Area is comprised of several large blocks of multiple-use ranchland and forestland in central Oregon. The species composition is primarily western juniper, mountain mahogany, ponderosa pine, and Douglas-fir. The forest project lies in the 6b climate zone as shown of the USDA Plant Hardiness Zone mapping for the region.

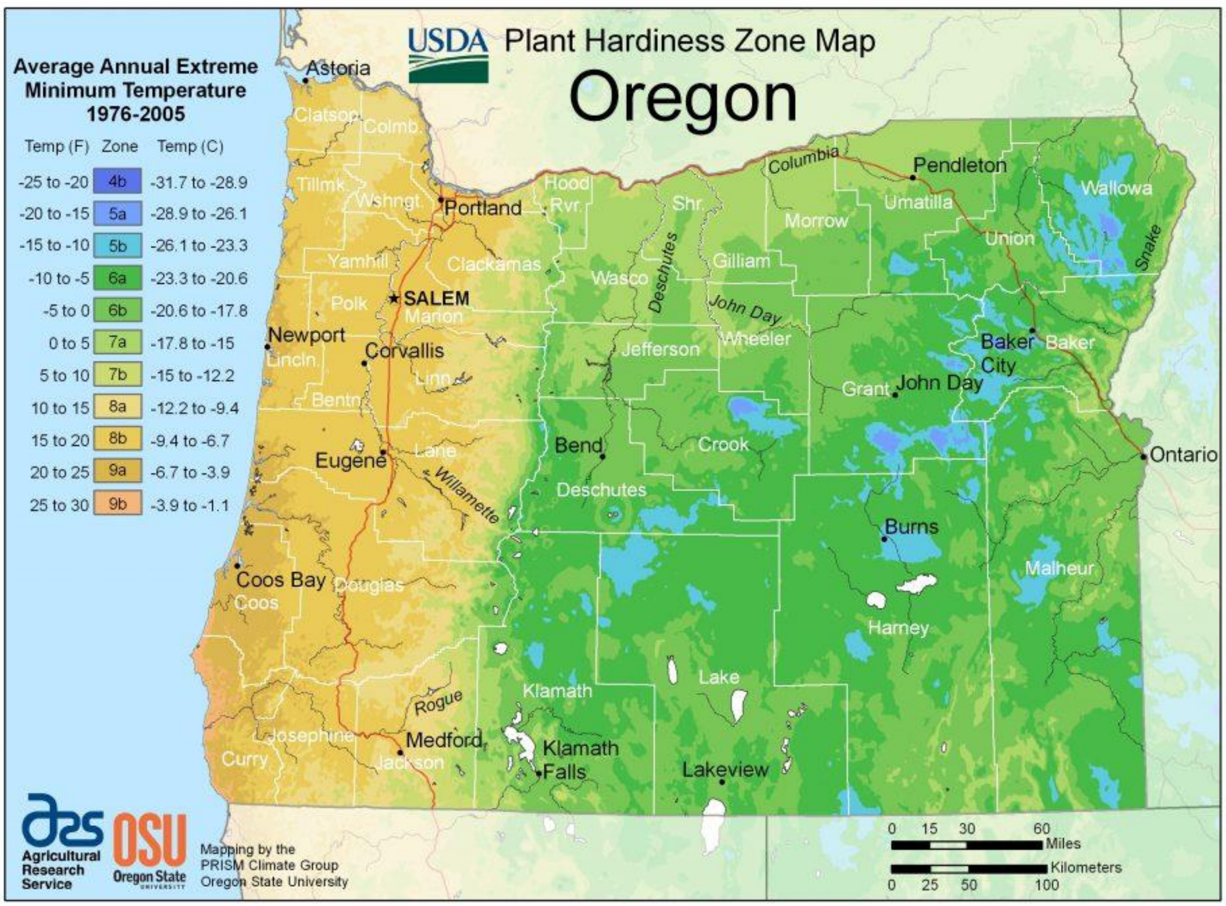


Figure 1. Plant Hardiness Zones (source: https://planthardiness.ars.usda.gov/)

Further review of a series of publicly available aerial imagery taken over time indicates that land use change pressure in this region is moderately low with little to no residential development and only minor changes to other land uses from ranchland and forestland. Stands within age classes less than 20 years are approximately 9% of the total project area. Topography across the project area is steep and ranges between 3,500 and 5,500 feet above sea level. The property is owned by Opal Mountain Ranch LLC, which is a timberland investment entity affiliated with the Lyme Timber Company.

The primary purpose of the inventory is to accurately quantify the onsite forest stocks of the standing living and dead tree carbon pools in the project area for registration and approval as a forest carbon offset project with the California Air Resources Board compliance offset program. This inventory shall be conducted in a manner that can be verified, facilitates growth and yield modeling, and is replicable. The following inventory procedures will be the guiding requirements for future inventory work done on this site to comply with the offset program, including updates of sample data done as forests are affected by management annually and periodically.

Inventory data collected will be independently and/or jointly audited by the contractor and Finite Carbon for accuracy. As all carbon claims for this project site will also be independently verified at a later date by an ARB accredited verifier, the accuracy and precision of the data collection for this project is paramount to project success for the landowner.

Description of the Offset Project's GHG Assessment Boundary

Table 1. GHG Sources, Sinks, and Reservoirs

SSR	Description	Type	Gas	Quantification Method	Justification/Explanation
Primary Effect Sources, Sinks, and Reservoirs					
IFM-1	Standing live carbon (carbon in all portions of living trees)	Reservoir / Pool	CO_2	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by field measurements and updating forest carbon inventory The methodology described in Cairns, Brown, Helmer, & Baumgardner (1997) at the plot level was used to estimate below-ground biomass density based on above-ground biomass density in tons per hectare. Application of Cairns was applied consistently for both baseline and project activity.	Increases in standing live carbon stocks are likely to be the largest primary effect of Improved Forest Management Projects.
IFM-3	Standing dead carbon (carbon in all portions of dead, standing trees)	Reservoir / Pool	CO_2	**Baseline:** Modeled based on initial field inventory measurements **Project:** Measured by updating forest carbon inventory	Improved Forest Management Projects may significantly increase standing dead carbon stocks over time.

				The methodology described in Cairns, Brown, Helmer, & Baumgardner (1997) at the plot level was used to estimate below-ground biomass density based on above-ground biomass density in tons per hectare. Application of Cairns was applied consistently for both baseline and project activity.	
IFM-7	Carbon in in-use forest products	Reservoir / Pool	CO_2	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes	Included because many Improved Forest Management Projects may significantly change carbon storage in in-use forest products relative to baseline levels. Treated as a "source/sink" because forest product carbon is quantified according to the change in harvesting volumes, relative to baseline levels, in each year. Of this change (increase or decrease), only the average amount of carbon expected to remain stored for 100 years is included in the final quantification of annual net GHG removals/emissions. This approach accounts for CO_2 emissions from decomposition or disposal of wood products (see SSR #IFM-17).
IFM-8	Forest product carbon in landfills	Reservoir / Pool	CO_2	**Baseline:** Estimated from modeled harvesting volumes **Project:** Estimated from measured harvesting volumes	Because of significant uncertainties associated with forecasting the quantity of forest product carbon that will remain stored in landfills, landfill carbon is excluded from quantification in years when project harvesting volumes exceed baseline volumes. Landfill carbon is included, however, in years when project harvesting volumes are below baseline levels. This case-dependent exclusion or inclusion is necessary to ensure that total GHG reductions and removals caused by the Forest Project are not overestimated.
Secondary Effect Sources, Sinks, and Reservoirs					
IFM-9	Biological emissions from site preparation activities	Source	CO_2	**Baseline:** N/A **Project:** Quantified based on measured carbon stock changes in included	Biological emissions from site preparation are not quantified separately, but rather are captured by measuring changes in included carbon reservoirs (soil carbon, where

				reservoirs (SSR #IFM-6, where applicable)	applicable). For other carbon reservoirs, changes are unlikely to have a significant effect on total quantified GHG reductions/removals.
IFM-14	Biological emissions/ removals from changes in harvesting on forestland outside the Project Area	Source / Sink	CO_2	**Baseline:** N/A **Project:** Estimated using a default 20% "leakage" factor applied to the difference in harvest volume relative to baseline	Improved Forest Management Projects may either increase or decrease harvesting relative to baseline levels. If harvesting is reduced in the Project Area, harvesting on other lands may increase to compensate for the lost production. This "leakage" effect is included in the GHG Assessment Boundary. If harvesting is increased in the Project Area, harvesting on other lands may decrease in response to the increased production. The reduction in harvesting may lead to increased carbon stocks on other lands. Carbon stock increases on other lands are excluded from the GHG Assessment Boundary, however, because it is not possible to ensure their permanence.
IFM-17	Biological emissions from decomposition of forest products	Source	CO_2	**Baseline:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #IFM-7) and landfills (SSR #IFM-8) **Project:** Quantified as a component of calculating carbon stored for 100 years in wood products (SSR #IFM-7) and landfills (SSR #IFM-8)	CO_2 emissions from the decomposition of forest products are built into calculations of how much forest product carbon will remain in in-use wood products and in landfills, averaged over 100 years.

Sampling Methodology

The project inventory design is based on the requirements for volume and biomass calculation as listed in the volume and biomass equations approved for use by the California ARB U.S. Forests Compliance Offset Protocol. Finite Carbon developed the following sampling design to be implemented to reduce overall sampling error and optimize the carbon results for the forest owner. The language below represents the requirements and guidance given to the inventory crew before they went to the field. As a result, verb tenses in this section indicate a future time frame, even though the work has been completed.

Inventory Design

The inventory design is based on the requirements for volume and biomass calculation as listed in the volume and biomass equations approved for use by the California ARB U.S. Forests Compliance Offset Protocol. Finite Carbon developed the following sampling design in an effort to reduce overall sampling error and thereby optimize the carbon results. The instructions that follow were provided to the inventory crew prior to completing their work.

Sampling Method for all samples involved with this inventory will be a 1/10 acre (37.2 foot radius) fixed radius sample plot for all stems 5.0 inches DBH and larger and a 1/150 acre (9.6 foot radius) fixed radius plot for all stems equal to or greater than 1.0 inch DBH and less than 5.0 DBH. All eligible standing living and standing dead trees shall be tallied. Definitions for eligibility are provided later in this document. All borderline trees will be measured to the geometric center of the base or point of origin of the tree using approved devices, including slope adjustments for slopes of 10% and greater in accordance with guidance provided later in this specification document. Walk though plot techniques will be used for samples on mapped non-forest edges or boundaries.

Table 2: Fixed Plot Description

Plot Radius	Tally Measurement
1/150th acre (9.6' radius)	All live trees: equal to or greater than 1.0" and less than 5.0" DBH; All dead trees: equal to or greater than 1.0" and less than 5.0"DBH and total height equal to or greater than 15'
1/10th acre (37.2' radius)	Live trees: equal to or greater than 5.0" DBH; Dead trees: equal to or greater than 5.0" DBH and total height equal to or greater than 15'

Sampling Intensity has been determined as **279** total nested samples across the project site. Sample intensity was established based on the variability of existing plot data. All sample locations have been pre-determined randomly on field maps and have been assigned GPS coordinates.

Statistical Standards of Inventory will be a minimum of +/- 5% of total carbon volume expressed at the 90% confidence interval for forest stratum on the project. If, after processing, the original sample does not yield the target statistical targets, additional samples may be commissioned on a per plot basis until the target statistical results are realized. All additional samples will be located randomly using GIS forestry tools.

Edge Plots shall be collected using the "walk through" procedure (Ducey, et. al., 2004). Obvious potentials locations for walk-through plots will be labeled on the plot map for cruisers in advance of field activities.

In order to be eligible for this procedure, the hard edge must fall within two plot radii of the edge. If a plot falls wholly within the sample frame but within two plot radii, use the walk-through method and denote the plot as being within the sample frame in the notes. Cruisers are directed to implement the walk-through technique on hard edges such as mapped non forest areas, strata boundaries where the timber type change is abrupt (i.e. pine plantation to hardwood, etc.), marked property boundary lines, etc. In some cases, cruisers will also be given a bearing and distance to the edge in advance of field activities. If the actual bearing and distance to the edge differs in the field, note that in the tally with the new metrics.

On every plot, when a hard edge is encountered, this method should be followed for any "in" tree along the edge:

- Measure the distance from the sample point (plot center) to the geometric center of the point of origin of the tree. Then, duplicate that distance in a straight line through the other side of the tree. If the doubled distance intersects the hard edge, then record that tree twice.
- Record as two identical measured trees with 2 separate tree numbers.

- If the measured distance across a narrow hard edge or double edge (such as a truck road, swamp, or wide non forest stream) is encountered, measure the full doubled distance for the edge tree.
  - If the location is in the narrow non forest area (in the road), **count the tree twice**
  - If the location is across the feature and back into the sample frame for the same strata the plot center falls in, **do not count it twice**
  - If the location is across the feature and back into the sample frame for a different strata the plot center falls in, **count it twice**

Guidance: Every hard edge is considered an absolute boundary of the sample frame (like a property boundary line). Trees within the plot radius that fall across the hard edge (if within the sampling frame) are NOT eligible and thus, not tallied. Also, the plot radius itself does not have to be intersected by the hard edge. The key measurements of the walk-through procedure are defining where the hard edge is located and then the distance from plot center to the tree of interest and extending that distance through the tree in a straight line to determine whether or not the walk-through distance intersects the hard edge.

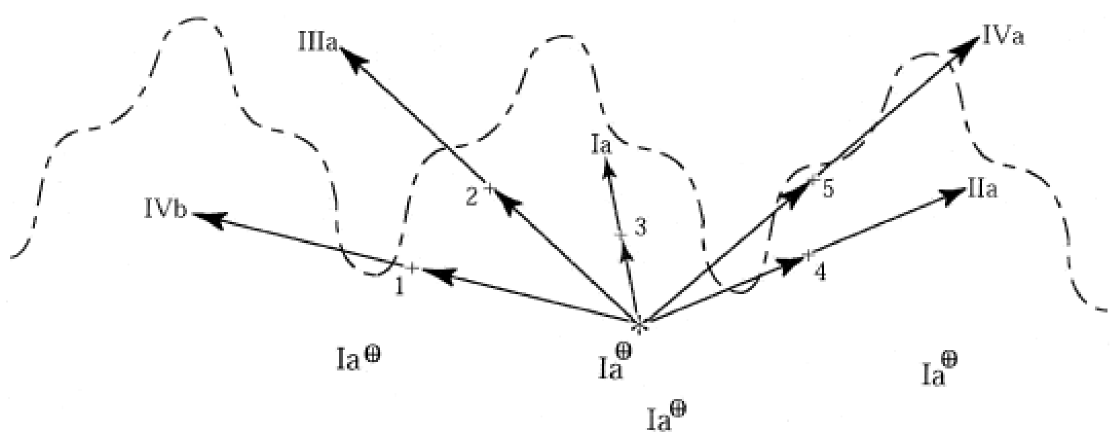


Figure 5. Graphic illustration of the walkthrough method. Five sample objects (+), lying close to the boundary, have been tallied from a sample point (*). The arrows indicate the layout of the walk-through points for each object; the outcome on the key in Table 1 is indicated for each walkthrough point. Objects 1, 3, and 4 are tallied normally; objects 2 and 5 are double-tallied. Four objects (⊕) lie "close to the boundary" but in positions where they would be single-tallied, and no measurements would be needed.

Table 1. A decision key for field implementation of the walk-through method. The key is entered whenever a tallied object appears close to the boundary.

I. Is it possible that the tallied object is closer to the boundary, than to the sample point?
- Ia. NO—No action needed. Tally the object normally.
- Ib. YES—Proceed to II.

II. Measure the distance from the sample point to the object—call this distance *x*. Now measure the distance from the object to the boundary, continuing on the same bearing. Call this distance *y*. Is *y* less than *x*?
- IIa NO—No action needed. Tally the object normally.
- IIb. YES—Proceed to III.

III. Does the boundary curve back across the walkthrough line?
- IIIa. NO—Walkthrough point must be outside the tract. Double-tally the object.
- IIIb. YES—Proceed to IV.

IV. Move to the walkthrough point, so that the distance to the object equals the previously measured distance *x* along the same bearing, or to a point where that location can be clearly identified. Is the walkthrough point inside the tract?
- IVa. NO—Double-tally the object.
- IVb. YES—Tally the object normally.

Figure 2: Ducey, et. al. 2004

Monumentation of walk-through plots shall include a flagged and or painted line (at least three marked points) where the edge is declared. This required monumentation will be checked during the plot audits. When declaring an edge location, cruisers should look for obvious physical features like the top of the ditch line on a road, edge of a river bank or lake shore, or in cases where the edge is forest to forest, the drip line or edge of the canopy for the polygon the plot center falls in. It is impossible to escape the use of good judgement on the part of the cruiser in this task as edges take many configurations. In some instances, the edge location may be an estimate based on these principles. Any trees double tallied using the attached procedures shall receive two tree numbers painted above DBH. The tree will be entered twice in the tally in accordance with the assigned tree numbers.

> **Guidance:** Cruisers may also run into plot locations where non forest area or strata edges are incurred unexpectedly (not previously designated on mapping). If a cruiser questions whether or not to install a walk through plot at any location they are to cruise, monument, and tally the plot normally (no walk through trees), flag the potential edge, and designate any potential double count trees in the notes section of the tally only. All plots executed in this manner must be brought to the attention of Finite Carbon at the completion of the inventory. On any plot where a walk-through procedure is used, the cruiser is asked to provide a bearing and distance to the shortest point to the declared edge as a note for the plot.
>
> Some edge plots may be located next to marked property lines. In this instance, trees bisected by the line as evidenced by fence, blazes, or signage are considered out of the sample frame. Trees bisected by the line are considered the property of both landowners and are not in the direct control of the project owner, therefore they are not cruised.

FIELD PROCEDURES

Plot Records shall include the following information: plot number, date measured, cruiser name or initials, slope aspect, percent slope, and comments as needed.

Tools/Materials required include: 3 to 5-meter accuracy GPS unit, laser hypsometer, diameter tape/calipers, calculator, hammer, paint, surveyors' ribbon, grease pencils or permanent markers, and metal tree tags. Tools selected for height and diameter measurements can be determined prior to field data collection but must be consistent for all trees and plots unless a device failure is experienced (note, laser hypsometers and steel loggers' tapes are preferred).

Navigate to all sample plots using GPS units. Cruisers not able to use their GPS due to reception or other reasons may locate and collect data using compass and pacing. When plots are located in this manner, the declination, bearing, and distance from a key starting point (i.e. road intersection, other data samples located with GPS, etc.) should be noted in the notes section of the tally file. Appropriate declination for the subject tract shall be pre-determined by the contractor and provided to all parties collecting data, including Finite Carbon foresters at the beginning of the project. When using GPS for plot location, the cruiser is instructed to establish the plot at the first indication from the GPS receiver that they have reached the target location using an audible alarm. **UNDER NO CIRCUMSTANCES SHOULD ANY PLOT BE OFFSET OR MOVED FROM ITS MAPPED LOCATION; MEASURE THE PLOT AS IS WHERE THE PLOT COORDINATES ARE POSITIONED ON THE GROUND.**

Cruisers are also asked to collect a GPS point at the location of the pin and provide that to Finite Carbon as a shapefile at the end of the inventory. This requirement is meant to ensure non-bias in sample location. Should a cruiser navigate to assigned coordinates for a sample plot and find that it is across a marked boundary line the cruiser should drop the plot and make notes to indicate the nature of the line. The cruiser should also collect at least two GPS points on the marked boundary or preferably nearby corners so that the GIS representation of the project area can be addressed post cruise.

Monumentation of sample locations is critical to project success. The contractor shall select one uniform, brightly colored paint for use in all plot markings. Colors that may be used include blue, orange, bright red, or yellow. Paint should be of high quality to persist into the future.

> Best Practice: Cruisers are encouraged to use paint marks to help check cruisers and verifiers understand the process used to address tree measurements. Monumentation such as a paint dot at the geometric center of an edge tree that was measured, a dot at the estimated junction of the piths on a forked tree, arrow showing that a DBH was moved above some defect, a paint dot at the root collar location for a stilted tree DBH measurement starting point, etc. are all good practices and are encouraged in the inventory.

Plot Center shall consist of a highly visible 3/8 to ½ inch diameter by 24-inch-long painted metal stake inserted into the ground at plot center with 4 to 6 inches of the pin visible above ground level. Above (or as close as possible to) the marker the cruiser shall also hang a 2 to 3-foot-long highly visible survey ribbon. On the survey ribbon the plot identification and cruisers initials will be written with black waterproof markers or grease pencils. Some samples will fall on or near rocky outcrops, talus slopes, or other rocky areas. Cruisers shall do their best to place the steel pin in the ground at each sample. Should the site preclude the placement of the pin, a heavily painted X shall be painted on the sample center with the pin placed in an area nearby that facilitates placement. Cruisers shall record the offset of the pin in feet along with the bearing and distance to the sample center along with witness tree data as specified below.

Witness Trees. At each sample <u>two witness</u> trees shall be selected. The witness trees should (preferably) be a living and large diameter tree for the area that is easily seen from plot center. All witness trees will have a metal tag at stump height with the plot number etched on it. Witness trees shall also have a highly visible painted ring around the stem at eye level. The species and size of the witness trees will be recorded in the notes section of the

tally, as will the azimuth from the tree (stump level tree tag) to the pin, and slope distance to plot center from the stump level tree tag. Ideal witness tree selection should consider the angle created from each witness tree to the plot center. Ideally an angle near 90 degrees will be created facilitating accurate plot center replacement should the center pin be disturbed in the future.

Tree Numbering. Cruisers will tally all trees 1.0-inch DBH and greater beginning with the first stem clockwise from due north from plot center. The measurement of the rest of the plot will proceed clockwise around the plot center. All eligible standing living stems and standing dead wood measured as "in" trees will be tallied. On all trees in the larger overstory plot the tree number and location of the measurement of DBH will be marked with spray paint. Smaller trees (>=1.0' through <5.0') may only be designated with a DBH mark and are not included in the overstory tree numbering. Cruisers may tally the overstory plot first, then the sub plot at the end. Cruisers may also use paint to indicate alternative measurement locations such as the junction of the piths on forked trees, indications that DBH was moved up the tree due to a swell, etc.

Borderline Trees. The most sensitive part of the plot measurements are borderline trees. Cruisers should be very diligent in their measurement and assessment of these trees to avoid failed plots. All borderline trees will be determined in or out based on the critical distance and slope correction in compliance with USDA FS procedures. (Note: the critical measurement on borderline trees is the point of origin or stump of the tree. It is possible that a tree has a point of origin inside the plot while being outside the plot at DBH.) All trees measured for critical distance and found to be "out" should be marked with an "X" facing plot center. Best practice on borderline trees is to determine the measurement point on the tree, mark it with paint or a lumber crayon, then measure the distance to plot center.

