Lukens (ACR265/CAFR5205) OPDR Attachment X

Forest Carbon Inventory and Calculation Methodology

Table of Contents

The following Standard Operating Procedures (SOPs) were employed to inventory the required carbon pools on the Green Assets – Lukens Avoided Conversion project. The inventory methodology was developed in accordance with Appendix A.3 – Developing Onsite Forest Carbon Inventories, of the California Environmental Protection Agency Air Resources Board (ARB) Compliance Offset Protocol (COP) for U.S. Forest Projects, adopted Nov. 14, 2014.

1. Offset Project Boundary description, including a list of all carbon pools

The project is located in eastern North Carolina, near Sealevel. The project area is in Carteret County and consists of 4,134.88 acres. The project area is in the Northern Atlantic Coastal Plain supersection, and encompasses two ARB assessment areas: Northern Atlantic Coastal Plain Swamp Hardwood & Cypress and Northern Atlantic Coastal Plain Southern Pine.

The most common forest health concerns to monitor for in this region are Fusiform Rust (Cronartium fusiforme) and Southern Pine Beetle (Dendroctonus frontalis). Based on current monitoring, there are currently no significant forest health issues present on the property.

Fusiform Rust (Cronartium fusiforme) is a fungus that produces orange spores on the surface of fusiform-shaped pine galls in the spring. Fusiform rust infections that occur on the main stem within the first 5 years of a tree's life normally cause tree death. Infections that occur later in the life cycle of the tree weaken the stem, resulting in wind breakage at the canker or quality loss at rotation. Loblolly (Pinus taeda L.) and Slash pine (Pinus elliotii) are the most susceptible species. Longleaf (Pinus Palustris) is fairly resistant, while shortleaf pine (Pinus echinata) is highly resistant. Oak is the alternate host of Fusiform Rust.

The southern pine beetle (Dendroctonus frontalis) is one of the most destructive pests in pines of the southern United States, Mexico, and Central America. This insect killed approximately 4.5 million board feet of pine timber from 1973 through 1977 in the southern United States. The beetle occurs Pennsylvania to Texas and from New Mexico and Arizona to Honduras. It attacks and can kill all species of pines, but prefers loblolly (Pinus taeda L.), shortleaf (Pinus echinata), Virginia (Pinus virginiana), pond (Pinus serotina), and pitch pines (Pinus rigida).

In accordance with Table A.1 of the COP, the project includes the following required carbon pools:

- Standing Live
- Standing Dead

2. For each carbon pool, a detailed description of the inventory sampling methodology used to quantify that carbon pool, with references clearly documented.

2A. Standard procedures for the collecting of field measurements.

These procedures must be detailed enough so that any qualified forester would be able to accurately repeat the previous measurements. These procedures must include a description of the types of sample plots, location of plots, and frequency for updating or replacing sample plots as well as the forest carbon inventory as a whole.

Measurement protocols to be used employ standard forest sampling and measurement practices and were developed referencing Avery and Burkhart (1994) and USFS (2012) Forest Inventory and Analysis National Core Field Guide. Volume I: Field Data Collection Procedures for Phase 2 Plots Version 6.0.

Equipment list

Each field crew will carry the following equipment at all times:

Cellphone and emergency contacts list

First aid kit

Field Map

GPS

Compass

Flagging

Rebar and mallet

PVC pipe and caps

Aluminum tags and wire

Diameter at breast height (dbh) pole

100’ measurement tape

Diameter tape (metric)

Height and slope measuring equipment (hypsometer and clinometer)

Distance measuring equipment (DME) – Haglöf DME 201 Cruiser

Backpack

Machete

Digital camera

Datasheets

Aluminum clipboard

Pencil

Replacement batteries

Establishment of Sample Plots

Sampling intensity was allocated among strata using an optimal allocation - see "Lukens Strata and Stats 2015 05 23.xlsx". Plots within strata were allocated at random using ArcGIS random point generator. Navigating with a GPS, the instant the distance to waypoint reads 1-2 meters the plot center is marked by planting the DME pole directly in front of the crew member using the GPS. Once a plot center location is set, the plot will be marked by hammering a 1 cm diameter metal rebar into the ground. The metal rebar should be approximately three feet in length with about 24” of rebar (or until secure) going into the ground. A 4-foot length of PVC pipe (with internal diameter > 1 cm) should be placed over the rebar and hammered into the ground. Significant efforts shall be taken to ensure PVC pipe is perpendicular to the ground. An aluminum tag, labeled with a unique monitoring plot identification name, should be placed inside the PVC pipe for all permanent sampling plots. Finally, a PVC end cap should be placed on the top end of the PVC pipe.

Where at the time of re-measurement an established plot center can no longer be located exactly, a new plot will be established in the same stratum, allocated randomly using GIS, and marked in the field using the same procedures described above.