> Best Practice: Cruisers measuring an edge tree that is close to the plot radius should measure the distance on two sides of the stump and average them before concluding that a tree is in or out. Make paint marks at the two measurement locations to indicate that this was the process used.

Site Trees. On all plots one site tree should be considered for coring, if a suitable tree exists.. Site trees may be located within the larger diameter inventory plot or outside of the plot. If the plot is located outside the inventory plot, it should be placed nearby within the same general forest type. Select trees off the subplot where possible. Each tree selected for coring shall be monumented with a prominent painted "S" facing plot center. Cruisers should work clockwise from North until a candidate tree is located. Use only trees that have remained in a dominant or co-dominant crown position throughout their entire life span. If possible, trees should be 5.0 inches in diameter, or larger, and at least 20 years old. Trees that are visibly damaged, trees with ring patterns that exhibit signs of suppression, and trees with rotten cores should be rejected. If there are no acceptable site trees, record that in the plot notes and leave this section blank. Details about selecting site trees can be found in the Appendix to this document.

Ideally, site trees should be between 20-70 years old. If preferred trees cannot be found in this age range, expand the age range to 15-120 years. Reject trees outside the 15-120-year age range, trees that exhibit signs of damage, trees with ring patterns that show signs of suppression, trees less than 5.0 inches DBH, trees with abnormalities at DBH, and trees with rotten cores. A list of preferred site-tree species is provided. Site trees should be selected in the following order of preference:

- 1st Choice: representative of the stand, on the list for your region.
- 2nd Choice: representative of the stand, on the list for an adjoining eastern region.
- 3rd Choice: not representative of the stand, on the list for your region.

Cruisers shall paint a prominent S on the stem facing plot center. Cruisers will record the species (USDA FS FIA three-digit codes), diameter to the 0.1 inch, and total tree height in feet. Cruisers will also core the tree at DBH, to the pith is preferred, however the cruiser may also average the rings per inch on the core they can physically extract and extrapolate the age estimate of the tree. Tally tree age for each site tree. Cruisers are not required to save sampled cores or photos of cores (insert them back into the tree and make a paint circle around the location);

however it is recommended that they take a digital picture of the core alongside a scale (6 inch with tenths) for verification purposes if possible.

TALLY MEASUREMENTS

Live trees are defined as those having living buds, foliage, and or living cambium. The tree must be attached to the stump and the stump must be partially rooted. Living trees may be downed or leaning in other trees provided they are living as defined above.

Wildfires: Plots affected by recent wildfires. When plots fall in recent fire affected areas cruisers are asked to consider whether or not the burned trees will survive to the anticipated verification date next year. When tallying trees in these conditions use the following rule when designating either Alive or Dead in the tally.

- If the tree is a ponderosa pine and has less than 20 percent of its crown remaining tally the tree as dead.
- If the tree is a Douglas-fir or larch and has less than 30 percent of its crown remaining tally the tree as dead.
- If the tree is a grand fir, or any other species and has less than 40 percent of its crown remaining, tally the tree as dead.
- Tally all hardwoods as dead.

Cruisers are to provide a plot comment where a plot falls in a fire affected area. Cruisers are also to provide a tree comment on live trees tallied as dead based on the above criteria.

Species shall be recorded in accordance with the USDA FS FIA numerical three-digit species codes. No miscellaneous species codes should be used. Cruisers should make their best assessment of species possible. This can often be inferred by other species on or near the plot. All tree species within the project area must be measured regardless of the merchantability of the trees.

Diameter at breast height (4.5') on the high side of the stump, measured with a diameter tape to the nearest 0.1 inch. Should the tree have a defect, swell, branch or other deformity at diameter at breast height (DBH) the cruiser shall take the DBH measurement just above the defect.

Trees will be measured to the nearest 0.1-inch diameter class using the following rounding rules (≤0.05 rounds down, ≥ 0.06 rounds up).

Table 3: DBH Rounding Examples

DBH Measurement	Recorded Diameter Class	Plot Eligibility
0.99 inches	None, as it is absolutely less than 1.00 inches.	Not eligible
1.05 inches	1.0 inches	1/150th acre fixed radius plot
1.06 inches	1.1 inches	1/150th acre fixed radius plot
4.95 inches	4.9 inches	1/150th acre fixed radius plot

4.96 inches	5.0 inches	1/10th acre fixed radius plot

Alternative DBH Locations.

All trees should be measured with a steel diameter tape at DBH (4.5 feet above the ground on the high side of the stump). Exceptions include:

- There are swells, branches or other abnormalities at the required location. In this case, measure the tree just above the abnormality.
- The tree forks below 4.5 feet. In this case measure each fork 3.5 feet above the estimated junction of the piths. In this case each fork is recorded as a separate tree. Trees that join within a foot of the ground level can be measured at 4.5 feet.
- The tree has a distinct butt swell. In this case, measure the tree 1.5 feet above the swell.
- For leaning trees measure the DBH location (4.5 feet) from the underside of the lean or the face of the tree closest to the ground. Trees are considered leaning when the angle of the tree to the ground in the direction of the lean is less than 90 degrees.

Note: For oddly shaped trees please reference the USFS FIA diameter location document included with this specification. Interference at DBH by other plants or features must be considered by the cruiser. Moss, vines or abnormal large bark ridges must be removed or otherwise accounted for in the measurement of diameter. Make a note if necessary. Cruisers should keep in mind that the spirit of the DBH location is to measure the stem 4.5 feet above highest side of the root collar location. Odd tree configurations at the root collar can sometimes give the cruisers more than one possible location. Use the location that pushes the DBH location the furthest up the stem.

Height of each stem shall be measured with a clinometer or preferably a laser hypsometer in one-foot increments for all height measurements. Note: for leaning trees, the total tree length shall be the measurement objective, not height off the ground. Leaning tree height can be calculated using the A^2+ B^2=C^2 formula. When this method is used, please note such in the comments section of the tally. Cruisers are cautioned to be sure they get back a sufficient distance from the stem to get an accurate height measurement. A good rule of thumb is 2/3 to 1 tree height away from the stem to be measured at grade or slightly uphill of the tree.

Total Height (THT)
Record total height (THT) in one-foot increments for all standing live trees >= 1” DBH.

- Total height is recorded to the most vertical tip of the stem or crown. Note, on some trees with large broad crowns, this will entail shooting through the crown to measure, as best you can, to the top of the middle of the crown.
- A total height should be recorded for every tallied tree regardless of species or size.
- If the top of the tree is dead or missing, total height should be measured at the point it is broken or becomes dead unless a new leader has developed, in which case the height of the new leader should be measured.

Best practice: Tie a flag at the location you take large tree heights so that it can be replicated. Always strive to be up hill or on the same elevation as the tree to be measured and about 1 tree length away at 90 degrees to the lean of the tree.

Soundness/Defect deductions for any missing biomass and visible possibilities of rot or cavities in the bole (including bark) shall be recorded. When estimating loss, only consider missing portions on the merchantable

bole/portion of the tree, from a 1-foot stump to a 4-inch top. It should not consider missing branches or estimated missing/broken tops. Deductions for blemishes such as "cat faces" should not be made unless the blemish has caused visible rot or cavities. Deductions should be made using the USDA Forest Service Table provided with this document. For example, a tree that is 90% sound should be recorded as a 10 in the deduction column.

Standing Dead Trees

Standing dead trees greater than or equal to 1.0" DBH are eligible to be tallied only if they are a minimum 15 feet in total height, connected to the stump, with the stump at least partially rooted. Standing dead trees that are leaning at more than a 45-degree angle from vertical shall not be tallied.

Species shall be recorded in accordance with the USDA FS FIA numerical three-digit species codes. Species must be recorded for dead stems. If the tree has no bark or other identifiable features, the cruiser must make a best guess as to the species. No miscellaneous species codes should be used. Cruisers should make their best assessment of species possible. This can often be inferred by other species on or near the plot.

Tree Status shall be recorded for every tallied dead tree. Standing dead trees shall be designated as zero (0).

Standing Dead Tree Decay Class. Each standing dead tree shall be given a Decay Class (1 through 5) as defined below:

1: All limbs and branches are present; the top of the crown is still present; all bark remains; sapwood is intact, with minimal decay; heartwood is sound and hard.

2: There are few limbs and no fine branches; the top may be broken; a variable amount of bark remains; sapwood is sloughing with advanced decay; heartwood is sound at base but beginning to decay in the outer part of the upper bole.

3: Only limb stubs exist; the top is broken; a variable amount of bark remains; sapwood is sloughing; heartwood has advanced decay in upper bole and is beginning at the base.

4: Few or no limb stubs remain; the top is broken; a variable amount of bark remains; sapwood is sloughing; heartwood has advanced decay at the base and is sloughing in the upper bole.

5: No evidence of branches remains; the top is broken; <20 percent of the bark remains; sapwood is gone; heartwood is sloughing throughout.

Note: Cruisers should start with Class 5 with every standing dead tree. If the tree does not meet all qualities of that class, move upward in the scale until the most accurate designation is reached. Cruisers are also reminded that in addition to the categories above, soundness deductions for structural loss are also required on all standing dead trees.

Diameter at breast height (4.5') on the high side of the stump, measured with a diameter tape to the nearest 0.1 inch. Should the tree have a defect, swell, branch or other deformity at diameter at breast height (DBH) the cruiser shall take the DBH measurement just above the defect. <u>The cruiser shall comply with the rounding rules described for live trees above</u>.

Height of each stem shall be measured with a clinometer or preferably a laser hypsometer in one-foot increments for all height measurements. Note: for leaning trees, the total tree length shall be the measurement objective, not height off the ground. Leaning tree height can be calculated using the A^2+ B^2=C^2 formula. When this method is used, please note such in the comments section of the tally. Cruisers are cautioned to be sure they get back a sufficient distance from the stem to get an accurate height measurement.

Total Height (THT)
Record total height (THT) in one-foot increments for all standing dead trees >= 1" DBH and >= 15' in total height. (Note, a total height of 15.0 or greater is required for a standing dead tree of any diameter to be eligible for tally). Total height is recorded to the most vertical tip of the stem.

- Total height is recorded to the most vertical tip of the stem or crown. Note, on some trees with large broad crowns, this will entail shooting through the crown to measure, as best you can, to the top of the middle of the crown.

- A total height should be recorded for every tallied tree regardless of species or size.

- If the top of the tree is dead or missing, total height should be measured at the point it is broken or becomes dead unless a new leader has developed, in which case the height of the new leader should be measured.

Best practice: Tie a flag at the location you take large tree heights so that it can be replicated. Always strive to be up hill or on the same elevation as the tree to be measured and about 1 tree length away at 90 degrees to the lean of the tree.

Soundness/Defect deductions for any missing biomass and visible possibilities of rot or cavities in the bole (including bark) shall be recorded. When estimating loss, only consider missing portions on the bole portion of the tree, from a 1-foot stump to a 4-inch top. It should not consider missing branches or estimated missing/broken tops. Deductions for blemishes such as "cat faces" should not be made unless the blemish has caused visible rot or cavities. Deductions should be made using the USDA Forest Service Table provided with this document as a guide along with the cruiser's judgement. For example, a tree that is 90% sound should be recorded as a 10 in the deduction column.

Species Specific Measurements: Five eligible species, standing live and standing dead, within this region require a diameter at root collar measurement (DRC) and stem count rather than a DBH measurement. All species require a total height measurement.

These species are:

- Rocky mountain juniper [*Juniperus scopulorum*] (FIA Code 066]
- Rocky Mountain maple [*Acer glabrum*] (FIA Code 321)
- Bigtooth maple [*Acer grandidentatum*] (FIA Code 322)
- Curl leaf mountain-mahogany [*Cercocarpus ledifolius*] (FIA Code 475)
- Desert ironwood [*Olneya tesota*] (FIA Code 990)

These species have a calculated value for the DRC that converts multiple-stem measurements to a single record within the inventory. Since the calculation of volume (and ultimately carbon) has a different equation for single-stem trees versus multi-stem trees, it is necessary to record the number of stems for each single record which will identify which equation will be used.

Methods and details of taking DRC measurements can be found within the FIA guidelines for field inventory (page 64 of this document).

Inventory Audit (QA/QC)

Finite Carbon shall jointly and independently audit the project cooperatively to ensure that the data quality meets the standards of the CA ARB program and Finite Carbon expectations. (Note, if a contractor enlists the services of

additional sub-contractors, the quality of data collection should not be left to this audit procedure alone. It is the contractor's responsibility to ensure the quality of work done by sub-contractors they employ).

The joint audit will consist of a minimum of 7% of the samples collected. Initially, audits will address all cruisers equally. If, however, individual cruisers are found to be consistently out of compliance, the auditor or audit team may focus on individuals in order to verify compliance with the specifications. Additional audits may be conducted by Finite Carbon or their assigns at any time and at any intensity.

Audit report summaries will be generated for Finite Carbon by the contracted auditor periodically throughout the inventory project and will be submitted with per cruiser audit totals and results. A final audit results summary shall be provided to Finite Carbon at the completion of the project which shall include audit dates, number of audited samples per cruiser including sample location identifiers, total audited samples vs. total samples as a percent, corrective actions per cruiser, any plots re-done due to noncompliance, and overall auditor's comments.

Audit results will be based on a per cruiser assessment of plot tally on a percent error basis. Error will be expressed as the number of errors (as noted below) divided by the number of trees sampled on a minimum of 6 randomly selected sample plots. The maximum acceptable error threshold for accuracy is 1 error in 10 trees or 10%.

Table 4. Check Cruise Error Calculations

Incorrect Species	1 error
Incorrect Diameter (tolerance +/- 0.2")	1 error
Incorrect Height (tolerance of +/-8 feet on trees 139 feet and lower, +/- 10 feet on trees 140 feet and higher) on THT only	1 error
Incorrect tree status designation	1 error
"In" tree marked "Out" (tolerance 0.2 foot)	2 errors
"Out" tree marked "In" (tolerance 0.2 foot)	2 errors
Plot location (greater than 1.5 chains from map location/coordinates)	1 error
Incomplete tally file label	0.5 error
Incorrect or poor monumentation	1 error

When an audit of a cruiser is completed, the total number of errors will be divided by the total number of trees included in the audit plots and expressed as a percent. Error ratings at or below 10 percent require no further action. Error ratings above 10% should result in further investigation and corrective actions. If the error rate is close to 10% and no trend in errors is evident (i.e. consistent height problems) the auditor may choose to select another 2 to 4 samples for the non-compliant cruiser to fully assess the errors before determining corrective action.

Corrective actions: Re-training non-compliant cruisers and correcting erroneous samples are the minimum corrective actions to be implemented. Based on the results of audits, if a cruiser repeatedly cannot or did not meet the quality standards (fails two consecutive audits) for allowable error, all plots for that cruiser must be re-done at the expense of the contractor by a cruiser that can consistently meet quality thresholds.

Inventory Deliverables:

- Electronic data files for both the raw field tally and screened tally with an edit log summarizing changes to the data set in the screening process. These files will be submitted in Excel, or Access formats providing the full tally and notes. All electronic files shall be screened for obvious errors such as missing data, and data outside of normal parameters for forests of the region. If paper tally is done, scanned copies of the tally cards must be submitted.

- Any joint audit field files, notes, and summary report.

- Summary report of all cruiser comments, including field maps with noted plot relocations and natural disturbances noted.
- A description of the methods used to screen completed data files and otherwise ensure data quality and integrity.

Review and Approval:

Once received, Finite Carbon representatives will also screen and edit the data files for approval to the written requirements. Following the screening process, the work will be deemed acceptable or unacceptable. Contractors will be provided with feedback on any omissions, missing data or deficiencies in the product and will be granted the opportunity to correct any issues in a timely fashion. Pending final approval of the data, all outstanding fees will be paid to the contractor as per the terms of the Services Agreement.

Stratification

The project area was stratified for inventory and assessment area purposes. The goal of the project area stratification was to provide an unbiased stratification of the project area's vegetative communities and to remove non-forested areas. Finite Carbon used a combination of spatial analysis, academic research into locations of species, and imagery data, as well as their professional experience with regional forest cover types to identify different assessment areas and inventory strata.

Prior to sampling the project area, Finite Carbon assesses the overall quality and integrity of the mapped boundaries and underlying spatial data. Ancillary spatial data is taken from a variety of sources including publicly available data, landowner shapefiles, and files created from site visit field work. In all cases, GIS shapefiles are projected to the proper coordinate system, checked against publicly available shapefiles for ownership and boundary issues, ground-truthed using GPS and other field equipment, and then stored in geodatabases to ensure compatibility with outside data and data integrity. Tools used include ESRI ArcMap and Geodatabase, GPS devices, acquired orthorectified aerial photography.

Stratification Process

There are no published guidelines or methods to determine assessment areas. The protocol states a need to compare species on the property with the Appendix F species lists when assigning assessment area. The Appendix F data is a grouping of FIA Forest cover types along with several other considerations adopted by ARB. A project operator must rely on the species lists and professional knowledge of forest ecology to determine the appropriate assessment area for a given area within the project.

Finite Carbon used a combination of the following data sets relied on by professional foresters to define inventory stratification boundaries:

- Spatial data that can determine local ecology and species occurrence.
- Individual tree records at the plot level, including species dominance by basal area, number, and occurrence of diagnostic (species listed within Appendix F) species and species unique to assessment areas.
- Multi-temporal aerial imagery that helped identify physiognomic factors that distinguished different areas of management, species mix, topography, geology, etc.
- Professional judgment and experience of foresters. This includes local knowledge of forest ecology, geology, geography, edaphic conditions, hydrology, etc. – all factors that can all influence species found at a location and how these species may be grouped into ARB-defined assessment areas.

In defining the assessment area stratification between plots, Finite Carbon used the full range of data at our disposal. Finite Carbon began with the OPO provided property map and then evaluated areas near plot treelist data to determine if the stratum suggested by a plot was similar in appearance as observed from multitemporal

imagery to the area between plots. If that did not provide enough clarity, we relied on other tools such as local knowledge, hydrology, spatial data, etc.

The inventory stratification and assessment area mapping generally followed these steps:

Step 1: Delineation of Forested and Non-Forested Areas
The OPO provided a property shapefile. Within this boundary Finite Carbon defined a project area based on logical management units, forest/non-forest areas, roads, and other criteria. Roads were considered non-forest areas and were removed from the project area. These were limited to service roads and timber haul roads while skid roads were not included in this delineation. All roads are defined as areas within the overall ownership file provided by the OPO. These polygons were created through heads-up digitizing of visible road boundaries as seen in aerial imagery. Finite Carbon did do not use the roads layer from the original acquisition or publicly available road polygons as these may have errors.

Step 2: Review of Publicly Available Data sets
Initial work defining strata relied on the publicly available data sets provided by agencies and researchers to define forest types and key species across eastern Oregon. A great deal of work has been completed in the past few decades documenting species targeted for restoration activities, primarily western juniper (*Juniperus occidentalis*). As a target for removal to rehabilitate eastern Oregon grasslands, prevent soil erosion, and improve local hydrologic function, detailed spatial data has been created to identify juniper focus areas.

Finite Carbon utilized these maps to identify the presence of western juniper in the landscape as a key element of Assessment Area delineation. The data located at the Oregon Spatial Data Library provides detailed results of researchers' work on this topic and formed a key component of defining inventory strata and assessment areas (https://spatialdata.oregonexplorer.info/geoportal/search;q=*juniper*). Some of the key parameters were maps of juniper presence, percentage of canopy cover in juniper, and percentage of basal area in juniper.

Step 3: Common spatial data

Finite Carbon also mapped aspect, canopy cover, slope, and elevation across the property to help delineate the assessment areas. The ecology of western juniper and other eastern Oregon species is highly correlated with these variables across the landscape. For example, western juniper rarely occurs above 7,000 feet in elevation (Miller, et al., p. 6) and occurs on drier sites with more open canopies. These can be found on southern facing slopes where solar radiation limits moisture availability, and in areas where the canopy of larger trees (ponderosa pine, Douglas-fir) have not overtopped them. Junipers also tend to encroach grassland areas so will be found on the edges of open meadows, often at high points in local elevation.

Step 4: Inventory data
Finite Carbon placed an evenly spaced grid of plots with a random starting point across the property to establish permanent inventory plot locations. Once the data resulting from that inventory was received, Finite Carbon began stratification into assessment area and inventory strata by comparing species within the Appendix F assessment area species' lists to field information. Our final analysis evaluated predominant species at each plot, unique occurrence of diagnostic species at each plot, and the history of land use in a particular area.

Finite Carbon's final project stratification resulted in a division of the project area into the three different strata that is our interpretation of the forest communities associated with the regional assessment areas. The stratification appears appropriate and consistent as the final species distribution with each stratum is distinct and reflects the list of species from Appendix F. While the process described above is repeatable, it would be nearly impossible to find identical stratification results based on these multiple sources if different experienced foresters were making the determination. This stratification was reviewed and approved by certified professional foresters who visited the site and determined that conditions on the ground matched what they expected to see given the strata/assessment area descriptions.

Stratification Results

JP1 Stratum

This stratum consists of more open canopy areas with a high component of western juniper and mountain mahogany relative to other species. This occurs in areas at the high points of local elevational gradients, areas with canopy cover that appears more open often abutting meadows, and on southern slopes that are generally hotter and drier than northern facing slopes.

JP2 Stratum

This stratum forms a transition zone between the more open canopy of the western juniper/mountain mahogany dominated sites. There is generally greater basal area of ponderosa pine and a more closed canopy. This transition zone occurs on slopes between lower elevation JP1 sites and the more mixed conifer areas at higher elevations. This zone will have a higher proportion of ponderosa pine than the JP1 stratum and a more closed canopy. In addition, these areas occur at lower elevations and occur more frequently with ponderosa pine than Douglas-fir and other conifers.

MC Stratum

The mixed conifer stratum is found at higher elevations and on moister cooler sites such as those found on northern facing slopes. The canopy closure of these areas is generally greater than either the JP1 or JP2 strata. Species found at greater levels within this stratum are Douglas-fir, western larch, and grand fir.

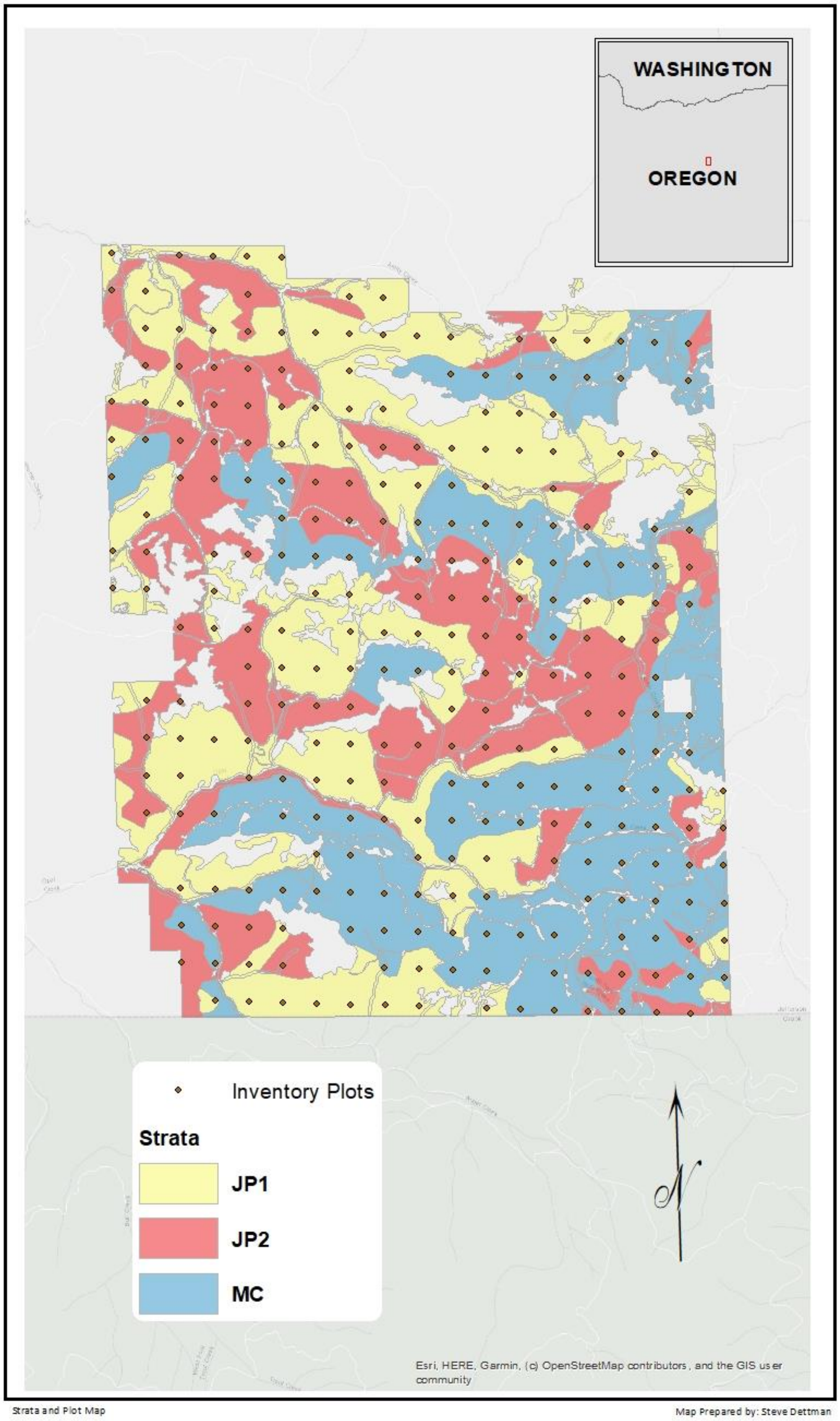


Figure 3. Cruise Plots and Inventory/Management Strata

Data Management & Analytical Systems

This section describes the data management and analytical systems used to estimate the baseline and project carbon stocks of selected carbon pools within the Project Area.

Data Creation

Finite Carbon, in coordination with the inventory contractor, implemented a continuous forest inventory (CFI) completed in summer of 2020. These plots will be re-measured over time per the specification outlined in the inventory specifications document. Once field measurements have been collected, the raw inventory data will be compiled by the inventory contractor. A database is then transferred to Finite Carbon in an MS Excel worksheet and/or MS Access database. The database contains multiple tables with the plot and individual tree measurements recorded by the cruisers.

Spatial data is provided to Finite Carbon from the Forest Owner's GIS department while the forest inventory data in tabular form is provided to Finite Carbon from the inventory contractor. The two most relevant spatial files are the forest area polygons and the inventory points; they are provided in either ESRI shapefiles or feature classes. All GIS files are then input into the project geodatabase which is the underlying foundation of the Project's Monitoring, Reporting and Verification System (MRVS) and will serve as the central carbon data spatial repository.

Converting Data Formats

After receiving the data, Finite Carbon reviews it and executes a quality control/assurance process for validation. Keys are also setup to standardize relations between spatial and tabular data. Once the raw data has been assured for quality, it is formatted into a MS Access database for input to FVS. The FVS input database tables are read by the FVS program using the Database Extension of FVS (Crookston 2003).

Forest Vegetation Simulator (FVS)

General Overview

Finite Carbon uses the Forest Vegetation Simulator (FVS) model to accept processed inventory data from the Preparatory Module and to output tree lists for the current inventory year so that carbon can be calculated in the Carbon Modules. The growth functions of FVS are applied, if necessary, to grow carbon stocks forward to the current reporting period end date.

The Forest Vegetation Simulator (FVS) is a family of forest growth simulation models supported and maintained by a special unit of the USDA Forest Service (www.fs.fed.us/fmsc/fvs/). Since its initial development in 1973, it has become a system of highly integrated analytical tools. These tools are based upon a body of scientific knowledge developed from decades of natural resources research. The FVS growth model is an approved ARB FOP growth model (FOP, Appendix B, Section B (a)).

The FVS is an individual-tree, distance-independent growth and yield model (Dixon 2002). It has been calibrated for specific geographic areas (variants) of the United States. FVS can simulate a wide range of silvicultural treatments for most major forest tree species, forest types, and stand conditions. The Blue Mountains (BM) Variant has been used for this project (Keyser 2011).

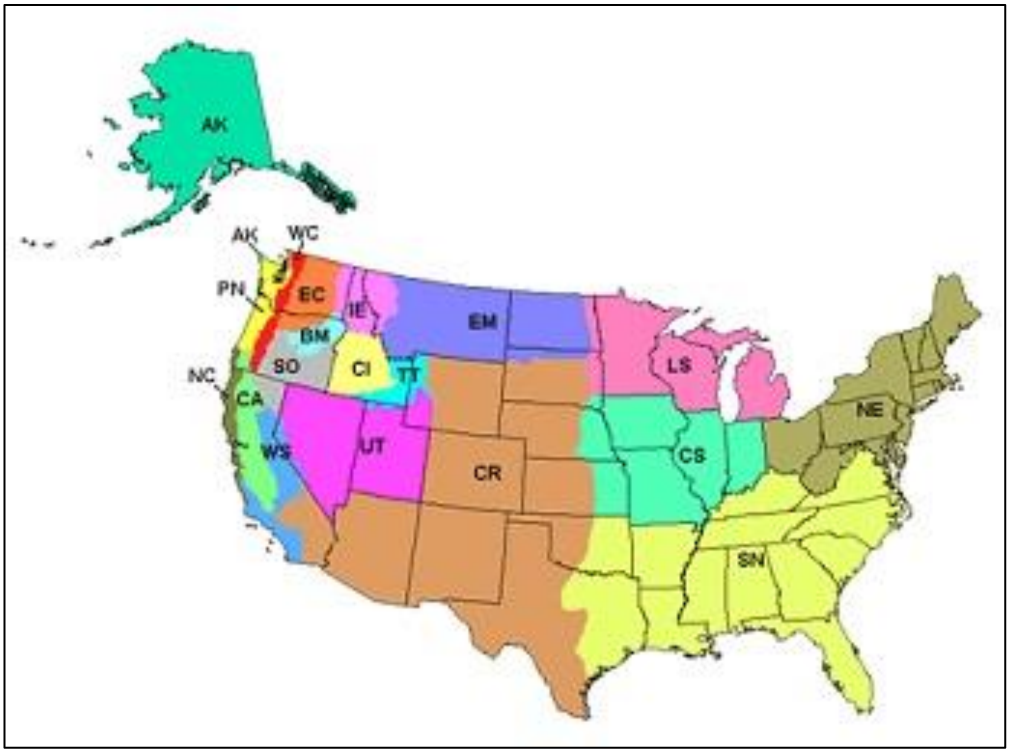


Figure 4. FVS Variants

The following summarizes basic FVS operation and the major model execution steps. Specific operation details will vary for different variants.

1. Process keywords and input data - FVS begins by reading keywords to establish location, environment, and stand parameters; then reads the tree record file.

2. Compute initial stand characteristics - FVS computes stand characteristics for the initial year (cycle 0). This is typically the inventory date or the stand regeneration date. Input tree records with missing heights or crown ratios have these dubbed in.

3. Backdate densities and compute calibration statistics - If sufficient large tree diameter increment data is contained in the input tree data (and/or small tree height increment data), FVS back-dates the stand one default cycle length. FVS then “grows” the stand back to the inventory date, compares the values from the actual inventory date with simulated values, and computes scale factor adjustments to account for differences in actual and model values.

4. Check event monitor (pre-treatment) - FVS continues with the steps it repeats every cycle. FVS checks the Event Monitor keywords and functions to see if the user scheduled any activities based on existing stand conditions at the start of the cycle. Event Monitor capabilities are powerful and very useful for modeling situations and creating variables not covered in standard FVS output. Crookston (1990) describes Event Monitor functions and processes along with several good examples.

5. Perform treatment - Almost any silvicultural operation imaginable can be structured using one or more treatment keywords in a direct or conditional (If..Then) context.

6. Check event monitor (post-treatment) - FVS Event Monitor checks for conditions and scheduled operations that are based on post-treatment activity conditions within the same cycle.

7. Grow large trees - If “large” trees exist in the tree-list, FVS estimates their new diameter (first) and height (second) one growth cycle into the future. The user can specify a different time interval length.

8. Grow small trees - FVS estimates small tree height (first) and diameter (second) one growth cycle into the future. FVS uses a weighting procedure to compute tree height increment to obtain a smooth height-growth transition from small to large tree models.

9. Mortality - Following growth estimation, FVS estimates mortality based on individual tree variables such as diameter and crown ratio, and on stand variables such as maximum stand density index or basal area.

10. Insect and disease impacts - If the variant has available extensions to cover specific disease or insect agents, and if the user calls for these, FVS estimates and incorporates these effects.

11. Regeneration - FVS adds new seedlings to FVS tree-lists in the regeneration step. Some FVS variants have natural regeneration routines, but most variants depend on the user to specify the species and number of trees to plant. Some variants have a stump sprouting algorithm, whereby certain species will sprout after a harvest.

12. Crown change - FVS estimates crown ratio change for all trees based on stand density and the trees position in the density distribution.

13. Update stand characteristics and compute volume - After projecting the stand for the growth cycle, FVS computes, summarizes, and records the stand attributes, including volume. Volume is computed using corporate equations from the National Volume Estimation Library.

14. Test for more cycles to be projected - FVS repeats the sequence from the initial "Check Event Monitor", per Figure 2, to this point for each cycle until the specified number of cycles is completed.

15. Final FVS Output file reports and post-processor files - After FVS completes the scheduled cycles, it prints final output file reports and generates files specified by the user for running post-processors, including SVS.

Mountain mahogany

FVS was used in this project to model growth for all species. In the case of mountain mahogany (*Cercocarpus ledifolia*), growth and mortality rates were set to 0, *e.g.* mountain mahogany was acknowledged as a stand component competing for resources in the growth simulations, but its abundance was conservatively kept constant throughout growth projections.

There are two concerns about using FVS to model the growth of mountain mahogany.

First, there is lack of clarity on what measurements would serve as inputs to the model. The biomass and volume equations approved by the ARB require diameter measurements to be made at the root collar. However, the FVS model requires diameter measurements to be made at breast height. There is no available conversion equation to convert single or multiple stem mountain mahogany measurements made at the root collar to equivalent measurements at breast height. As a result, in almost all instances, a multiple stem mountain mahogany measured at root collar would not map to the same number of stems at breast height since many of these stems do not

achieve 1" diameter at this height. This means that coordination of individual measurement records would be difficult or impossible to maintain when converting from the model to the carbon calculations.

Second, the Blue Mountain variant of FVS automatically maps mountain mahogany to an "other hardwood" within the model. Growth elements in the Blue Mountain variant such as small diameter growth, large diameter growth, height growth, crown competition factor, and crown ratio for an "other hardwood" have the same values as cottonwood, an extremely fast growing and canopy dominant early seral species. In our opinion this mapping would overestimate growth for mountain mahogany as it is a true understory tree that grows very slowly and almost never achieves heights above 20'.

Based on these factors, Finite Carbon adopted a conservative modeling approach of this tree for the baseline which assumes no change to the biomass -- i.e. keeping the current stocking constant within the model. Since this species has no commercial value, it would play no role in calculating the harvested wood products within the baseline.

Note: the total tCO_2e of mountain mahogany within the project area is 0.31% of the standing carbon total and therefore represents a de minimis quantity for the purposes of this protocol.

Functions

The FVS growth model is used in this project to estimate growth and mortality based on field measurements and management activities over time.

Data and FVS Settings

FVS Input Data

The FVS input database is comprised of three tables: FVS_GroupAddFilesAndKeywords; FVS_StandInit; and FVS_TreeInit.

Table 5. FVS Input Data

Table Name	Field Name	Description
FVS_GroupAddFilesAndKeywords	Groups	Used to assign keywords to all strata or a specific stratum
	AddFiles	Not used
	FVSKeywords	A list of FVS Keywords which define the FVS run (described further below)
FVS_StandInit	Stand_CN	Stand Control Number: Used for the FVS yield curve ID number
	Stand_ID	Stratum
	Variant	"BM" Blue Mountains Variant
	Inv_Year	"2020" - The inventory year of the plots associated with the Stand_CN.
	Location	"607" – Ochoco National Forest. Indicates the closest National Forest Region and Forest Number to the project area.

	PV_Code	This is the plant association code. Plant association codes are used to set default site information such as site species, site indices, and maximum stand density indices. Codes were based on qualitatively matching inventory strata and understory vegetation observed in the field, to the plant associations described in Johnson and Clausnitzer (1992).
		Inventory Stratum — PV_Code JP1 — 62 (PIPO/CELE/FEID-AGSP) JP2 — 62 (PIPO/CELE/FEID-AGSP) MC — 54 (PIPO/CAGE)
	Basal_Area_Factor	"-10" - The inverse of the fixed plot size in acres (1/10-acre) using negative value to indicate fixed radius rather than Basal Area Factor.
	Inv_Plot_Size	"150" - The inverse of the fixed plot size in acres (1/150-acre fixed radius plot) – used for subplots, in this case to measure trees less than 5.0" DBH.
	Brk_DBH	"5.0" – indicates that all tree records >= 5.0" DBH are processed using the Basal Area Factor (1/10-acre plot in this design), all trees less than 5.0" DBH are processed using the subplot.
	Num_Plots	Total number of plots associated with Stand_CN.
	NonStk_Plots	Number of non-stockable plots associated with Stand_CN (not used because total number of plots used).
	Site_Species	Used to assign the species associated with the Site_Index field. Site species and site indices were assigned using the SITECODE keyword (see details below)
	Site_Index	Used to assign site index. Site species and site indices were assigned using the SITECODE keyword (see details below)
FVS_TreeInit	Stand_CN	Stand Control Number: Used for the FVS yield curve ID number
	Stand_ID	Stratum
	Tree_ID	Tree identification code for plot
	Plot_ID	Plot identification code
	Tree_Count	The number of trees on plot with the exact same measurements (always 1, no repetition counts used).
	History	Tree history code, e.g. alive, recent mortality, "older" mortality
	Species	Tree species
	DBH	Diameter at breast height
	Ht	Total height in feet
	HtTopK	Height to top kill in feet

	Damage1	“25” - Percent defect of tree’s merchantable cubic foot volume
	Severity1	“1-99” (99 = 100%) – percent defect
	Damage 2	“55” – Custom code
	Severity 2	Product code (if dead tree then dead tree decay class)
	TreeValue	Tree value class, in this case it is used to distinguish live cull trees (using a code value of “3”). “8” is used to indicate a no-tally plot. All other values indicate a live tree or dead tree, e.g. “1”.

FVS Settings

The FVS model has many program options to control the inputs and variables which affect growth and yield. These options are typically set using “FVS Keywords.” They are programmed in the FVS input tables or selected in Suppose[2]. The following keywords are used for this project:

NOTRIPLE (No tripling) – Random effects are incorporated in the Forest Vegetation Simulator in the manner originally described by Stage (1973), and subsequently updated to reflect changes in program control variables. The program assigns all random effects to the distribution of errors associated with the prediction of the logarithm of basal area increment. Basal area increment was selected to reflect the stochastic variation because the effects of differing diameter growth rates extend in highly nonlinear ways through most of the remaining components of the model. This distribution of errors is assumed to be Normal, with a mean of zero. The variance of this Normal distribution is computed as a weighted average of two estimates; the first estimate is derived from the regression analysis that developed the prediction function, and the second estimate is the standard deviation of the differences between the recorded growth for the sample trees in the population (transformed to the logarithm of basal area increment) and their corresponding regression estimates. The weights assigned to these two estimates are (1) the number of observations by species and/or habitat type in the database for the model for the prior component of error, and (2) the number of growth-sample trees in the stand for the second component of error (Mehta 1972).

The random component of change in tree diameter is treated in two ways, depending on how many tree records make up the stand being projected. When there are many tree records, the effects of any one random deviation on the growth rate of one tree would be blended with many other trees, and the stand totals should be quite stable estimates. Accordingly, a random deviate from the specified distribution is added to the logarithm of basal area increment.

When relatively few sample trees represent the stand, however, a different strategy is used. In order to increase the number of replications of the random effects, two additional records augment each tree record. These new records duplicate all characteristics of the tree except the predicted change in diameter and the number of trees per acre represented by the source tree record. The trees per acre value of the original tree record are reduced to 60 percent of its current value. The two new records are given 15 and 25 percent of the original value; thus, the three records together still represent the same number of trees per acre. This process is known as tripling.

Because each stratum in the project area contains an adequate number of tree observations, <u>tripling is not used in this modeling</u>; it is turned off with the NOTRIPLE keyword.

[2] Suppose v2.02 is the FVS graphic user interface (GUI).

SPGROUP - Defines a group of species that can be referenced by a single name, or FVS sequence number, and will be treated as a group in management actions or event monitor functions. Two species groups were defined in this project, COM and NCOM. COM included all softwood species excluding Western juniper (due to differing merchantability specs), while NCOM included all hardwood species, which were not considered merchantable.

BFVOLUME - Sets the merchantability limits for board foot volume calculation. This keyword was used to set merchantability specs for commercial softwood species according to a survey of local mill specs taken at the time of project development. All hardwood species were considered non-commercial and excluded from sawlog totals.

The following keywords in the input table FVSGroupAddFilesAndKeywords were used in conjunction with SPGROUP to set merchantability specs for all tree species in FVS regime simulation

```
BFVOLUME  0.   COM    7.0    6.0    1.0   80.   6.
BFVOLUME  0.   WJ     10.5   8.0    1.0   80.   6.
BFVOLUME  0.   NCOM   999.0  999.0  1.0   80.   6.
```

VOLUME - Sets the merchantability limits for cubic foot volume calculation. In the western half of the US, this keyword sets the merchantability limits for merchantable cubic foot volume. This keyword was used as follows to keep cubic foot projections consistent with board foot projections as follows (sawtimber was modeled as the only merchantable product with no possibility for pulpwood):

```
VOLUME  0.   COM    7.0    6.0    1.0   80.   6.
VOLUME  0.   WJ     10.5   8.0    1.0   80.   6.
VOLUME  0.   NCOM   999.0  999.0  1.0   80.   6.
```

MINHARV (Minimum Harvest) - Specifies minimum acceptable harvest standards for board-foot volume, merchantable cubic-foot volume, basal area per acre, or total cubic foot volume. The accumulated removals across all thinnings in a cycle must exceed the standards for all the units of measure (fields 2, 3, 4, and 5), or none of the thinnings in that cycle will be implemented.

This keyword was used in baseline harvest treatments (Clearcut-Convert) to ensure that a silvicultural treatment (harvest) satisfies a minimum harvest level for financial and operational feasibility. The minimum harvest volume was set to 2000 board feet per acre based on industry survey results indicating the lowest level of commercial harvest volumes per acre reported by forest managers in the Pacific Northwest (Opalach and Arney 2019).

THINBBA(THIN from Below to Basal Area target). Schedules a thinning from below to a basal-area-per-acre target. Only trees with DBH's and heights within the user-defined ranges are considered for removal. The tree record with the smallest diameter within the specified range is considered for removal first, and the proportion of that tree record specified in field 3 is removed. The tree record with the next smallest diameter is considered next, then the next smallest and so on until the residual basal area target is met or all records in the specified range have been considered.

This keyword was used in shelterwood regimes to specify the shelterwood cut. Stands were thinned from below to a residual density of 40 – 50 square feet of basal area to provide an overstory canopy of seed trees to facilitate natural regeneration.

THINDBH (Thin from a DBH range) – Schedules a thinning from throughout a specified DBH range for any or all species to a basal area per acre or trees per acre target. If the target trees per acre or target basal area is nonzero, thinning occurs uniformly throughout the specified DBH range until the target is met (cutting efficiency is ignored). In other words, a calculated proportion of each of the eligible tree records is removed such that the target trees per acre or target basal area is exactly met. If both residual targets are 0 (zero), the cutting efficiency determines the proportion of trees represented by each eligible tree record that will be removed (residual targets are

ignored). Only trees of the user-specified species that are within the user-defined DBH range are considered for removal. The residual target basal area per acre or trees per acre is specified only for that species and DBH range and does not represent the total residual unless the DBH range includes all trees of all species in the stand.

In commercial thin regimes, the THINDBH keyword was used to simulate the periodic removal of commercially-sized overstory species subject to the wildlife tree requirement. The abundance of Western juniper on the property was used to meet this target. For the overstory removal, all commercial species except juniper greater than 7" DBH were removed, while most of the Western juniper was removed except for 2 trees per acre greater than or equal to 11.0" DBH with the following THINDBH statements:

```
THINDBH   0.      PARMS(7.0,999.0,1.0,COM,0,0)
THINDBH   0.      PARMS(11.0,999.0,1.0,WJ,0,2)
```

ESTAB (Establishment Model) – signifies the beginning of keywords for the Regeneration Establishment extension. The ESTAB keyword sequence must be terminated with an END keyword. All keywords between ESTAB and END are considered Establishment extension keywords.

Two establishment model keywords were used in simulated treatments: PLANT and NATURAL

PLANT (Plant seedlings) - Specifies planting of seedlings that will be added to the stand.

This keyword was used in commercial thin treatments to simulate interplanting required to keep stocking levels above minimum levels required by the Oregon Forest Practices Act. Following commercial thinning, the equivalent stocking of seedling trees per acre < 1.0" was calculated using the following formula per the Oregon Forest Practices Act:

stocking = seedlings + (saplings/0.6) + (treesBA/0.4)

where seedlings represent the number of trees per acre (tpa) < 1.0", saplings represent the number of tpa 1.0" to 10.9" DBH, and treesBA represents the basal area per acre of trees >= 11.0" DBH. These variables are all calculated from the internal tree records maintained by FVS using the SPMCDBH command, described below.