The slope (in %) of each plot will be measured with a clinometer and recorded on the field data sheet. The slope will be recorded so the plot dimensions can later be adjusted to calculate the equivalent horizontal area. To measure the slope of the sample plot using a clinometer, one field crew member stands in the plot center (or directly upslope of plot center). Another crew member stands downslope (approximately 20 m away from the first crew member). The first crew member then aims the clinometer at the eye-level of the second crew member and records the % slope displayed in the clinometer.

Photos will be taken in each of the four cardinal directions. If the GPS accuracy reading is greater than 5 m, actual UTM coordinates will be recorded.

These established plots are intended to be permanent plots and will not need to be replaced for future inventories. Forest inventory updates will occur, minimally, every 12 years, as required

by section A.3 of the COP. However, interim updates may be performed more frequently, as needed.

The inventory employed a random, stratified sampling design, with an overall sampling intensity of 105 10-meter radius fixed area plots (detailed in table below).

Stratum	**Acres**	**Sample size**
Hardwood. Mostly black gum, sweetgum and red maple, some minor pine component	645.5	24
Mixed Forest with Pine. Mostly loblolly and pond pine, naturally-regenerated, many areas with dense shrub understory.	1746.1	46
Pine. Mostly loblolly, with minor pond and longleaf pine component, planted and naturally-regenerated.	1743.3	35
Total	4134.9	105

2B. Standard procedures for where and how to measure parameters used in biomass calculations.

Includes items such as diameter at breast height (dbh) and height (including for irregular trees), how to classify dead wood, and for any other aspects of sampling where a consistent method is documented.

All measurements were taken with metric units.

Determination of Measure Trees

The inventory employs stratified random sampling on 10 m fixed radius circular plots. Within each plot, all stems $\geq$ 12.7 cm dbh and taller than 4.6 m (15 feet) will be measured and species recorded. Distance Measuring Equipment (DME) will be used to determine if a stem falls within the plot radius. The DME will be calibrated at the beginning of each day of field work, and re-calibrated during the day after significant changes in temperature and humidity or when odd

readings are obtained. For any borderline trees, the distance from the plot center to the center of the base of the tree will be measured to the nearest cm. Trees will be marked with paint, chalk, or logger crayon. Trees will be temporarily numbered to ensure measurements are accurately assigned for the corresponding tree.

Measurement of Live Trees

For each live tree ≥ 12.7 cm (5”) dbh and ≥ 4.6 m (15 feet) height, the following will be recorded:

- Azimuth from plot center to tree
- Species (or identification to genus if species cannot be identified), preferentially using a four letter code with first two letters of the genus and first two letters of the species (e.g. PIPA = *Pinus palustrus,* Longleaf Pine)
- Dbh in cm (to within 0.1 cm)
- Visual appraisal of percent defect in each of three sections (top, middle and bottom thirds) of the merchantable stem to a 4” top
- Total height in m (to within 1 m)

Diameter of all trees will be measured at breast height (4.5 feet or 1.37 m above ground level, see Figure 1). Diameter of trees with buttresses (e.g. baldcypress, water tupelo) will be measured 1.5 feet above the point of termination of the buttress when the tree is buttressed at breast height (e.g. Figure 2). Dbh will be marked using paint, chalk, or logger crayon.

To aid in the determination of breast height, dbh poles (1.37 m in height) will be carried by each team. Additionally, each pipe will be scored and marked with a permanent marker at 1.5 feet below the top of the pipe establishing a permanent reference for measuring the 1.5 feet above buttress termination, when applicable.

To avoid either missed trees or double recording, the point of initiation of measurement will be marked. The first tree should be flagged and measurement should proceed in a consistent clockwise or counter-clockwise fashion.