If stocking fell below 125 tpa equivalent seedlings following commercial thinning, interplanting of 100 trees per acre of a ponderosa pine / Douglas-fir mix using the following keywords:

```
PLANT    0.      PARMS(PP,XX,100,2,2,2)
PLANT    0.      PARMS(DF,YY,100,2,2,2)
```

where XX and YY are strata-specific quantities determined by analysis of the project inventory described below. In the above instance, the survival percentage is estimated as 100% at the end of the cycle, the seedlings planted in the ground are 2 years total age, the average seedling height after 5 years is 2 feet tall, and seedlings are planted in areas with less overstory basal area (the final code "2').

NATURAL (Natural regeneration) – Specifies natural regeneration that will be added to the stand.

This keyword was used in all treatments to simulate natural regeneration following shelterwood harvest treatments. Natural regeneration was called into the strata the same year as the treatments occurred with a species-specific distribution in each strata and with a specific total trees per acre for each treatment. The number of trees per acre for each treatment was determined by consultation with local foresters and analysis of the average TPA of trees less than 5" DBH in the carbon inventory for the property. In all treatments, seedlings have an 100% expected survival rate, an average seedling age of 2 (default) in years for the year specified in Field 1, and a shade code of 0 (seedlings occur more uniformly on plots throughout the strata). The average seedling height in feet five years from the time of seedling appearance or at the end of the cycle, whichever is earlier, is estimated by the average seedling age set in Field 5 of the keyword parameters. Thus, an average seedling height was not

entered. Further details regarding the amount and species distribution of naturally regenerated stands may be found below in the Baseline Silviculture section of this document.

SPMCDBH - returns the trees, basal area, total cubic volume, merchantable cubic foot volume, total board foot volume, quadratic mean diameter, average height, percent cover, average mistletoe rating, stand density index, or average diameter growth per acre for a given species or species group, tree-value class, tree status, and range of diameter and height. These metrics can be obtained for live trees, cut trees, dead trees, live trees after thinning, or mistletoe infected trees. For more information on how SPMCDBH is used, please refer to Dixon (2002).

COMPUTE - allows the user to define variables expressed as mathematical expressions containing constants, Event Monitor variables, Event Monitor functions, and variables previously defined using the COMPUTE keyword. Variables are defined using mathematical equations in supplemental records, which are up to 80 characters long. The Event Monitor feature of FVS allows users to specify a set of conditions that must occur, or thresholds that must be reached in order for FVS to simulate a management activity or set of management activities. The COMPUTE keyword is used to define variables that are evaluated by the Event Monitor to determine if necessary conditions or thresholds have been met.

The COMPUTE keyword was used, in conjunction with FVS Keyword SPMCDBH to create variables which help monitor legally required stocking levels throughout silvicultural regime simulations by calculating the number of seedlings, saplings, and trees >= 11.0" DBH. COMPUTE was also used to calculate potential merchantable harvest volumes prior to harvest to determine if adequate volume was present.

IF-THEN-END IF - also known as scheduling by condition, the IF-THEN-END IF code block is used to execute FVS actions once certain conditions are met. The Event Monitor keyword sequence must begin with an IF keyword. The next record must be a condition statement that evaluates to true or false. The next record is a THEN keyword. The sequence ends with an ENDIF keyword. All keywords contained between the THEN and ENDIF keywords will be executed whenever the condition is true. The condition is checked every cycle unless that cycle falls within the minimum waiting time since the last time the condition was true.

NUMCYCLE - Specifies the number of cycles to run the projection. A cycle is the period of time for which tree characteristics are predicted, and for which inventories are reported (see TIMEINT).

TIMEINT - Specifies the length, in years, of any or all projection cycles. This keyword is used to ensure that an action can be implemented in the same year that it is scheduled rather than the FVS default, which is the first year of a cycle. The default projection cycle for the LS variant of FVS is 10 years. TIMEINT was used in conjunction with NUMCYCLE and IF-THEN-END IF code blocks to offer different timing possibilities of silvicultural actions throughout the 100-year planning horizon for each stand type. Having multiple prescriptions available for each stand in which different sequences and timing of harvest events and other silvicultural events occur ensures that property-level constraints, such as upper or lower limits on harvest volumes, can be met in the baseline planning model described below.

RESETAGE - Sets the stand age to zero to make FVS model output correspond to the actual age of the stand. Age is strictly for reporting purposes and has no effect on growth or survival prediction. Its only effect is on the calculation of mean annual increment. This keyword is useful when average stand age has changed due to thinnings and plantings. This keyword was used to reset stand age after shelterwood harvests so that the age of subsequent harvests could be calculated and controlled programmatically if necessary.

SITECODE - Sets species-specific site index values. If a SITECODE keyword is present, all species for which site index values were not explicitly set will be assigned site index values derived from the site index of the specified site species. If no SITECODE keyword is present, default site index values are assigned. Site index can be described for the site species of an entire stand, which is equivalent to entering a species code in the "Site_Species" field in the FVS_StandInit table, and for all other species in the stand. This keyword was used to assign site index values derived from field-sampled site tree data as described in the following section.

FIXDG - Multiplier used to modify the diameter growth rate of the specified species within the specified diameter range. This modifier is applied after growth prediction calculations, therefore adjusting the diameter growth will not affect height growth for that cycle. However, the changed diameter growth and resulting change in basal area will affect mortality that cycle.

FIXHTG- Multiplier used to modify the height growth rate of the specified species within the specified diameter range. This modifier is applied after growth prediction calculations, therefore adjusting the height growth will not affect diameter growth for that cycle.

FIXMORT- Induces mortality of a fixed proportion of the trees per acre represented by tree record of the specified species and within the specified diameter range. This can replace the predicted mortality or be in addition to the predicted mortality, or the effective mortality can be the larger of the two. For example, if a tree record represents 200 trees per acre of the designated species and within the specified diameter range, and the mortality rate is set to 0.3 and set to replace predicted mortality, 60 trees per acre (30%) from that record will die strictly due to this keyword.

The FIXDG, FIXHTG, and FIXMORT keywords were used in growth simulations to set diameter growth, height growth, and mortality equal to zero for mountain mahogany, the sole representative of the "NCOM" species group. These adjustments were made to hold the biomass of the mountain mahogany component constant (please see section above titled "A note on FVS and mountain mahogany").

The following keyword sequence was used in all FVS simulations to hold the mountain mahogany component constant:

```
FIXDG     0.       PARMS(NCOM,0.0,0.0,999.0)
FIXHTG    0.       PARMS(NCOM,0.0,0.0,999.0)
FIXMORT   0.       PARMS(NCOM,0.0,0.0,999.0,0)
```

A record of how all keywords were used in the modeling can be found in the FVS input databases submitted as part of the baseline modeling package.

Site Index, Site Productivity Class, Oregon Site Class, and Growth Determination

Site Index

Site index data across the property was collected through field procedures described above. The methods of Hanson et al. (2002) were used to calculate site indices compatible for use in the FVS-BM variant.

In the FVS-BM variant, Douglas-fir growth depends on the 50-year breast height age-based site index system of Cochran (1979). Hanson et al (2002) describe the method we used to transform measured field data into Cochran site indices as follows:

$$SI = 84.47 - AB + B(H - 4.5)$$

where

$$A = EXP\{-0.37496 + 1.36164 Ln(bha) - 0.00243434 [Ln(bha)]4\}$$

$$B = 0.52032 - 0.0013194\, a + 27.2823/a$$

SI = site index in feet for breast-height age 50 years

bha = field measured breast height age, and

H = field measured height in feet

Ponderosa pine growth depends on the 100-year breast height age-based site index system of Barrett (1978). Hanson et al (2002) describe the method we used to transform measured field data into Barrett site indices as follows:

SI = 100.43-(1.198632-0.00283073*bha+8.4441/bha)*(128.8952205*
(1-EXP(-0.016959*bha))^1.23114)+((1.198632-0.00283073*bha+8.4441/bha)*(H-4.5))+4.5

where

SI = site index in feet for breast-height age 100 years

bha = field measured breast height age, and

H = field measured height in feet

The final FVS-ready site index estimates by project inventory strata are shown below. Only Douglas-fir and Ponderosa pine measurements were used to develop site indices for FVS.

Table 6: Site index data by species

Project Strata	Species	DF Site Index (Cochran 1979)	PP Site Index (Barrett 1978)	# of Measurements
JP1	DF	43	0	5
JP1	PP	0	67	77
JP2	DF	52	0	13
JP2	PP	0	73	57
MC	DF	51	0	22
MC	PP	0	75	60

Site Productivity Class

Some ARB Assessment Areas are distinguished by site productivity class. The ARB FOP defines high site classes as USDA Forest Service Sites I, II, III and IV and low site classes as Forest Service Sites V – VII. The Forest Service separates site classes by potential yield, or mean annual increment expressed as merchantable cubic feet per acre (see USDA Forest Service Forestland Productivity Classes table below). High site classes have productivity greater than or equal to 85 cubic feet per acre per year potential mean annual increment ("MAI") while Low site classes have productivity less than 85 cubic feet per acre per year potential MAI.

Table 7. USDA Forest Service Forestland Productivity Classes

Code	Potential Yield, Mean Annual Increment
1	225 or more cubic feet per acre
2	165 to 225 cubic feet per acre
3	120 to 165 cubic feet per acre
4	85 to 120 cubic feet per acre
5	50 to 85 cubic feet per acre
6	20 to 50 cubic feet per acre
7	Less than 20 cubic feet per acre

In the subject Supersection, the Mixed Conifer assessment area in the project is separated into site classes (i.e. High and Low).

Hanson et al (2002) also describe PNW-FIA methods to calculate MAI from Ponderosa pine, Douglas-fir, and grand fir site data. First, an appropriate 100-year site index is calculated from field data similar to methods described above. Then the 100-year site index value is input into an appropriate MAI equation. A series of MAI equations, also called yield equations, were derived by PNWFIA from yield data found in published normal yield tables.

For MAI estimates based on Douglas-fir and grand fir site indices, first the 100-year site indices of Curtis et al (1974) were calculated for Douglas-fir and grand fir as follows:

SI = 4.5 + (0.010006*(100-bha)^2) + (1+(0.00549779*(100-bha)) + ((1.46842*10^(-14))*(100-bha)^7))*(H-4.5))

where

SI = site index in feet for breast-height age 100 years

bha = field measured breast height age, and

H = field measured height in feet

Next, these site index values were input into an estimator equation for MAI based on yield tables published by Cochran(1979a) for Douglas-fir as follows:

$MAI = 0.00473\ SI^{2.04}$,

and for grand fir as follows:

$MAI = EXP\ (\ 8.24227 - 23.53735\ SI^{-0.4})$.

For MAI estimates based on Ponderosa pine site indices, first the 100-year site indices of Barrett(1978) were calculated as described previously. Then these site indices were input into an estimator equation for MAI based on yield tables published by Myer(1961) for Ponderosa pine as follows:

$MAI = EXP\ (0.702695SI^{0.42} - 0.51367)$

The final breakout of MAI by High (>= 85 cubic feet per acre per year) and Low site classes is shown below in Table

Table 8: Productivity by strata

	Number of Measurements by Productivity		Percent of Measurements by Productivity	
Strata	High	Low	High	Low
JP1	2	80	2.44%	97.56%
JP2	3	68	4.23%	95.77%
MC	6	89	6.32%	93.68%

The percentage of site trees classified as “low” site class was used as a proxy to determine the percentage of acreage in each inventory stratum that was considered to be “low” site class for the purposes of determining common practice (only MC, overlaying the Mixed Conifer Assessment Area applied in this case).

Oregon Site Class

The Oregon Forest Practices Act uses six forest site classes, ranging from I, the highest site class, down to VI, the lowest. In Eastern Oregon, Ponderosa pine is listed in the Oregon Forest Practices act as the indicator species for site class, based on 100-year site index (OFRI, 2018). Ponderosa pine with 100-year site indices greater than 109 classify as Site III or higher, while those with 100-year site indices less than 64 classify as Site VI. For management considerations regarding required stocking levels prior to and after harvest activities, the same set of rules generally applies to both site classes IV and V. For management considerations in the baseline, meeting the reforestation and stocking requirements of Site IV/V acres will also fulfill the requirements of Site Class VI. Only 1% of Ponderosa pine site indices measured on the property registered as Site III or higher. **For the purposes of baseline modeling, 100% of the property was assumed to be subject to reforestation and stocking methods proscribed for Site IV or lower lands.**

Table below shows the composition of project inventory strata by site class according to measured Ponderosa pine site index.

Table 9: Ponderosa Pine Site Class

Inventory Strata	**Ponderosa Pine Site Class Estimate based on 100-year measured site index**		
	III+	**IV/V**	**VI**
JP1	1	40	36
JP2	1	41	15
MC	0	49	11
Grand Total	**2**	**130**	**62**

Annual Growth and the Initial Project Inventory

The project inventory was conducted June through July of 2020, after the majority of the year's growth, or effectively year-end 2020. The initial reporting period start date is shortly after the completion of the project inventory, July 30,2020. The initial reporting period end date is February 26, 2020, also after the 2020 growing season. Therefore, the beginning and ending carbon inventory stocks are assumed to be the same.

Carbon Modules

This section describes the steps to process the FVS output data subject to the ARB volume and biomass equations for projects located in California, Washington and Oregon using the *carbon modules*. The carbon modules are a set of proprietary MS Access relational databases setup primarily to calculate carbon stocks from the FVS_TreeList and FVS_CutList. The carbon modules are based on a series of queries that select data and perform the calculations necessary to summarize onsite and harvested carbon stocks by stratum in a fashion that is compliant with the Forest Offset Protocol.

Step 1: Run FVS and create tables for FVS module.

Inventory data is processed in the FVS to obtain modeled data. This includes: growth (accretion and in-growth), mortality, and harvesting. FVS output tables are maintained in output databases (e.g. ForestCarbon_FVS_OUT.mdb) and include the following tables: FVS_Cases; FVS_Summary (or FVS_SummaryEast for eastern variants); FVS_TreeList; and FVS_CutList.

Step 2: Run the Central Module.

The purpose of this module is to calculate the cubic foot volume, biomass, and ultimately carbons stocks by stratum and year, from the tree list and cut list output from FVS. The database is programmed to relate each tree

by species to the appropriate volume equation and biomass coefficients associated with the project. The database includes a form with instructions and buttons to execute commands.

Step 2a: Calculate cubic foot volumes (VOLCFGRS & VOLCFSND) using "Volumetric Equations for California, Oregon, and Washington (September 19, 2014)" as published by ARB on their website.

a. Open the CRM_Central_Module.mdb database.
b. Follow instructions in tab 1 of the form (Setup) to make the Strata-Species-Site Index table (StrataSppSI) for species that require site index as a volume equation input.
c. Follow instructions in tab 3 the form (ORWACA + AK Methods) to make the ORWACA Species Table to create a crosswalk table for cubic foot volume and biomass equation references, wood density values, and Harmon Density Reduction factors for the ORWACA method.
d. Follow instructions in tab 3 of the form (ORWACA + AK Methods) to calculate cubic foot volumes which will apply the appropriate ARB cubic foot volume equations as indicated in the species look up table.

Quality Control Note: After making these tables, open them up and sort the 'VOLCFGRS' column in descending order. Observe the highest value. If the value equals 5,000,000 then an error occurred because the species was not recognized, i.e. a species code or equation reference was not related correctly.

Step 2b: Calculate biomass using the "Biomass Equations for California, Oregon, and Washington (September 19, 2014)" as published by ARB on their website and the volumes calculated in the previous step.

a. Still within the CRM_Central_Module.mdb database.
b. Follow instructions in tab 3 of the form (ORWACA + AK Methods) to calculate biomass which will apply the appropriate biomass equations as indicated in the species look up table by species.

Step 2c: Create Final Stand Summary

a. Still within the CRM_Central_Module.mdb database.
b. Follow instructions in tab 4 of the form (Summary) to create a Final Stand Summary. This will execute several sub-queries to convert biomass to carbon and then aggregate volumes and carbon stocks by strata by year.

Further description of Carbon Pool Calculation Assumptions

Allometric Equations used

The Forest Protocol requires estimates of total above-ground and below-ground biomass. OPOs/APDs with projects located in Alaska, California, Oregon, and Washington should use these instructions[3] to estimate volume and convert biomass to tons of CO2e emissions or removal enhancements. The Protocol requires use of specific volume equations found in "Volumetric Equations for California, Oregon, and Washington (September 19, 2014)" and "Biomass Equations for California, Oregon, and Washington (September 19, 2014)". See Table 10 below, which is also provided in Excel format in the OPDR Worksheet Calculations.

IFM-1: Standing Live Carbon (carbon in all portions of living trees)

1. Live trees were inventoried. Rotten material was measured by percent of the main bole and deducted from gross volume to determine sound volume.

[3] https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/2015/instructions-ca-or-wa_2015.htm

2. Growth data (diameter and total height increment) is processed in the FVS-NC Variant.
    a. Species with a volume equation that required total height used the FVS output estimated total height. The total heights of each tree from the inventory were input to FVS; FVS projects total height increment in subsequent years. The height to top kill was used if this type of height was present for a tree.
3. FVS is only being used for DBH and height data – the FVS_TreeList cubic foot volumes are not used in carbon calculations. Carbon calculations are based on the ARB Cubic Foot Volume Equations for gross cubic volume (VOLCFGRS) in the United States for projects located in California, Oregon, and Washington. Gross cubic foot equation references used for this project are shown below in.
4. Sound volume (VOLCFSND) is calculated for both standing live and standing dead trees by deducting the volume of wood that is rotten or missing from the VOLCFGRS based on the percentage of missing or rotten volume estimated in the field during the inventory
5. The CRM Central Module houses the volumetric and biomass equations tables which contain the species-specific formulas as provided by ARB in the "Volumetric Equations for California, Oregon, and Washington (September 19, 2014)" and "Biomass Equations for California, Oregon, and Washington (September 19, 2014)" documents under the Forest Offset Protocol instructions page.
6. The central module stores a species table that relates the FVS_TreeList.SpeciesFIA field to the Species_LU_ORWACA.SpeciesFIA field to match the equation reference numbers and wood density.
7. The FVS_TreeList, CRM_CFVolume, and CRM_biomass tables are then related to each other and tree records are summed by stratum to calculate standing live trees per acre, basal area, merchantable cubic feet, and forest carbon.

Table 10. Volume and Biomass Equation Assignments by Species

Species Name	FIA Code	ARB ORWACA CuFt Reference	ARB ORWACA Biomass Live Branches Reference	ARB ORWACA Biomass Stem Bark Reference	ARB ORWACA Wood Density
grand fir	17	23	1	2	21.84
western juniper	64	21	13	16	28.08
western larch	73	22	20	24	29.95
ponderosa pine	122	4	7	9	23.71
Douglas-fir	202	2	22	25	28.08
curl leaf mountain-mahogany	475	45			32.45

IFM-3: Standing Dead Carbon (carbon in all portions of standing dead trees or snags)

Standing dead trees (i.e., snags) were inventoried using the same sampling methodology as live standing trees. Dead tree decay status was classified using the classes and density reduction factors described by Harmon, et al. (2011) for inventoried standing dead trees. The five decay classes (listed below) are qualitative, based on the physical characteristics of the standing dead tree. The decay class is indicated in the inventory data in the FVS_TreeList.SSCD column. The dead tree decay status codes are concatenated with a 3 for programmatic reasons (e.g. 23 = "There are few limbs and no fine branches; the top may be broken; a variable amount of bark remains; sapwood is sloughing with advanced decay; heartwood is sound at base but beginning to decay in the outer part of the upper bole."; 33 = "Only limb stubs exist; the top is broken; a variable amount of bark remains; sapwood is sloughing; heartwood has advanced decay in upper bole and is beginning at the base."). The five decay classes are described below in Table 11.

Table 11. Decay Class Definition

Decay Class	Description
1	All limbs and branches are present, the top of the crown is still present, all bark remains, sapwood is intact with minimal decay, heartwood is still sound and hard.
2	There are few limbs or fine branches, the top may be broken, a variable amount of bark remains, sapwood is sloughing, heartwood has advanced decay in upper bole and is beginning at the base.
3	Only limb stubs exist, the top is broken, variable bark remains, sapwood is sloughing, heartwood has advanced decay at the base and is sloughing in the upper bole.
4	Few or no limb stubs remain, top is broken, variable bark remains, sapwood is sloughing, heartwood has advanced decay at the base and is sloughing throughout.
5	No evidence of branches remains, the top is broken, less than 20 percent of the bark remains, sapwood is gone, heartwood is sloughing throughout.

Applying density reduction factors (DRF) and Structural Loss Adjustments (SLA):

The standing dead carbon pool must be adjusted for density reduction and structural loss. Density Reduction Factors can be found in Harmon (2011) Appendix B and D. For projects located in Alaska, California, Oregon, and Washington, the Domke method of applying Structural Loss Adjustment Factors by tree component using the Component Ratio Method is not applicable. To account for structural loss on standing dead trees in these states, any observed soundness deduction from the inventory for standing dead trees in applied to the gross cubic foot volume before applying the density reduction factors.

The central module stores a species table that relates the FVS_TreeList.SpeciesFIA field to the Species_LU_step2.SpeciesFIA field to match the equation reference numbers and wood density. It also matches the FVS_TreeList.SSCD code (described at the beginning of this section) to the same look-up table which also contains the Harmon DRF values for each species.

Note: The reductions and adjustments described above are made to the sound volume (VOLCFSND), which is calculated for each record using the steps outlined for IFM-1 above.

Table 12. Density Reduction Factors

Species Name	FIA Code	rel1	rel2	rel3	rel4	rel5
grand fir	17	1.013	0.966	0.855	0.574	0.574
western juniper	64	0.994	0.951	0.902	0.605	0.605
western larch	73	0.994	0.951	0.902	0.605	0.605
ponderosa pine	122	0.925	1.007	1.154	0.481	0.481
Douglas-fir	202	0.892	0.831	0.591	0.433	0.433
Curl-leaf mountain-mahogany	475	0.982	0.793	0.618	0.525	0.525

For all snags less than 20 inches and for all but the last 5 percent of snags over 15 inches the number of snags in a record that fall each year is calculated as:

$$R = -0.001679d + 0.064311 \qquad \text{Eq. (1)}$$

$$F = mRN_0 \qquad \text{Eq. (2)}$$

Where:

R = rate of fall

D = initial diameter at breast height in inches of the snag

N_0 = initial density (stems/acre) of snags in the record

m = multiplier that can be used to change the rate of fall (as listed in the FVS Variant Overview)

F = density of snags (density of snags, stems/acre) that fall each year from that record

For the last 5 percent of snags over 20 inches, the number of snags falling each year is:

$$F = \frac{0.05}{A - T} N_0 \qquad \text{Eq. (3)}$$

Where:

F = density of snags (density of snags (stems/acre) that fall each year from that record

A = maximum number of years that snags will remain standing (i.e. the time when all snags will have fallen, based on FVS snag class)

T = time when 95 percent of the snags had fallen

N_0 = initial density (stems/acre) of snags in the record

This ensures that some large snags persist throughout the period of Time A, but that none persist beyond this time.

Assessment Area Analysis

This section describes the steps followed in the FOP (Appendix F Determining a Value for Common Practice) to determine the standing live, above-ground carbon common practice statistic.

Supersection

The project area lies within the Blue Mountains FOP Supersection (see ACR554 OPDR RP1 Attachment E and F Maps.pdf).

Assessment Areas

The project area was stratified by Finite Carbon as described in the Stratification Rules section of the Sampling Methodology.

Site Class

Site class acres by Assessment Area were determined using the methods described previously in the Site Index, Site Productivity Class, Oregon Site Class, and Growth Determination section. Only the MC strata / Mixed Conifer Assessment Area has common practice values which differ by site class.

The final dispensation of the project inventory by inventory strata and assessment area is shown below in Table 13 along with the calculation of the common practice statistic for this project. The common practice carbon stocking for the Project Area is calculated to be 23.51 tons per acre.

Table 13. Common Practice Carbon Stocks

Supersection	Assessment Area	Site Class	Project Area (Acres)	CP Stock	Area Weight	Weight CP
Blue Mountains	Blue Mountain Juniper / Pinyon Woodland	**All**	9,164.6	13.38	64.97%	8.70
	Blue Mountain Mixed Conifer	**High**	312.1	64.98	2.21%	1.44
		Low	4,629.8	40.76	32.82%	13.38
TOTAL			14,106.5		100.00%	23.51

Baseline Modeling Constraints

In modeling the baseline for standing live and dead carbon stocks, the forest owner has considered and incorporated all operational, legal, and financial constraints that could affect baseline growth and harvesting scenarios.

Characterization

The baseline scenario models timber harvesting over 100 years, as a function of what it is legally allowable, financially feasible and physically possible, while at the same time adhering to the minimum baseline level (MBL). In the baseline model, forest development was projected using a combination of regeneration harvest and grow-only regimes. Forest stands were eligible for treatment types based primarily on their forest structure, site attributes, and baseline model constraints. Constraints that affect land-use specific to forest management activities have been incorporated into the baseline carbon modeling, as described in detail below.

Legal Constraints

Oregon Forest Practices Act and Rules (Oregon FPA)

The Oregon Forest Practices Act and Rules (as described in detail within Cloughesy et. al. 2018) makes clear the stewardship expectations of the public and ensures that landowners operating under its rules can manage their forests for a variety of objectives. This was the first forest practices act legislated in the United States (1971).

Activity-Specific Guidelines that are applicable to forest management activities include:

- Harvesting trees, especially around streams, lakes or wetlands
- Providing for the needs of wildlife
- Disposing of forest slash
- Building or improving forest roads
- Applying chemicals to forestland
- Protection from fire and use of fire

Riparian Areas
The requirements of the Oregon Forest Practices Act are intended to protect fish, wildlife and water quality when forest management activities occur near waters of the state and within riparian management areas. Protection measures are based on how the water body near an operation is classified, as well as the geographic region. Protection measures apply even when the water body is dry.

A Riparian Management Area (RMA) is the defined portion of the riparian area adjacent to a stream, lake, or open water wetland where RMA guidelines apply. RMA area is dependent on use and size.

Table 14: Riparian Classification Use Code

Use Code	Stream Type (Use)
F	Has fish and may be used for domestic water.
SSBT	Small or medium Type F streams that have salmon, steelhead or bull trout (west side of Cascades only)
D	Does not have fish but may be used for domestic water.
N	Has neither fish nor domestic water use.

Table 15: Riparian Size Class

Size Class	Stream Size
Small	Annual flow average 2 cu ft/sec, drain less than 200 acres, less than 7 feet in width.
Medium	Annual flow average >2 and <10 cu ft/sec, width 7-12 feet.
Large	Annual flow average >10 cu ft/sec, width >12 feet.

In Eastern Oregon, the RMA associated with streams is dependent on these two categories – use and size. For fish bearing streams (which we conservatively assumed included all streams on the property), the following table is applicable.

Table 16: Riparian Management Area (RMA) Widths

Waterbody Characteristics	RMA Widths
Small Stream, F (fish bearing)	50 feet
Medium Stream, F (fish bearing)	70 feet
Large Stream, F (fish bearing)	100 feet

These RMA widths were determined on the project area using the spatial data (Statewide Streams) provided by the Oregon Department of Forestry:

https://www.oregon.gov/odf/aboutodf/Pages/mapsdata.aspx

Reforestation

The requirements for reforestation in Oregon are based on Site Class (Cloughesy et. al. 2018) and are provided in Table 17.

Table 17: Reforestation Requirements by Site Class

Site Class	Seedlings (less than 1-inch DBH) or	Saplings & Poles (1-10 inches DBH)	Trees 11 inches and larger
High (Site Classes I, II and III)	200 per acre	or 120 trees per acre	or 80 square feet of basal area per acre
Medium (Site Classes IV and V)	125 per acre	or 75 trees per acre	or 50 square feet of basal area per acre
Low (Site Class VI)	100 per acre	or 60 trees per acre	or 40 square feet of basal area per acre

Baseline Model Considerations: The baseline model considers the management guidelines of the Oregon FPA by applying no-harvest regimes to project areas identified in the GIS that fall within the RMA buffers. Since almost all streams on site are classified as Small, we have applied a 53.5-foot buffer on the linear spatial data (50-foot RMA plus half-width of widest stream in this category – 7 feet.). Medium streams have a 76-foot buffer (70-foot RMA plus half-width of widest stream in this category – 12 feet.)

Other elements of the FPA regarding road construction, stream crossings, and logging systems are assumed to be followed and do not require alterations to the baseline modeling.

In order to meet reforestation requirements, we have adopted a natural regeneration or interplanting model as described in the Baseline Silviculture section.

Endangered Species Act (ESA)

The Endangered Species Act (ESA) provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The lead federal agencies for implementing ESA are the U.S. Fish and Wildlife Service (FWS) and the U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries Service. The FWS maintains a worldwide list of endangered species. Species include birds, insects, fish, reptiles, mammals, crustaceans, flowers, grasses, and trees. A full list is included in Attachment K.

Table 18: Listed Species Identified on the Project Area

Status and Location	Species
Threatened (Amity Creek and Opal Creek)	Steelhead (*Oncorhynchus mykiss*)

Baseline Model Considerations: There are no restrictions that impact modeling. We have reviewed recovery plans and management restrictions required by law for the above species, as well as reviewed spatial locations where these species are encountered and did not find any additional modeling restrictions that would have to be put into place to ensure compliance with the ESA. It is assumed that all management activities will avoid a taking and that if

additional endangered species are discovered in the property, a voluntary harvest protection plan will be developed.

Operational Constraints

Outside of the legal considerations listed above, there are few operational constraints affecting timber harvesting on the property. The methods and modeling parameters are described below. In addition, Finite Carbon has provided a financial feasibility analysis (Attachment L) which demonstrates that operations meet a standard of economic viability.

Baseline Silviculture

Commercial Thin/ High Grade Harvest Regimes

In the Commercial Thin/High Grade ("HG") regime, the practice of "high grading" – thus the acronym HG - was simulated to reflect harvest of all merchantable commercial species greater than 7.0" DBH besides Western juniper. Western juniper, present in all strata, is also harvested to the minimum wildlife tree requirement of 2 trees per acre greater than or equal to 11.0" DBH. Additional opportunistic recruitment of wildlife trees via snag retention is assumed but not explicitly modeled. A minimum removal volume of 2,000 board feet per acre is required for a harvest entry.

Reforestation is also required if stocking levels fall below legally required levels for Site IV/V lands. Stocking levels in the HG regime are evaluated at each cycle of FVS, before and after and harvest removal to check whether minimum legal stocking requirements are maintained or not with the following variables calculated via the COMPUTE keyword:

```
Seedlngs=SPMCDBH(1, All, 0.0, 0.0, 0.99, 0.0,999.0,3)
Saplngs=SPMCDBH(1, All, 0.0, 1.00, 10.49, 0.0,999.0,3)
treesBA=SPMCDBH(2, All, 0.0, 10.50, 999.0,0.0,999.0,3)
stocking = seedlngs + (saplngs/0.6) + (treesBA/0.4)
```

The first three variables represent the definitions of seedlings, saplings, and trees in the 11.0" diameter class and larger per the Oregon Forest Practices act, while the last variable, "stocking" calculates the equivalent stocking of seedlings per acre that is required to meet minimum reforestation standards per OAR 629-610-0020 in the Oregon Forest Practice Rules. For Oregon Site Class IV and V timberlands, the minimum required reforestation stocking level following harvest is 125 seedlings per acre.

After each harvest entry in the HG regime, the variable "stocking" above is calculated. If the stocking level falls below 125, interplanting of 100 tpa is simulated using the PLANT keyword sequence described previously. Douglas-fir and Ponderosa pine seedlings are planted at the following levels, based on the relative proportion of trees less than 5" as measured in the project inventory.

Table 19: Regeneration planting assumptions

Project Inventory Strata	Ponderosa Pine interplant seedlings per acre	Douglas-fir interplant seedlings per acre
JP1	92	8
JP2	77	23
MC	67	33

Commercial Thin/High Grade ("HG") harvest regimes were applicable to all project inventory strata for acreage not falling in a riparian management area ("RMA") buffer.

Clearcut-Convert Harvest Regimes

Clearcut-Convert harvest regimes were designed to simulate the removal of all canopy trees (which includes all species except for mountain mahogany) to convert forestland to rangeland for grazing to simulate juniper removal and conversion activity. This simple regime removes all trees except for mountain mahogany and assumes that any natural regeneration will be managed and removed as part of the ongoing function of the converted land for grazing.

The Clearcut-Convert regime applied only to the inventory strata associated with the Juniper-Pinyon assessment area; that is, the JP1 and JP2 strata. All areas were eligible for this treatment, but no more than 100 total acres falling within RMA zones was set as an upper limit for RMA juniper conversion. As stated in the OFPA, juniper removal or treatment is not considered a "forest operation" (Cloughesy 2018, p. 4) and is a widely funded practice across the state (https://www.oregon.gov/oweb/data-reporting/EM/Pages/Juniper-Mgmt-EM.aspx) . Finite Carbon interviews with a local consultants (Gabe Williams and Jake Polvi) who have managed agency (Oregon Watershed Enhancement Board) grant funding for juniper conversion indicate that on average 10,000 acres of projects are funded across the state. Their experience has shown that 500-1500 acres is a reasonable project size that could receive annual funding, and that successful projects often attracted funding in consecutive years. As a result, the baseline model assumes a maximum of 1,000 acres treated annually with no more than 4,000 acres treated over the lifespan of the baseline planning model. This model simulates the application of juniper removal restoration dollars and treatments across the property.

Grow-only Regimes

Grow only regimes simulate natural growth of forest stands with no silvicultural intervention. With the exception of some juniper conversion acres, this was the only allowable option for RMA areas, However, in concert with all property wide goals of the baseline planning model, all stands were eligible to receive the Grow-only regime.

Baseline Planning Model

In compliance with the requirements of Appendix B(a) of the FOP, FVS and the carbon modules were used to create yield tables representing a variety of 100-year silvicultural regimes for each of the project strata. Over 300 regimes consisting of 100-year FVS simulations were run, and their FVS Outputs processed through the modules to create a series of yield curves based on the timing options specified by the FVS Keywords used to simulate each regime. These yield curves were then loaded into a proprietary Excel workbook in which the yield curves are interpolated to provide annual values of key carbon metrics. The final, annualized set of yield curves are next imported into Remsoft's Woodstock planning model to evaluate and allocate acres to each FVS yield table to help determine a final baseline harvest schedule that complies with the Minimum Baseline Level, legal constraints, and financial considerations. The final, optimized set of yield curves is then used to calculate 100-year averages of onsite carbon pool inventories, harvested carbon outputs, and cord volumes harvested on a per acre basis. Results of the Baseline Planning Model may be found in the ACR554 Baseline Worksheet.

ROC/ARBOC Monitoring Calculation Worksheet

After completion of the baseline modeling, the results are summarized in a MS Excel worksheet. The results are then inserted to the ROC/ARBOC Monitoring Calculation Worksheet and the Harvested Wood Products Calculation Worksheet tool for the baseline and project scenarios.

Monitoring Plan (Inventory Updates and Data Management)

This portion of the Inventory Methodology describes the Project's annual monitoring plan. The primary purpose of the project's annual monitoring plan is to ensure up-to-date estimates of project carbon stocks and provide assurance that GHG reductions or removals achieved by a project have not been reversed.

Components of the Monitoring Plan

The major components of the property's monitoring plan are:

1. Continuous forest inventory and carbon stock updates: This component focuses on updating the forest carbon inventory and includes conducting forest carbon inventories by following the *Sampling Methodology*. It also encompasses the process of recording any timber harvests or other activities that affect the overall carbon stocks. The output of this process is used to complete the Annual Forest Monitoring Report, as well as the ROC/ARBOC Monitoring Calculation Worksheet and the Harvested Wood Product Calculation Worksheet.

2. Forest carbon project verification by an ARB accredited verifier. Each year, the project is required to be verified by an accredited third-party auditor. This audit will serve to provide assurance to the ARB that the project is operating in compliance with the Forest Offset Protocol.

Forest Health

As per the requirements of the FOP Appendix A(a) this subsection of the monitoring plan identifies any known and potential insects or diseases that may affect the health of the project's inventory, specifically above-ground standing live and dead trees.

Known insects in the area include scattered pockets of bark beetles (Western pine beetle, Mountain pine beetle), Ips beetles, Pandora moth (*Coloradia pandora*), Pine sawfly (*Neodiprion annulus contortae*), ponderosa needle miner moths (*Coleotechnites ponderosae*), eastern larch beetle, larch casebearer, Douglas-fir beetle, and Douglas-fir tussock moth (USFS ODF, 2020).

Common diseases that may impact stocking levels include armillaria root disease, western gall rust, pine dwarf mistletoe, Black pineleaf scale, larch needle cast, larch dwarf mistletoe, Laminated root rot, Blackstain root disease, Swiss needle cast, Rhabdocline needle cast, Douglas-fir dwarf mistletoe, and Heart and stem decays (USFS ODF, 2020).

Updating Forest Carbon Stocks

There are three major inputs for updating forest carbon stocks: activity data, emissions factors, and the confidence deduction.

Activity Data

Activity data is defined as the aerial extent of a land-use category. It is the "area data" in units of acres. In this case, land-use will be stratified across the property in order to classify forest versus non-forest, and within forests, the forest type based on the dominant tree species or representative vegetative community. These strata are described in the earlier Stratification Rules section, and all changes to the activity data should follow these stratification criteria.

Activity data can change for several reasons including growth, timber harvests, natural disturbances and succession or selling property within the project area; these changes in activity data are collectively labeled as *events*. Events can affect the proportion of strata within the project area; however, the total aerial extent of the project area cannot change. For this project, activity data will be monitored and reported over time using spatially explicit datasets, also known as a Geographic Information System or GIS. On a continuous basis throughout the year, changes in activity data will be mapped, attributed and recorded by professional foresters during timber harvest operations and timber cruises. Changes will be submitted to and edited by the forest owner's GIS controller. Edits to the activity data will be compiled and delivered to the project developer at the end of each reporting period. The project developer will store and archive all activity data by year in the project's geodatabase in the "stands" feature class, which will also serve as the activity data change log.

Emissions Factors

Emissions factors are defined as the emissions/removals of greenhouse gases per unit area. In this case, metric tons of CO_2 equivalents (tCO_2e) will be used to express emission factors as a result of changes in forest carbon stocks. Emission factors vary based on the category of activity data (i.e. strata) and are derived from forest inventory plots.

Forest inventory plots will be conducted according to the Sampling Methodology and processed by Finite Carbon using the data management and analytical systems outlined under Analytical Methods and Biomass Equations. The forest owner will use permanent and temporary inventory plots as needed, to annually update the project's forest carbon stocks. Measuring the same plots through time will reduce sampling variability and provide reliable estimates of actual growth through time. New temporary and/or permanent plots will be used where previous plots or continual forest inventory (CFI) plots are not able to accurately represent a particular change in activity data. Inventory plots input to growth & yield modeling, as well as tracking harvest volumes, will be used to assess the changes in carbon stocks. No forest inventory plot data greater than 12-years old will be used.

Events

Events are activities that occur within the project area that affect activity data or emission factors. Events will require spatial and tabular updates to the carbon database. A list of events including harvest volume summaries will be submitted by the Forest Owner to Finite Carbon at the end of each reporting period for the previous year and prepared for verification by completing a monitoring report.

1. Just Growth

Just growth events are assumed to occur in all areas of the project where no other event is assumed to occur. In this event, the activity data and emissions factors are updated by projecting inventory data using FVS growth and yield software, or with new plot data, assuming that accretion and mortality are only a function of the stand's structure and condition from the previous reporting period. Furthermore, growth also occurs in other areas where other events take place, e.g. a timber harvest. In this case, the activity data and emissions factors are updated in the same fashion as just growth events, but accretion and mortality are adjusted based on the other event's effects, e.g. timber harvesting will reduce the carbon stocking, but may increase growth rates while reducing mortality because crop trees are free to grow.

Annual growth increments are determined using the method described under Data and FVS Setting. The annual height and diameter growth increments specific to each tree record are added to those records at the end of each reporting period.

2. Land Sales

Land sales activity has a tremendous bearing on every carbon project. Should all or a portion of the area committed to the carbon project be sold while under the project's commitment terms, Finite Carbon will need to be notified as soon as possible. The forest owner will be required to provide digital mapping and possibly other documentation for the area affected by the sale. Please note that any Land Sales taking place on the Project Area will remain subject to the Forest Offset Protocol and Regulations, and therefore remain part of the Project. Should any portion of the Project Area be sold and wish to terminate the Project, the whole project will be considered terminated, as there is no provision which currently allows the Project Area to be divided into multiple projects. Once the Project Area for Improved Forest Management Projects has been verified, the Project Area cannot be changed for the duration of the Project's lifetime.

3. Natural Disturbances

Natural disturbance events can include beaver dams, wind storms, tornadoes, ice storms, floods, land-slides, earth quakes, insect or disease infestations, or other impacts of weather or nature on the forest carbon stocks. Finite

Carbon must be notified immediately following an event of this type. The forest owner will be required to supply mapping of the damaged area, and in some cases, a re-inventory of the original sample locations affected by the event performed to the specifications attached.

4. Harvests and Land Use Conversions

IFM projects typically encounter planned timber harvests, thinning, clearing for roadways, log yards, decks, or other uses on a regular basis. When these events occur, the forest owner is required to provide Finite Carbon with a digital (GPS or GIS) polygon file of the affected area. If harvest activities affect permanent plots, a complete re-inventory of those samples affected by the action may be required. All points re-inventoried will conform to the original specifications and shall be freshly flagged and painted for relocation. Finite Carbon shall also be informed if the activity produces or is expected to produce a forest type conversion. If the conversion is to non-forest use, such as new road construction, these areas will be mapped and the correct adjustment to the project acreage and total carbon stocks will be made. All new inventory plot data should be submitted electronically in Excel or Access formats. All areas of timber harvest will be associated with a harvest volume summary.

Harvest volume summaries will be submitted to the project developer by species group (Hardwood/Softwood) and product (Sawtimber/Pulpwood), at a minimum. All harvest volume summaries must be verifiable from mill/contractor receipts (pay-as-cut sales) and/or prospectus cruises (lump-sum sales).

Annual Inventory Updates

Carbon accounting within the project area will require accurate harvest shapefiles and volumes. The harvest polygons will be intersected with the project area shapefile to prorate the harvest volumes to the project area. This will allow for the quantification of carbon in harvested wood products from timber cut within the project area.

Post-harvest updates to project spatial data and the corresponding carbon stocks in those areas will be handled in one of two ways depending on the verification needs of the project for the current reporting period:

- For reporting periods subject to less-intensive verifications or deferring verification, updates to the project area stratification will be based on modeling. Treatments effects will be simulated based on the prescription provided by the forest owner (and following the requirements for using models to forecast carbon stocks established in Appendix B of the FOP). The end of reporting period carbon stocks in these areas will be calculated following the methodology outlined in Part VII.B. below. The resulting tCO2e per acre will be allocated to the approximate acreage treated based on the harvest polygons to allow for accurate carbon quantification across the project area for each reporting period.

- For reporting periods subject to full site visit verifications, the stratification across the project area will be updated to reflect the changes that have occurred during the previous reported-only years and all or some of the inventory plots will be remeasured.

Additional OPO Monitoring Activities

There are several procedures the OPO currently implements to ensure that all relevant events are monitored, documented, and reported. First, the property is routinely monitored by several staff members and a hired consulting forester. These team members visually inspect the forest conditions and can report unplanned activities they were not aware of such as significant natural disturbances. For planned events, the OPO will employ contractors appropriately licensed and dedicated to project coordination, maintaining deeds and records, and mapping/engineering. The OPO will ensure that planned activities with respect to impact of carbon stocks are reported in a manner that conforms to the project's inventory methodology.

On-going monitoring by the forest owner and its forest managers will ensure Unintentional Reversals will be reported to ARB and where necessary, an inventory of affected portions of the forest will be inventoried to account for unintentional reversals that create a need for ARBOC replacement from the Forest Buffer Account.

Inventory design to account for losses from unintentional losses will depend on the extent and intensity of the reversal should they occur.

Age Class

All OPO inventory records, including establishment year updates following harvest activities, will be updated and maintained on an annual basis or more frequently as part of normal business procedures. Monitoring OPO's compliance with the FOP age class distributions requirement will be achieved through querying OPO's inventory records combined with verification checks of imagery and field conditions.

Confidence Deduction

Offset Project Operators are required each year to apply a confidence deduction to the inventory of actual onsite carbon stocks based on field sampling (sample error based on the carbon in all carbon pools included in the forest carbon inventory calculated at the 90% confidence level). The confidence deduction must be updated each time the offset project is subject to a full, site visit verification, but must remain unchanged between verifications. If increased sampling over time results in a lower confidence deduction at the time of verification, the lower deduction must be applied to inventory estimates in the most recent reporting period subject to verification at that time. ARB or registry offset credits may be issued in the most recent reporting period for any verified increase in quantified GHG reductions and GHG removal enhancements associated with the new (lower) confidence deduction.

Conversely, if a loss of qualified sampling plots results in a higher confidence deduction, this higher deduction is applied to the inventory estimates in the most recent reporting period subject to verification at that time. Any resulting decrease in quantified GHG reductions and GHG removal enhancements from prior years as a result of the increased confidence deduction will be treated as an intentional reversal and must be compensated pursuant to the Regulation.

To determine the appropriate confidence deduction (also see ACR416 OPDR Calculations):

1. Compute the standard error of the inventory estimate by strata (based on the carbon in all carbon pools included in the forest carbon inventory).
2. Multiply the standard error by 1.645.
3. Divide the result in (2) by the total inventory estimate (strata mean tCO_2e) and multiply by 100. This establishes the sampling error (expressed as a percentage of the mean inventory estimate from field sampling) for a 90-percent confidence interval.
4. Consult Table A.4 from the FOP to identify the percent confident deduction that must be applied to the inventory estimate for the purpose of calculating GHG reductions and removals.

Table A.4. Forest carbon inventory confidence deductions based on level of confidence in the estimate derived from field sampling.

Sampling Error (% of Inventory Estimate)	Confidence Deduction
0 to 5%	0%
5.1 to 19.9%	(Sampling Error – 5.0%) to the nearest 1/10th percentage
20% or greater	100%

Monitoring Quality Control

Quality Control for this project is defined as a series of activities and documented procedures that serve to maintain an acceptable level of data quality for monitoring forest carbon stocks and demonstrating compliance with the Forest Offset Protocol. Quality control success will be measured by passing sequential sampling review by the verification body during the site visit.

Organization and Responsible Individuals

Individuals responsible for maintaining project operations have been defined in the Listing Form and listed under the forest owner's account information in both the Offset Project Registry account and the CITSS account. Any changes, including new contact information, will be updated to the account information immediately.

Document Control

Forest Owner and Finite Carbon will be responsible for maintaining critical documents and files that support forest carbon data collection and processing. All documents will be stored on company computers and back-up servers, as well as cloud-based data sharing folders, for a minimum of 15 years following the issuance of ARB Offset Credits related to each OPDR. The most critical documents and files necessary to be maintained include:

1. Offset Project Data Reports;
2. Project Inventory Methodology, including all requirements from the FOP Appendix A(b) (Appendix A);
3. Project geodatabase (GIS file geodatabase, Attachment I);
4. ROC/ARBOC Monitoring Calculation Worksheet; and
5. Harvest Wood Product Calculation Worksheets;

A change log specific to this monitoring plan to show updates made to raw inventory field data, inventory specifications, and data management and analytical systems will be recorded in the table below. When an update is made to the raw inventory field data or to the inventory methodology and calculations, it should be recorded in the Inventory File and Data Change Log. Modifications to inventory methodologies must be approved in advance by a third-party verification body and by ARB.

All edits and revisions to documents after project registration will be clearly marked and identified by placing a revision date or version number at the beginning of the document or within the name of the file. Outdated versions of documents will be archived. Other forms and documents required by ARB will be maintained and stored in the forest owner's account on the OPR software.

Central Data Repository

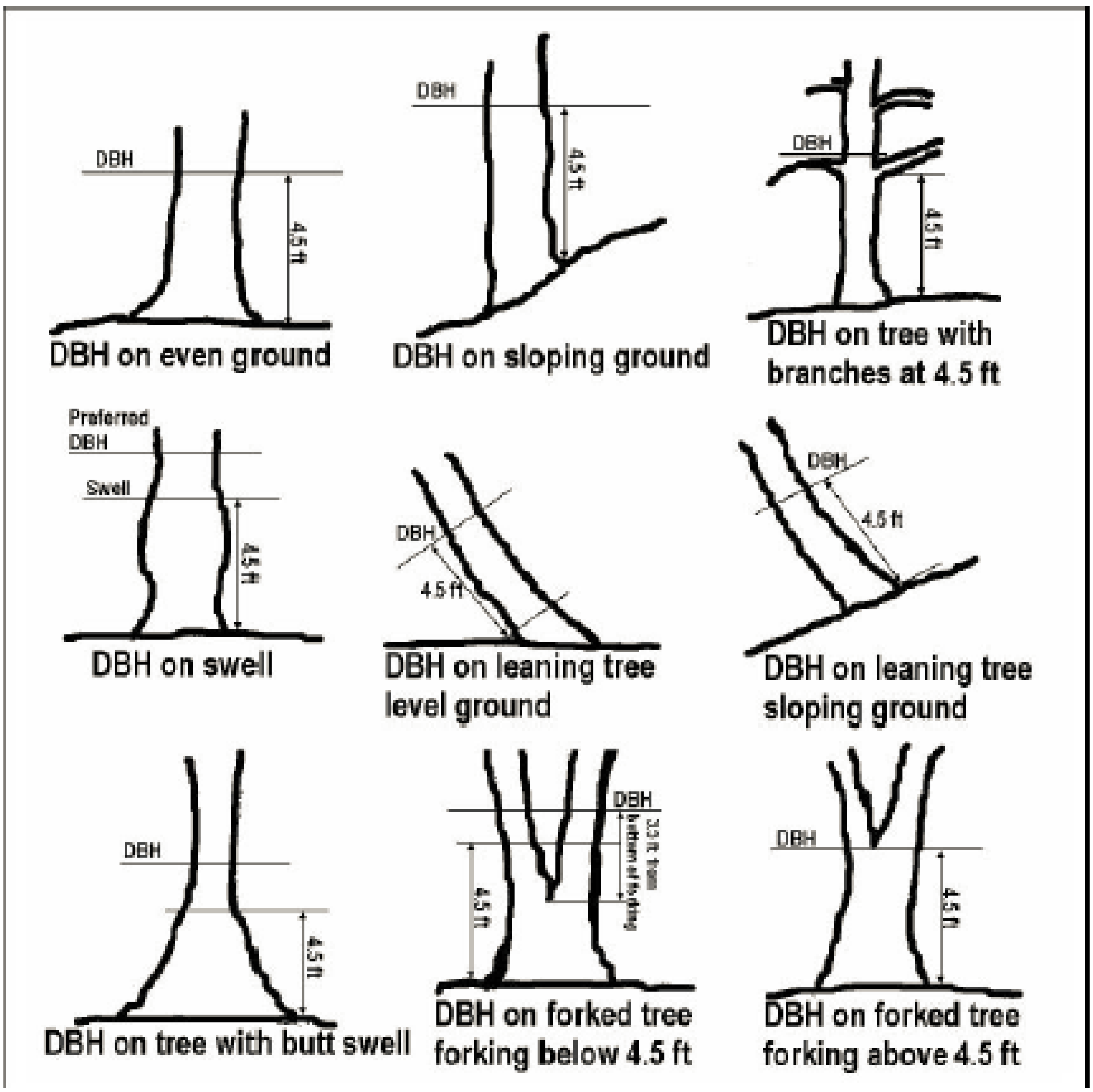
The ESRI personal geodatabase format will be used to store spatial and tabular project data. Built-in features of the geodatabase structure, such as domains (i.e. field value validation) and relationships, will help control data quality. Edits and updates will occur at the beginning of each reporting period to account for activities in the previous year unless an event such as a reversal occurs, in which case updates will take place and be reported to ARB in the required time frame. All results will be summarized in the Offset Project Data Reports.

Change Log

A unique number associated with change log record	Date change was made	This indicates the file that was updated	A full description of the update made
Change_ID	**Change_Date**	**Change_Reference**	**Change_Description**

Appendix: Field Inventory References and Tables

DBH ESTABLISHMENT EXAMPLES



FOREST INVENTORY AND ANALYSIS
NATIONAL CORE FIELD GUIDE

VOLUME I: FIELD DATA COLLECTION PROCEDURES FOR PHASE 2 PLOTS

Version 9.0

5.9.2 DIAMETER AT BREAST HEIGHT (DBH)

Unless one of the following special situations is encountered, measure DBH at 4.5 feet above the ground line on the uphill side of the tree. Round each measurement down to the last 0.1 inch. For example, a reading of 3.68 inches is recorded as 3.6 inches.

Special DBH situations:

1. Forked tree: In order to qualify as a fork, the stem in question must be at least 1/3 the diameter of the main stem and must branch out from the main stem at an angle of 45 degrees or less (figs. 24-28), AND must be judged to have, or have the potential to assume an obvious “tree like” form and function as opposed to an obvious “branch like” form and function. If there is any doubt as to the form and function of a potential fork, call it a fork instead of a branch. Figure 29 provides examples where the form and function are considerations. Forks originate at the point on the bole where the piths intersect. Forked trees are handled differently depending on whether the fork originates below 1.0 foot, between 1.0 and 4.5 feet, or above 4.5 feet. Seedling-sized stems, (i.e., stems that are less than 1 inch in diameter at the point of attachment or at the prescribed diameter location, 3.5 feet above pith separation), are not considered forks.

National Core Field Guide, Version 9.0, October, 2019
Section 5.0. Tree and Sapling Data

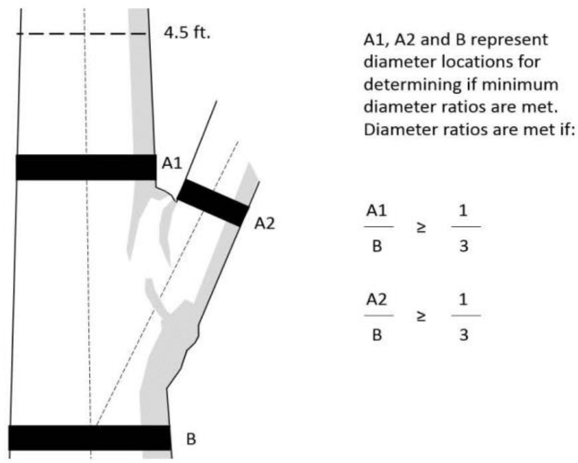


Figure 24. Determining diameter ratio of forks. When determining if a fork meets the 1/3 diameter requirement for qualifying as a fork, the diameter of the potential fork taken at locations A1 and A2 must be 1/3 of the diameter at location B.

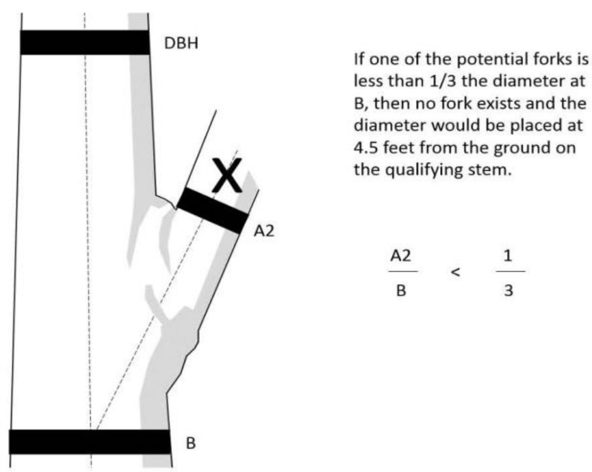
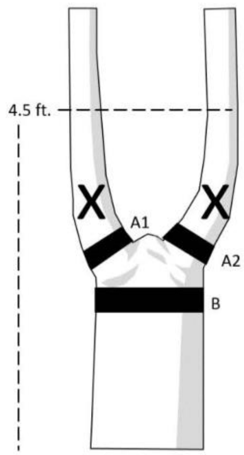


Figure 25. A single non-qualifying fork. If one of the forks does not meet the minimum ratio, then no fork exists and the diameter is placed at the normal location on the dominant stem.

81



If neither stem above a fork meets the minimum 1/3 diameter requirement, neither stem is tallied.

$$\frac{A1}{B} < \frac{1}{3}$$

$$\frac{A2}{B} < \frac{1}{3}$$

Figure 26. Two non-qualifying stems. If neither stem meets the 1/3 diameter requirement, neither is tallied. This is often associated with broken tops and is consistent with the point at which a stem is considered recovered from a break.

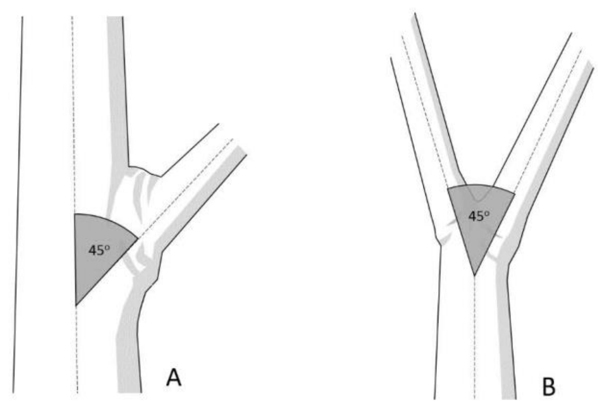


Figure 27. Forking angle. In order to qualify as a fork, the piths must diverge at an angle not exceeding 45 degrees from the main stem (A). In cases where there is no obvious main stem (B), consider the angle of pith separation between the two stems.

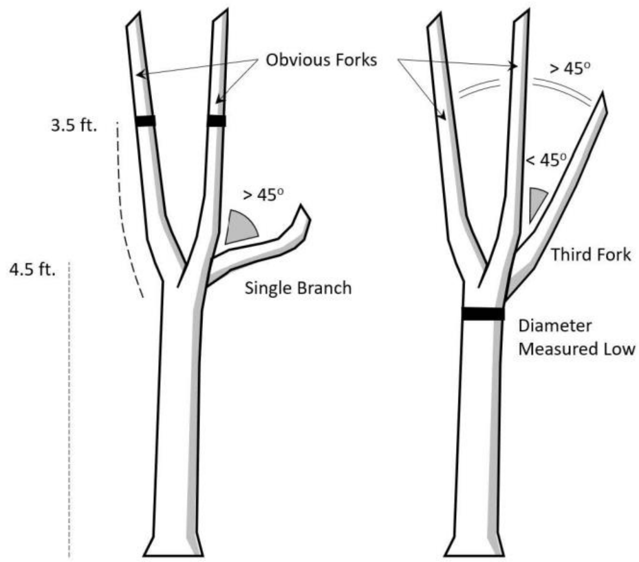


Figure 28. The tree on the left has two stems that are clearly forks and a single branch that departs at an angle of greater than 45 degrees from either existing fork. This branch is ignored when placing diameters. The tree on the right also has two stems that clearly qualify as forks, plus a third stem that is within 45 degrees of one fork, but not the other. So long as it is within 45 degrees of an adjacent qualifying fork, it too is considered a fork. In this case, it is the third fork from approximately the same location on this tree and the **Measure Low Approach** must be applied.

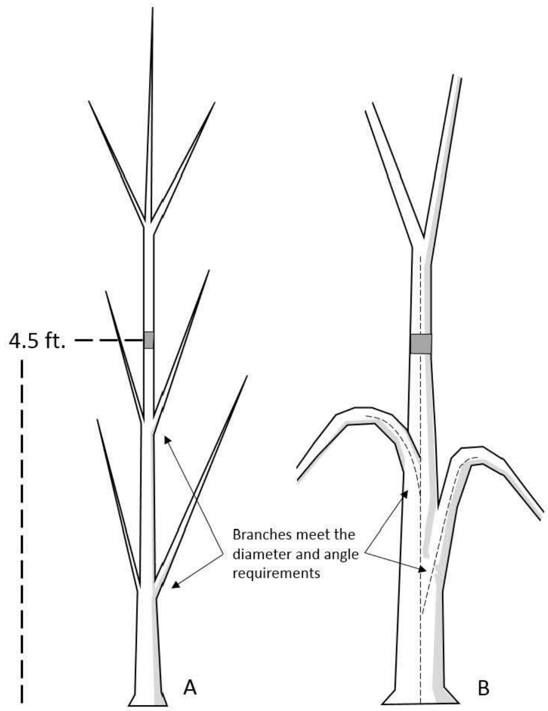


Figure 29. Forks that have branch-like form and function, leading to the tally of a single tree instead of multiple trees. In example A, although the potential fork is currently 1/3 the diameter of the main bole and is within 45 degrees of the main bole at the point of attachment, it appears to be serving as a branch as opposed to an additional independent tree. In addition, as the main bole continues to grow, the "branch" may reach the point where it is no longer 1/3 the main bole, dropping out of the inventory based on definition. Such potential forks would be ignored and the main bole would be tallied as a single tree with diameter measured at 4.5 feet. The tree is evaluated at each future visit and tallied following standard remeasurement procedures. In example B, although the potential fork is 1/3 the diameter of the main bole and is within 45 degrees of the main bole at point of attachment, it deviates drastically beyond 45 degrees about 1 inch from the main bole, taking on the form and function of a branch. This should be tallied as a single tree with diameter measured at 4.5 feet.

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- Trees forked below 1.0 foot. Trees forked below 1.0 foot are treated as distinctly separate trees (fig. 30). Distances and azimuths are measured individually to the center of each stem where it splits from the stump (fig. 35 A-C). DBH is measured for each stem at 4.5 feet above the ground. When stems originate from pith intersections below 1 foot, it is possible for some stems to be within the limiting distance of the microplot or subplot, and others to be beyond the limiting distance. If stems originating from forks that occur below 1.0 foot fork again between 1.0 and 4.5 feet (fig. 35-E), the rules in the next paragraph apply.

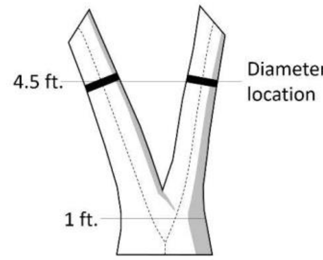

Figure 30. Forked below 1.0 foot.

- Trees forked between 1.0 foot and 4.5 feet. Trees forked between 1.0 foot and 4.5 feet are also counted as separate trees (fig. 31), but only one distance and azimuth (to the central stump) is recorded for each stem (fig. 35 D-F). Although a single azimuth and distance applies to all, multiple stems should be recorded as they occur in clockwise order (from front to back when one stem is directly in front of another). The DBH of each fork is measured at a point 3.5 feet above the pith intersection. When forks originate from pith intersections between 1.0 and 4.5 feet, the limiting distance is the same for all forks--they are either all on, or all off the plot.

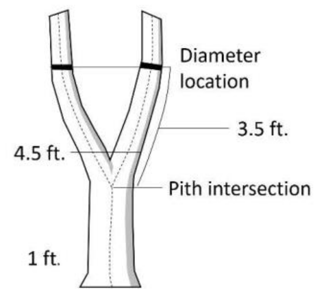

Figure 31. Forked between 1.0 foot and 4.5 feet.

Measure Low Approach

Crews may encounter trees of any species displaying growth forms with multiple forks that make applying traditional forking rules very difficult. In some instances these growth forms are species specific and in others they are the result of either the immediate growing conditions or the fact that the trees have been bred, pruned, or managed in a way that promotes multiple stems resulting in a specific crown shape.

In cases where such multiple forks (≥3) all originate from approximately the same point on the main stem, follow the **Measure Low Approach**, where the diameter is taken at the highest, most repeatable location between the 1-foot stump and initial pith separation. This approach is applicable in instances where any of the following are present between the 1-foot stump and DBH (4.5 feet):

(1) Multiple forks (≥3) (fig. 32 D).

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(2) Prolific branching originating from approximately the same location that prevents accurate and repeatable diameter (fig. 32 A and B). Prolific branching, as defined here, are those trees that often lack a defined main stem and/or qualifying forks, and take on a bushy appearance as the lower bole splits out into multiple branches at or below 4.5 feet. This is a rare situation that should not be confused with normal branching patterns that allow for accurate diameter placement (fig. 32 C).

(3) Any combination of multiple forks (≥3) and prolific branching originating at approximately the same location.

(4) The stems of a forked tree are grown together in such a fashion that an accurate DBH cannot be measured or estimated due to deformation resulting from the presence of the above mentioned criteria (fig. 33).

Figures 32 and 33 illustrate a combination of forks and or branches all originating at the approximate same location will trigger a measure low approach.

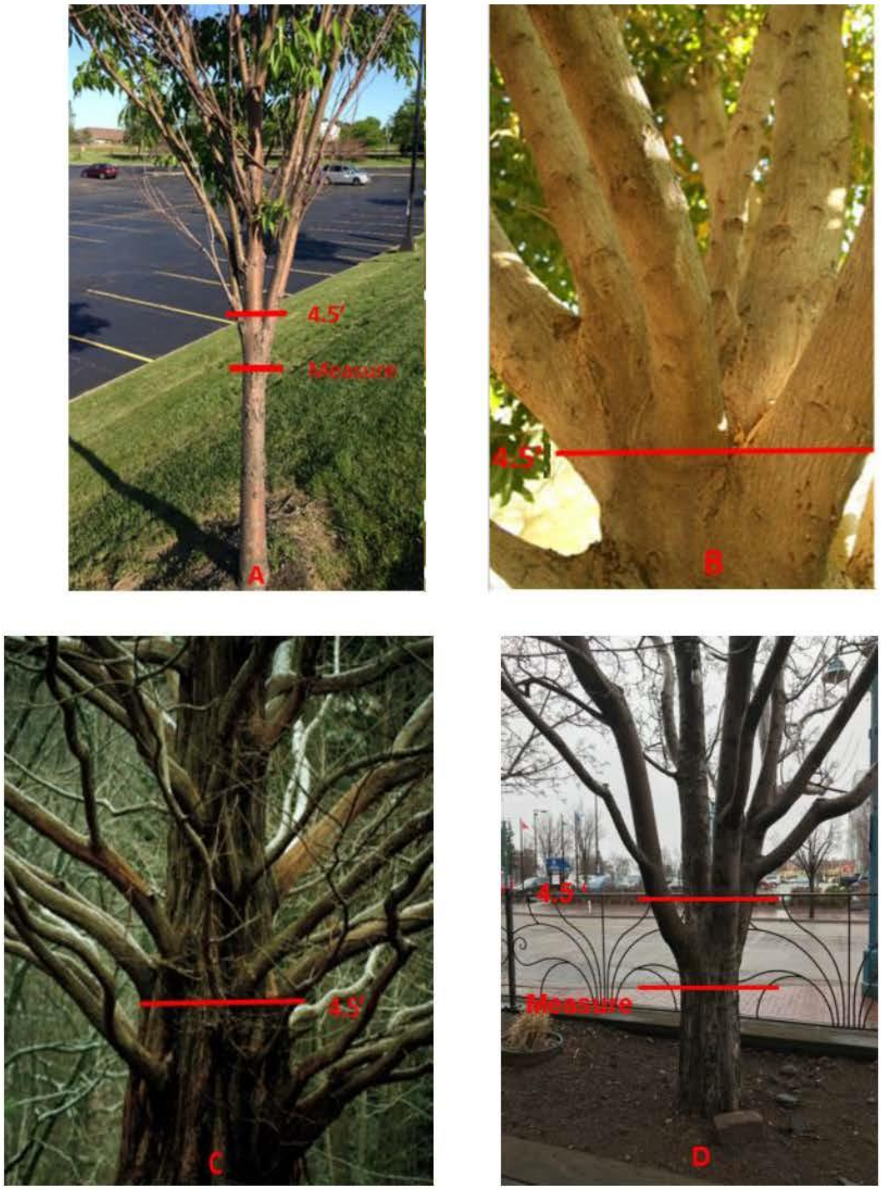

Figure 32. Both A and B are examples of Prolific Branching where the **Measure Low Approach** must be implemented causing the diameter to be taken below 4.5 feet. Although C has many branches, it is not a candidate for the **Measure Low Approach** because the branching is not deemed "Prolific"; traditional DBH measurement protocols would apply. D is an example of multiple forks originating from approximately the same area. Similar to Prolific Branching, the diameter is taken low, and D is treated as one tree.

A tree can only fork once. Following are specific procedures to **secondary** forking:

- Once a stem is tallied as a fork that originated from a pith intersection between 1.0 and 4.5 feet, do not recognize any additional forks (or potential forks) that may occur on that stem. Secondary forks need only meet the 1/3 diameter and 45 degree requirements to be considered forks; they do not need to be tree-like or 1 inch in diameter. When such secondary forks are encountered, measure/estimate the diameter of such stems at the most repeatable location below stem separation but above the **first** pith separation (fig. 35 F-I) while attempting to avoid measuring double piths (fig. 41) where possible (i.e., do not move the point of diameter the entire 3.5 feet above the first fork).

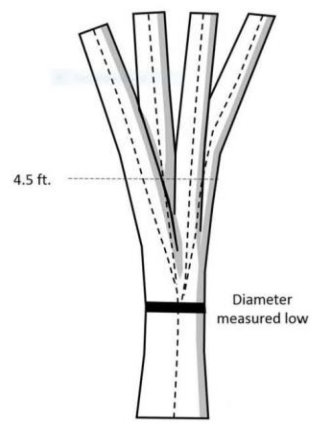

Figure 33. Using pith separation to determine diameter locations. In this example it is clear that all piths appear to separate from approximately the same location; this triggers the **"Measure Low Approach".** In cases where the piths do NOT originate within approximately the same location, normal forking rules are applied as demonstrated in figures 35 A-D and F-I.

- Trees forked at or above 4.5 feet. Trees forked at or above 4.5 feet count as one single tree (fig. 34). If a fork occurs at or immediately above 4.5 feet, measure diameter below the fork just beneath any swelling that would inflate DBH.

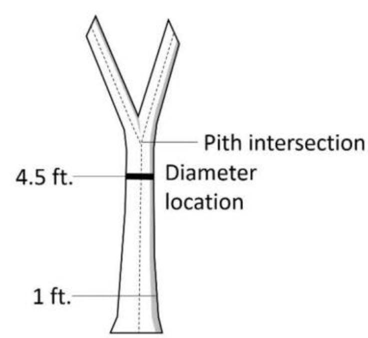

Figure 34. One Tree.

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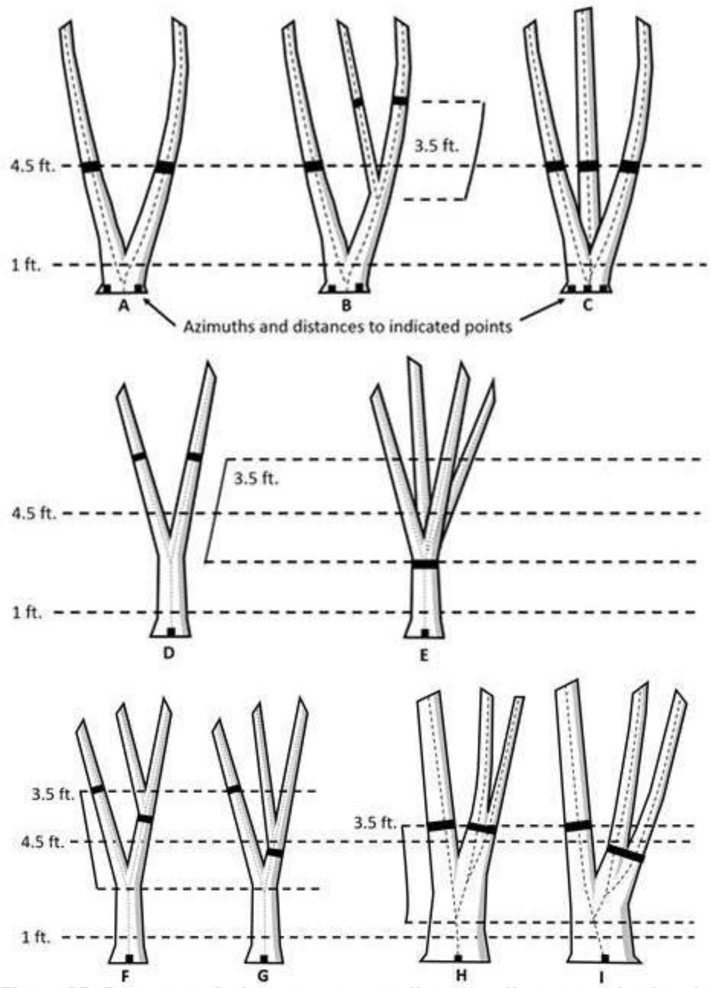

Figure 35 Summary of where to measure diameter, distance and azimuth on trees that fork below 1.0 foot (A, B, C) and trees that fork above 1.0 foot (D, E, F, G, H, I). Figure E represents the **"Measure Low Approach".** Figures F and G represent secondary forks with abnormal diameters at stem separation. Figures H and I represent secondary forks with normal diameters at stem separation.

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2. Stump sprouts: Stump sprouts originate between ground level and 4.5 feet on the boles of trees that have died or been cut. Stump sprouts are handled the same as forked trees, with the exception that stump sprouts are not required to be 1/3 the diameter of the dead bole. Stump sprouts originating below 1.0 foot are measured at 4.5 feet from ground line. Stump sprouts originating between 1.0 foot and 4.5 feet are measured at 3.5 feet above their point of occurrence. As with forks, rules for measuring distance and azimuth depend on whether the sprouts originate above or below 1.0 foot. For multi-stemmed woodland species, treat all new sprouts as part of the same new tree.

3. Tree with butt-swell or bottleneck: Measure these trees 1.5 feet above the end of the swell or bottleneck if the swell or bottleneck extends 3.0 feet or more above the ground (fig. 36).

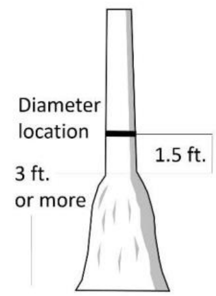


Figure 36. Bottleneck tree.

4. Tree with irregularities at DBH: On trees with swellings (fig. 37), bumps, depressions, and branches (fig. 38) at DBH, diameter will be measured immediately above the irregularity at the place it ceases to affect normal stem form. If the diameter point is out of reach above the irregularity, the diameter will be measured below the irregularity at the best repeatable location. If normal stem form does not exist, the diameter will be estimated at the prescribed location.

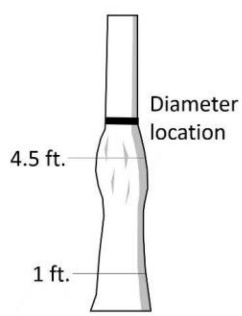


Figure 37. Tree with swelling.

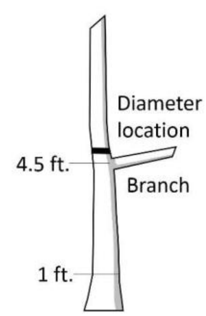


Figure 38. Tree with branch.

5. Tree on slope: Measure diameter at 4.5 feet from the ground along the bole on the uphill side of the tree (fig. 39).

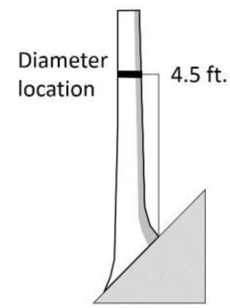


Figure 39. Tree on a slope.

6. Leaning tree: Measure diameter at 4.5 feet from the ground along the bole. The 4.5-foot distance is measured along the underside face of the bole (fig. 40).

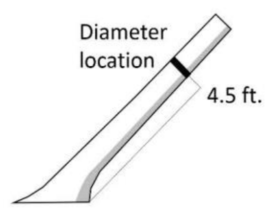


Figure 40. Leaning tree.

7. Turpentine tree: On trees with turpentine face extending above 4.5 feet, estimate the diameter at 10.0 feet above the ground and multiply by 1.1 to estimate DBH outside bark.

8. Independent trees that grow together: If two or more independent stems have grown together at or above the point of DBH, continue to treat them as separate trees. Estimate the diameter of each, set the "DIAMETER CHECK" code to 1, and explain the situation in the notes (fig. 41).

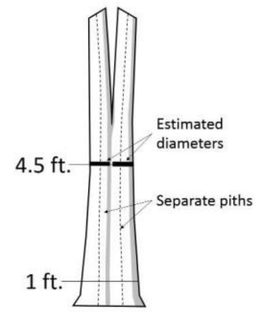


Figure 41. Independent trees grown together.

9. Missing wood or bark: Do not reconstruct the DBH of a tree that is missing wood or bark at the point of measurement. Record the diameter, to the nearest 0.1 inch, of the wood and bark that is still attached to the tree (fig. 42). If a tree has a localized abnormality (gouge, depression, etc.) at the point of DBH, apply the procedure described for trees with irregularities at DBH (fig.37).

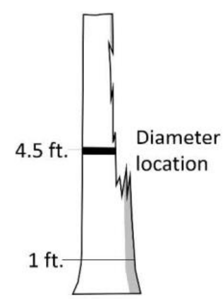


Figure 42. Tree with part of stem missing.

10. Live windthrown tree: Measure from the top of the root collar along the length to 4.5 feet (fig. 43).

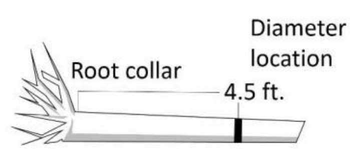


Figure 43. Tree on the ground.

11. Down live tree with tree-form branches growing vertical from main bole: When a down live tree, touching the ground, has vertical (less than 45 degrees from vertical) tree-like branches coming off the main bole, first determine whether or not the pith of the main bole (averaged along the first log of the tree) is above or below the duff layer.

- If the pith of the main bole is above the duff layer, use the same forking rules specified for a forked tree, and take all measurements accordingly (fig. 44).

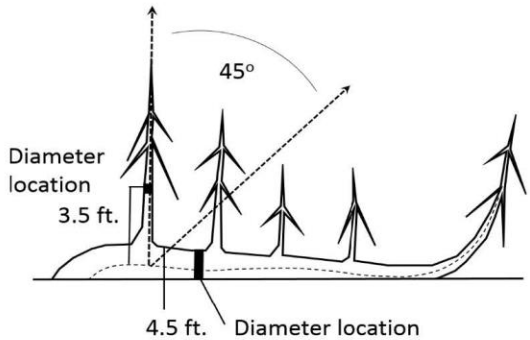


Figure 44. Down tree with pith above the duff.

- If the pith intersection of the main down bole and vertical tree-like branch occurs below 4.5 feet from the stump along the main bole, treat that branch as a separate tree, and measure DBH 3.5 feet above the pith intersection for both the main bole and the tree-like branch.
- If the intersection between the main down bole and the tree-like branch occurs beyond the 4.5 feet point from the stump along the main bole, treat that branch as part of the main down bole.
- If the pith of main tree bole is below the duff layer, ignore the main bole, and treat each tree-like branch as a separate tree; take DBH and length measurements from the ground, not necessarily from the top of the down bole (fig. 45). However, if the top of the main tree bole curves out of the ground towards a vertical angle, treat that portion of that top as an individual tree originating where the pith leaves the duff layer.

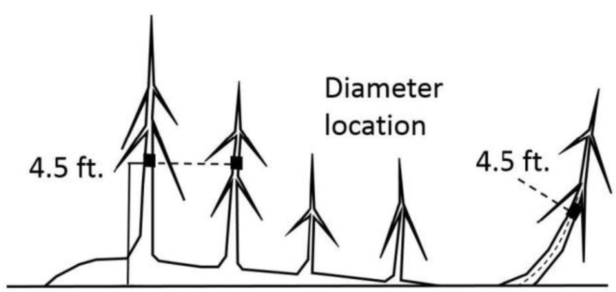


Figure 45. Down tree with pith below the duff.

12. Tree with curved bole (pistol butt tree): Measure along the bole on the uphill side (upper surface) of the tree (fig. 46).

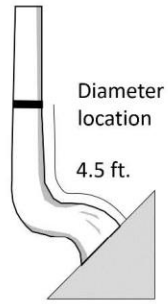


Figure 46. Tree with curved bole (pistol butt tree).

5.9.3 PREVIOUS DIAMETER AT ROOT COLLAR

This is the DRC assigned at the previous survey. It has been downloaded from the previous inventory. Any change made to this field signifies a misclassification at the time of the previous inventory. "DIAMETER CHECK" should be set to 2 and an explanation is required in the notes if previous DRC is changed.

5.9.4 Diameter At Root Collar (DRC)

For species requiring diameter at the root collar (refer to Appendix 3), measure the diameter at the ground line or at the stem root collar, whichever is higher. For these trees, treat clumps of stems having a unified crown and common root stock as a single tree; examples include mesquite, juniper, and mountain mahogany. Treat stems of woodland species such as Gambel oak and bigtooth maple as individual trees if they originate below the ground. For woodland trees, record DRC STEM DIAMETER and DRC STEM STATUS (described below). Then compute and record the DRC value from the individual stem diameter information.

Measuring woodland stem diameters: Before measuring DRC, remove the loose material on the ground (e.g., litter) but not mineral soil. Measure just above any swells present, and in a location so that the diameter measurements are a good representation of the volume in the stems (especially when trees are extremely deformed at the base). Stems must be at least 1 foot in length and at least 1.0 inch in diameter 1 foot up from the stem diameter measurement point to qualify for measurement. Whenever DRC is impossible or extremely difficult to measure with a diameter tape (e.g., due to thorns, extreme number of limbs), stems may be estimated and recorded to the nearest 1.0-inch class. Additional instructions for DRC measurements are illustrated in figure 47. For each qualifying stem of the woodland tree, measure and record DRC STEM DIAMETER (5.9.4.1) and indicate the DRC STEM STATUS (5.9.4.2).

Computing and Recording DRC: For all tally trees requiring DRC, with at least one stem 1 foot in length and at least 1.0 inch in diameter 1 foot up from the stem diameter measurement point, DRC is computed as the square root of the sum of the squared stem diameters. For a single-stemmed DRC tree, the computed DRC is equal to the single diameter measured.

Use the following formula to compute DRC:

$$DRC = SQRT\ [SUM\ (\text{stem diameter}^2)]$$

Round the result to the nearest 0.1 inch. For example, a multi-stemmed woodland tree with stems of 12.2, 13.2, 3.8, and 22.1 would be calculated as:

$$\begin{aligned} DRC &= SQRT\ (12.2^2 + 13.2^2 + 3.8^2 + 22.1^2) \\ &= SQRT\ (825.93) \\ &= 28.74 \\ &= 28.7 \end{aligned}$$

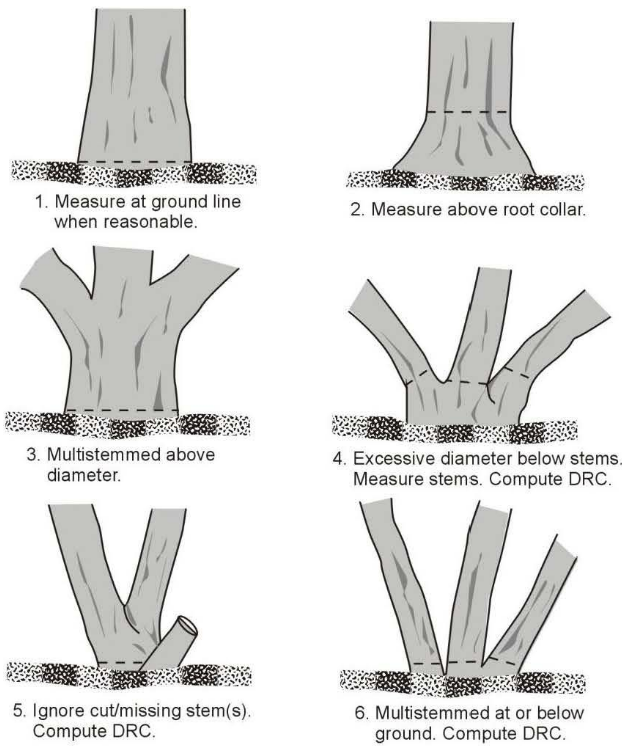


Figure 47. How to measure DRC in a variety of situations.

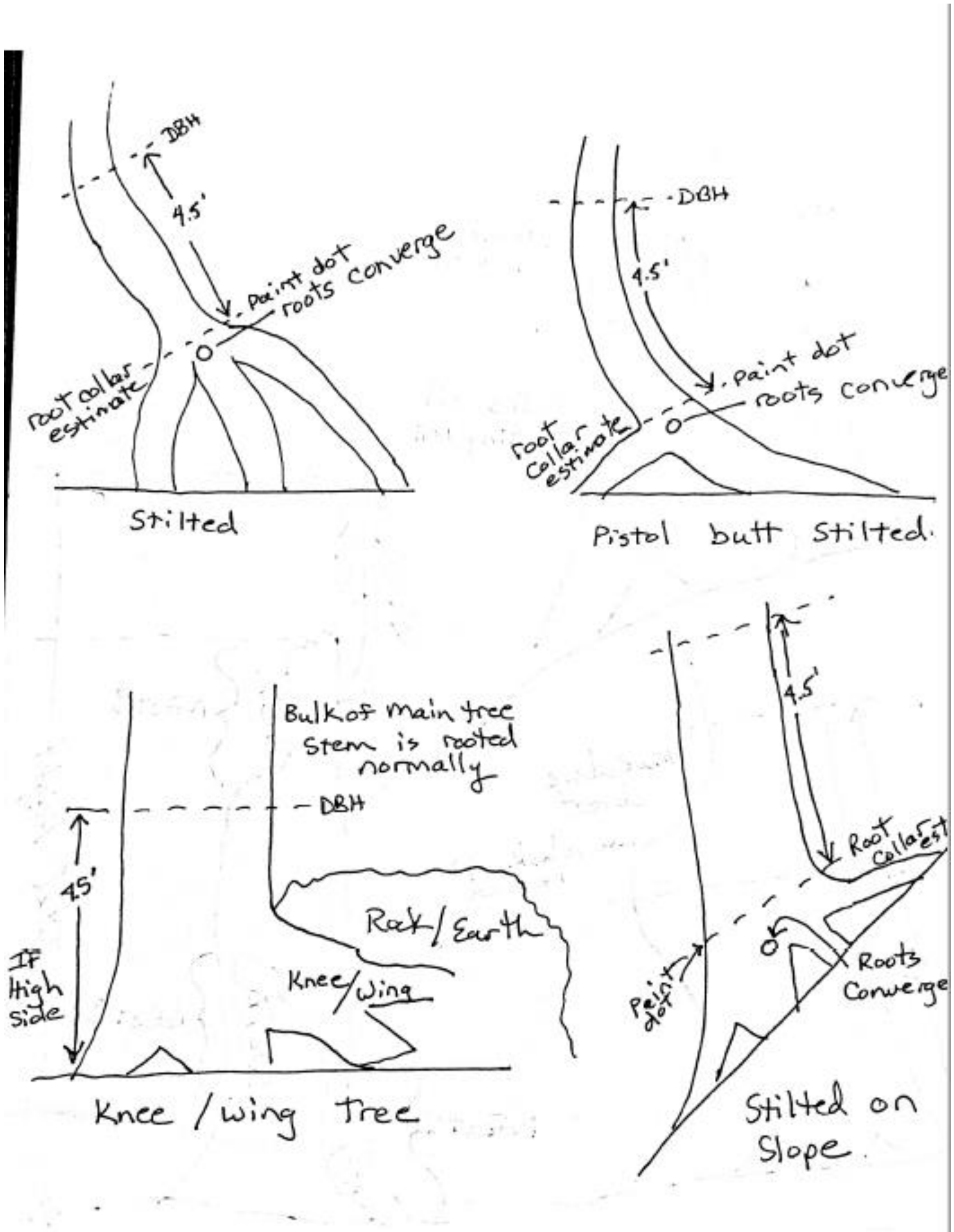
5.9.4.1 DRC STEM DIAMETER

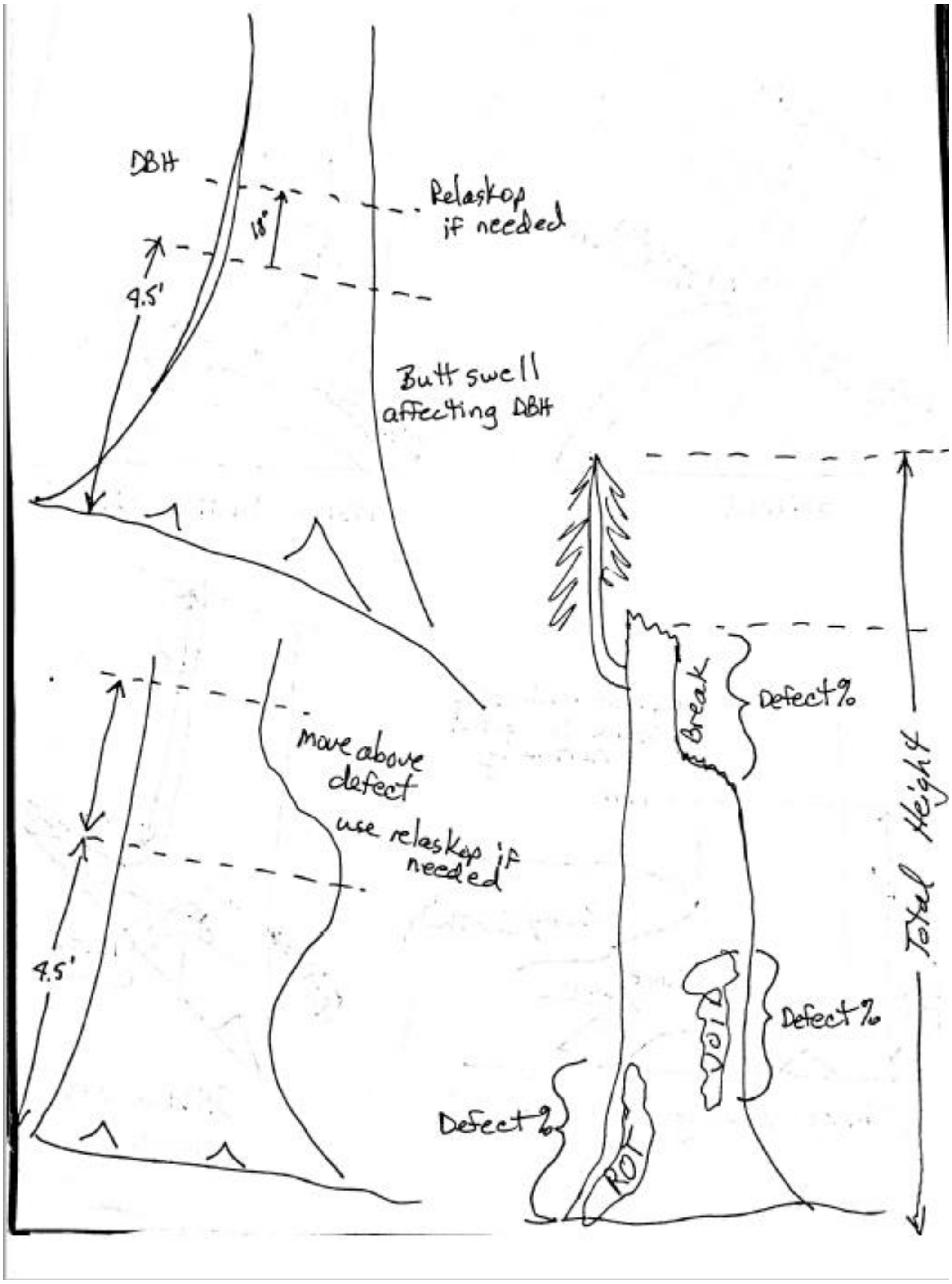
Record the diameter of each individual qualifying stem on the woodland tree.

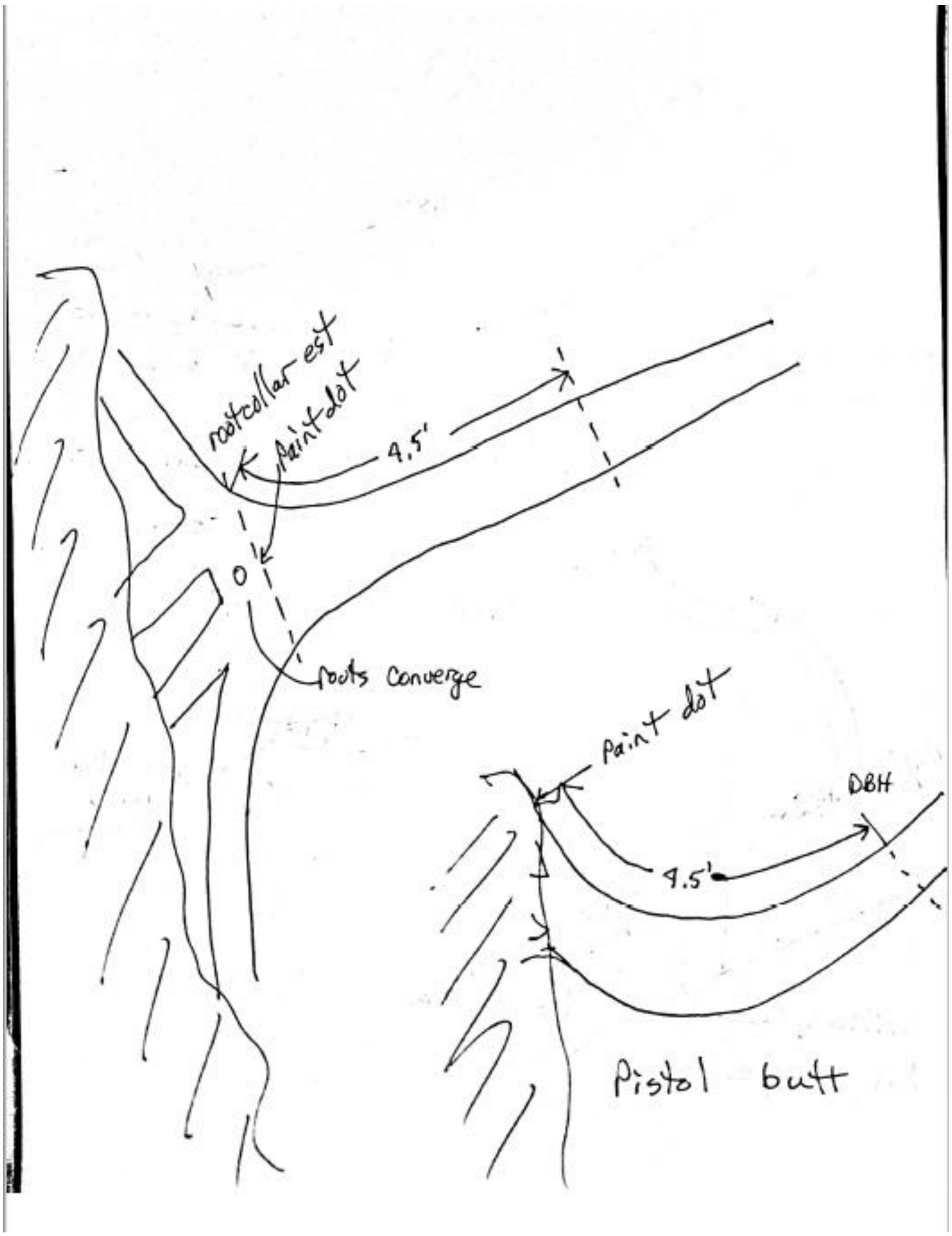
Values: 001.0 to 999.9

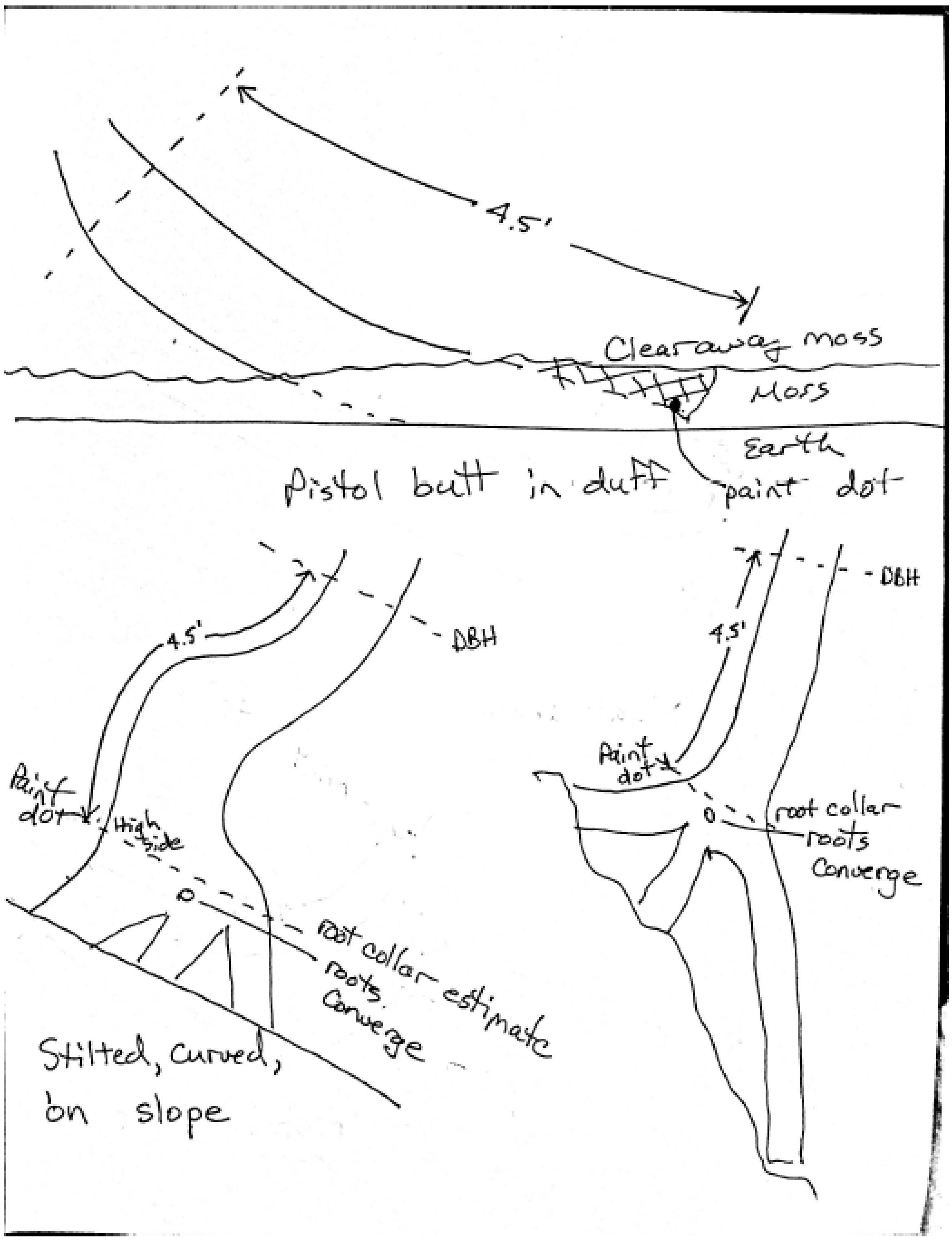
DRC species have been provided. All cruisers should be aware of the species and if they find any DRC species on a plot, DRC must be measured rather than DBH/DRC.

DIAMETER BREAST HEIGHT (DBH) – Stilted Roots




DBH
Relaskop if needed
18"
4.5'
Butt swell affecting DBH
move above defect
use relaskop if needed
4.5'
Break
Defect%
Total Height
Defect%
VOID
Defect%
ROT


rootcollar est
Paint dot
4.5'
roots converge
paint dot
DBH
4.5'
Pistol butt


4.5'
Clear away moss
Moss
Earth
Pistol butt in duff
paint dot
DBH
4.5'
DBH
4.5'
Paint dot
High side
root collar estimate
roots converge
Stilted, curved, on slope
Paint dot
root collar
roots converge

Percent volume allocation chart as a guide for soundness/defect deductions.

This table serves as a guide; exact values in table below do not need to be used. Source: PNW FIA Field Instructions for the Annual Inventory of California, Oregon, and Washington (2018).

Use Table 8.6: as a guideline to estimate the missing portion of a live tree because of cull. It shows the percentage of volume in typical trees of varying number of logs and heights. Use either the tree height in logs (divide the length to a 4-inch top – diameter inside bark [DIB] – by 16) or the measured TOTAL LENGTH to estimate what percentage of volume is estimated in each 16-foot log. Multiply each percentage in that log section times the percentage of rotten or missing volume. Then sum the values to get the total percentage of the tree that is rotten or missing.

- Example: A 9-log tree (measured at 160 feet TOTAL LENGTH) has a missing section that is about 1/3 of both the second and third logs. Table 8.6: shows the second log has about 18 percent of the volume in the tree, and the third log has about 16 percent of the volume in the tree.
  - Calculate the percentage of cull in each log and sum to estimate the total percentage of cull for the tree (about 11 percent):
    - (0.18 X 0.33) + (0.16 X 0.33) = 0.06 + 0.05 = 0.11

Table 8.6: Percentage of tree cubic foot volume distribution by 16-foot logs from tree total length or tree height in logs for a tree of average dimensions

Average Total Length	Tree Height in LOGS	Log1	Log2	Log3	Log4	Log5	Log6	Log7	Log8	Log9	Log10	Log11	Log12
28	1	100											
48	2	70	30										
64	3	54	32	14									
80	4	43	30	19	8								
96	5	36	27	20	12	5							
111	6	31	24	20	14	8	3						
127	7	28	22	18	14	10	6	2					
143	8	25	20	17	14	11	8	4	1				
158	9	24	18	16	13	11	8	6	3	1			
176	10	22	17	15	13	11	9	7	4	1	1		
194	11	20	15	14	12	11	9	7	5	4	2	1	
212	12	20	14	13	12	11	9	8	6	4	2	1	0

Figure 5. Soundness Deductions

Example: Cruiser has tallied a 2-log saw-timber tree and estimates there is a cavity representing 25% of the 4th bolt. The soundness deduction is recorded as 5% (19% X 25% = 4.75% rounded to the nearest percent = 5%

Slope Correction Table

Percent of Slope	Degree of Slope	Correction Factor
0 to 9	0-6	1.00
10 to 17	7-10	1.01
18 to 22	11-12	1.02
23 to 26	13-14	1.03
27 to 30	15-17	1.04
31 to 33	18	1.05
34 to 36	19-20	1.06
37 to 39	21	1.07
40 to 42	22	1.08
43 to 44	23	1.09
45 to 47	24	1.10
48 to 49	25-26	1.11
50 to 51	27	1.12
52 to 53	28	1.13
54 to 55	29	1.14
56 to 57	29	1.15
58 to 59	30	1.16
60 to 61	31	1.17
62 to 63	32	1.18
64 to 65	33	1.19
66 to 67	34	1.20
68 to 69	34	1.21
70	35	1.22
71 to 72	36	1.23
73 to 74	37	1.24
75	37	1.25
76 to 77	38	1.26
78 to 79	38	1.27
80	39	1.28
81 to 82	39	1.29
83	40	1.30
84 to 85	40	1.31
86	41	1.32
87 to 88	41	1.33
89	42	1.34
90 to 91	42	1.35

Percent of Slope	Degree of Slope	Correction Factor
92	43	1.36
93 to 94	43	1.37
95	44	1.38
96 to 97	44	1.39
98	44	1.40
99 to 100	45	1.41
101	45	1.42
102	46	1.43
103 to 104	46	1.44
105	46	1.45
106 to 107	47	1.46
108	47	1.47
109	47	1.48
110 to 111	48	1.49
112	48	1.50
113	48	1.51
114 to 115	49	1.52
116	49	1.53
117	49	1.54
118 to 119	50	1.55
120	50	1.56
121	50	1.57
122	51	1.58
123 to 124	51	1.59
125	51	1.60
126	52	1.61
127 to 128	52	1.62
129	52	1.63
130	52	1.64
131	53	1.65
132 to 133	53	1.66
134	53	1.67
135	53	1.68
136	54	1.69
137 to 138	54	1.70
139	54	1.71
140	54	1.72

Percent of Slope	Degree of Slope	Correction Factor
141	55	1.73
142 to 143	55	1.74
144	55	1.75
145	55	1.76
146	56	1.77
147	56	1.78
148 to 149	56	1.79
150	56	1.80

7.0 SITE TREE INFORMATION

Site trees are a measure of site productivity expressed by the height to age relationship of dominant and co-dominant trees. If suitable site trees are available, site tree data are required for every accessible forest land condition class defined on a plot. An individual site tree may be used for more than one condition class where differences in condition classes are not the result of differences in site productivity. For example, when different condition classes are caused solely due to differences in reserved status, owner class, and/or disturbance-related differences in density (e.g., heavily thinned vs. unthinned), a site tree may be used for more than one condition class. When in doubt, do not use a site tree for more than one condition class.

7.1 Site Tree Selection

Select at least one site tree for each accessible forest land condition class where no previous site tree data exist. The absence of site tree data may occur because:

- This is the first visit to the site
- On the previous visit no suitable site tree could be found for the condition
- Since the last visit there has been a change in condition class that renders the previous data incompatible with the current conditions

If a site tree is needed; select tree from a species common to the condition class being sampled, based on the criteria listed below. Select trees off the subplot where possible. Use only trees that have remained in a dominant or co-dominant crown position throughout their entire life span. If possible, trees should be 5.0 inches in diameter, or larger, and at least 20 years old. Trees that are visibly damaged, trees with ring patterns that exhibit signs of suppression, and trees with rotten cores should be rejected. If there are no acceptable site trees, record that in the plot notes and leave this section blank.

7.2 Site Tree Data Variables

7.2.1 CONDITION CLASS LIST

List all CONDITION CLASSES that the site index data from this tree represent.

Values: 1000 to 9876

7.2.2 SPECIES

Use the same procedures described in Section 5.8. Ideally, site trees in the eastern U.S. should be between 20-70 years old. If preferred trees cannot be found in this age range, expand the age range to 15-120 years. Reject trees outside the 15-120 year age range, trees that exhibit signs of damage, trees with ring patterns that show signs of suppression, trees less than 5.0 inches DBH, trees with abnormalities at DBH, and trees with rotten cores. A list of preferred site-tree species is provided. Site trees should be selected in the following order of preference:

- 1st Choice: representative of the stand, on the list for your region.
- 2nd Choice: representative of the stand, on the list for an adjoining eastern region.
- 3rd Choice: not representative of the stand, on the list for your region.
- 4th Choice: not representative of the stand, on the list for an adjoining eastern region.

Ideally, site trees in the western U.S. should be between 35-80 years old. If preferred trees cannot be found in this age range, expand the age range to 15-250 years. Reject trees outside the 15-250 year age range, trees that exhibit signs of damage, trees with ring patterns that show signs of suppression, trees less than 5.0 inches DBH, trees with abnormalities at DBH, trees with rotten cores, and woodland species. A list of preferred site-tree species is provided. Site trees should be selected in the following order of preference:

- 1st Choice: representative of the stand, on the list for your region.
- 2nd Choice: representative of the stand, on the list for an adjoining western region.
- 3rd Choice: not representative of the stand, on the list for your region.
- 4th Choice: not representative of the stand, on the list for an adjoining western region.

Values:

Eastern U.S. Site-Tree Species: NE = Northeast, NC = North Central, SO = Southern

Code	Common Name	Region
	-------------------- **Softwood Species** --------------------	
0012	balsam fir	NE, NC
0043	Atlantic white-cedar	NE
0068	eastern redcedar	NE, NC
0070	larch (introduced)	NE
0071	tamarack (native)	NE, NC
0094	white spruce	NE, NC
0095	black spruce	NE, NC
0097	red spruce	NE
0105	jack pine	NE, NC
0107	sand pine	SO
0110	shortleaf pine	NE, NC, SO
0111	slash pine	SO
0121	longleaf pine	SO
0122	Ponderosa pine	NC
0125	red pine	NE, NC
0128	pond pine	NE, SO
0129	eastern white pine	NE, NC, SO
0130	Scotch pine	NE, NC
0131	loblolly pine	NE, SO
0132	Virginia pine	NE, SO
0241	northern white cedar	NE, NC
0261	eastern hemlock	NE, NC
	-------------------- **Hardwood Species** --------------------	
0316	red maple	NE, NC
0317	silver maple	NE, NC
0318	sugar maple	NE, NC
0371	yellow birch	NE, NC
0375	paper birch	NE, NC
0402	bitternut hickory	NE, NC
0403	pignut hickory	NC
0404	pecan	NC
0405	shellbark hickory	NC
0407	shagbark hickory	NE, NC
0408	black hickory	NC
0409	mockernut hickory	NC
0462	hackberry	NC
0531	American beech	NE, NC
0541	white ash	NE, NC
0543	black ash	NE, NC
0544	green ash	NE, NC

Eastern U.S. Site-Tree Species: NE = Northeast, NC = North Central, SO = Southern

Code	Common Name	Region
0602	black walnut	NC
0611	sweetgum	NE, NC, SO
0621	yellow-poplar	NE, NC, SO
0741	balsam poplar	NC
0742	eastern cottonwood	NE, NC, SO
0743	bigtooth aspen	NE, NC
0746	quaking aspen	NE, NC
0762	black cherry	NC
0802	white oak	NE, NC, SO
0806	scarlet oak	NE, NC, SO
0809	northern pin oak	NC
0812	southern red oak	NE, SO
0813	cherrybark oak	NE, SO
0817	shingle oak	NE, NC, SO
0823	bur oak	NC
0826	chinkapin oak	NC
0827	water oak	NE, SO
0830	pin oak	NE, NC, SO
0832	chestnut oak	NE, SO
0833	northern red oak	NE, NC, SO
0835	post oak	NE, NC, SO
0837	black oak	NE, NC, SO
0901	black locust	NE, NC
0951	American basswood	NE, NC
0972	American elm	NE, NC
0975	slippery elm	NC
0977	rock elm	NC

Western U.S. Site-Tree Species: PNW = Pacific Northwest FIA, RMRS = Rocky Mountain FIA

Code	Common Name	Region
	-------------------- Softwood Species --------------------	
0011	Pacific silver fir	PNW
0015	white fir	RMRS, PNW
0017	grand fir	RMRS, PNW
0018	corkbark fir	RMRS
0019	subalpine fir	RMRS, PNW
0020	California red fir	RMRS, PNW
0021	shasta red fir	PNW
0022	noble fir	PNW
0042	Alaska yellow-cedar	PNW
0068	eastern red cedar	RMRS
0073	western larch	RMRS, PNW
0081	incense-cedar	RMRS, PNW
0093	Engelmann spruce	RMRS, PNW
0094	white spruce	RMRS, PNW
0095	black spruce	PNW
0096	blue spruce	RMRS
0098	sitka spruce	PNW
0101	whitebark pine	RMRS, PNW
0104	foxtail pine	RMRS
0108	lodgepole pine	RMRS, PNW
0109	Coulter pine	PNW
0112	Apache pine	RMRS

Western U.S. Site-Tree Species: PNW = Pacific Northwest FIA, RMRS = Rocky Mountain FIA

Code	Common Name	Region
0116	Jeffrey pine	RMRS, PNW
0117	sugar pine	RMRS, PNW
0119	western white pine	RMRS, PNW
0120	bishop pine	PNW
0122	ponderosa pine	RMRS, PNW
0135	Arizona pine	RMRS
0201	bigcone Douglas-fir	PNW
0202	Douglas-fir	RMRS, PNW
0211	redwood	PNW
0231	Pacific yew	RMRS, PNW
0242	western redcedar	RMRS, PNW
0263	western hemlock	RMRS, PNW
0264	mountain hemlock	RMRS, PNW
	-------------------- **Hardwood Species** --------------------	
0312	bigleaf maple	PNW
0351	red alder	RMRS, PNW
0375	paper birch	RMRS, PNW
0462	hackberry	RMRS
0544	green ash	RMRS
0741	balsam poplar	RMRS, PNW
0742	eastern cottonwood	RMRS
0745	plains cottonwood	RMRS
0746	quaking aspen	RMRS, PNW
0747	black cottonwood	RMRS, PNW
0748	Fremont poplar/cottonwood	RMRS
0749	narrowleaf cottonwood	RMRS
0972	American elm	RMRS

7.2.3 DIAMETER

Use the same procedures described in Section 5.9.

Values: 001.0 to 999.9

7.2.4 SITE TREE LENGTH

With a clinometer or other approved instrument, measure the total length of the site tree from the ground to the top of the tree. Record to the nearest 1.0 foot. SITE TREE LENGTH must be measured; no estimates are permitted on site trees.

Values: 005 to 999

7.2.5 TREE AGE AT DIAMETER

Record the tree age as determined by an increment sample. Bore the tree at the point of diameter measurement (DBH) with an increment borer. Count the rings between the outside edge of the core and the pith. Do not add years to get total age.

Values: 001 to 999

7.2.6 SITE TREE NOTES

Record notes pertaining to an individual site tree.

Values: English language words, phrases and numbers

7.2.7 SUBPLOT NUMBER (CORE OPTIONAL)

Record the subplot number to which the site tree is referenced.

Values:

Value	Description
1	Center subplot
2	North subplot
3	Southeast subplot
4	Southwest subplot

7.2.8 AZIMUTH (CORE OPTIONAL)

Record the AZIMUTH from the subplot center; sight the center of the base of each tree with a compass. Record AZIMUTH to the nearest degree. Use 360 for north.

Values: 001 to 360

7.2.9 HORIZONTAL DISTANCE (CORE OPTIONAL)

Record the measured HORIZONTAL DISTANCE, to the nearest 0.1 foot, from the subplot center to the pith of the tree at the base.

Values: 0001 to 2000

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