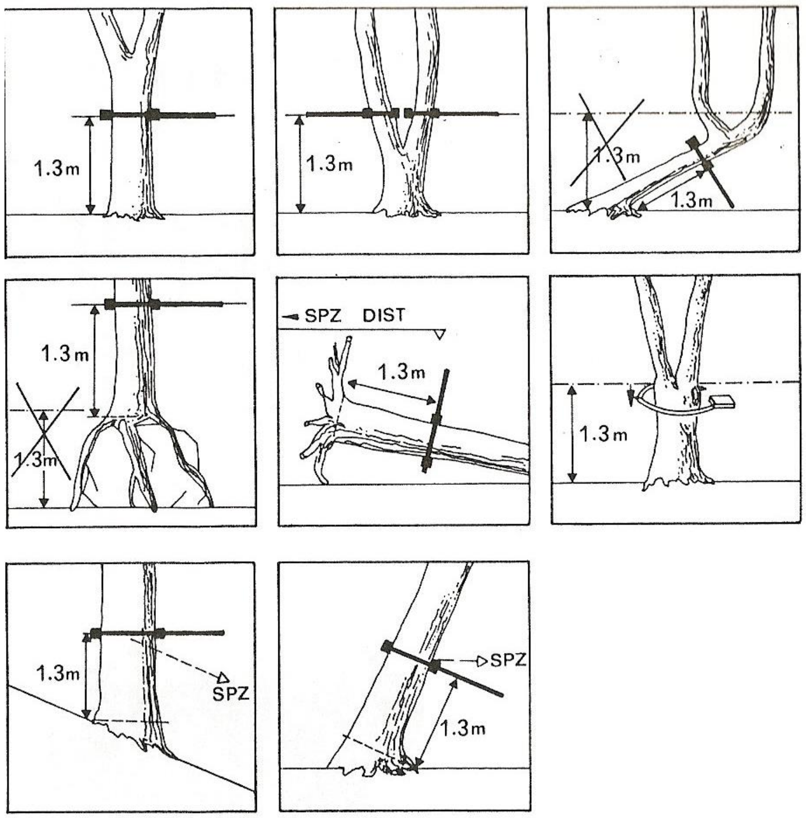

Figure 1. Point of measurement of diameter at breast height (from Pancel[1], 1993). Note, in the center right box, the tree forks at exactly breast height, in which case diameter is measured just *below* the swell associated with the fork. Otherwise, diameter at breast height is always measured *above* any irregularity causing swelling around the stem cross section.

[1] Pancel, L., ed. 1993. Tropical forestry handbook. Berlin, Germany, Springer-Verlag. Volume 1, 738 pp.

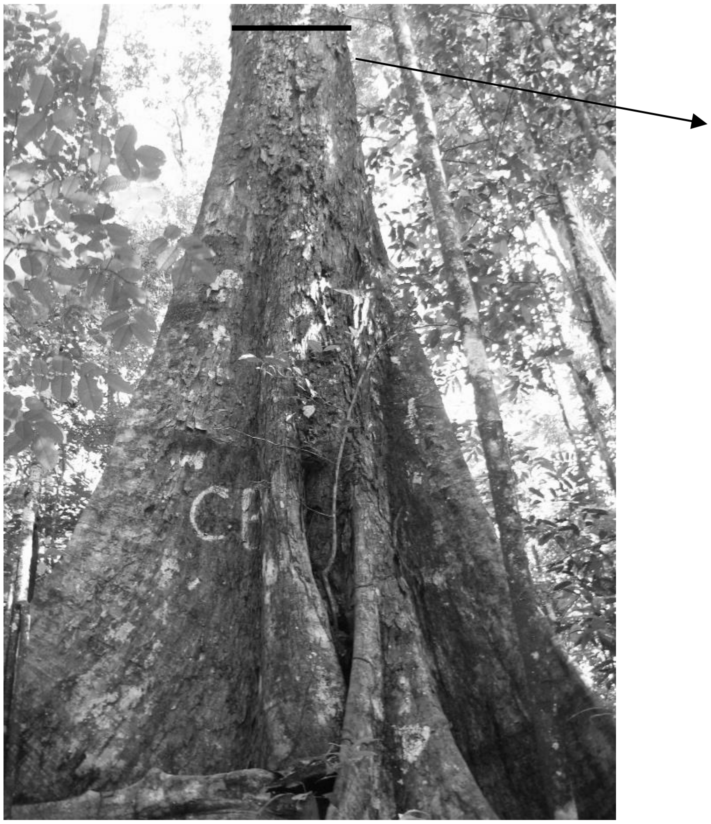

Figure 2. Demonstration of point of measurement for diameter of a buttressed tree (e.g. baldcypress or tupelo).

Percent defect is assessed visually, identifying any areas of breakage or cavities, by assigning the percentage missing (from a complete, un-damaged, state, specified in 10% increments) in each of three sections (top 1/3, middle 1/3 and bottom 1/3) of the merchantable stem; merchantable stem height is measured as the distance from the ground level to an approximately 4” top (see Figure 3).

Height is measured using a Haglof hypsometer. If readings cannot be acquired with the hypsometer, a clinometer will be used. The hypsometer will be calibrated at the beginning of each day of field work, and re-calibrated during the day after significant changes in temperature and humidity or when odd readings are obtained. Field crews will not carry the hypsometer inside their jackets to avoid changes in temperature (outside pocket of vest is okay).

Maximum slope angle from which height is estimated will not exceed 120%. Total height is measured as the distance from ground level to the highest visible point on the crown (or apical meristem). Total height requires sighting the level point on the trunk, the top, and the base of the tree at ground level (only level point on the trunk and the top may be sighted when using Haglof hypsometer Height 2P sampling). The data recorder will confirm for each tree that the full height is accounted for in the measurement. Care will be taken to be certain that the correct top is being sighted, being aware that part of the crown leaning toward the observer may give the false appearance of being the highest points of the tree. For leaning trees, total height should be

measured from an oblique angle and sighted by drawing a horizontal line from the tree top to a point over the tree base (see figure below). A minimum of two height measurements will be obtained, from different vantage points if necessary, and the recorded height taken as the average of the two measurements.

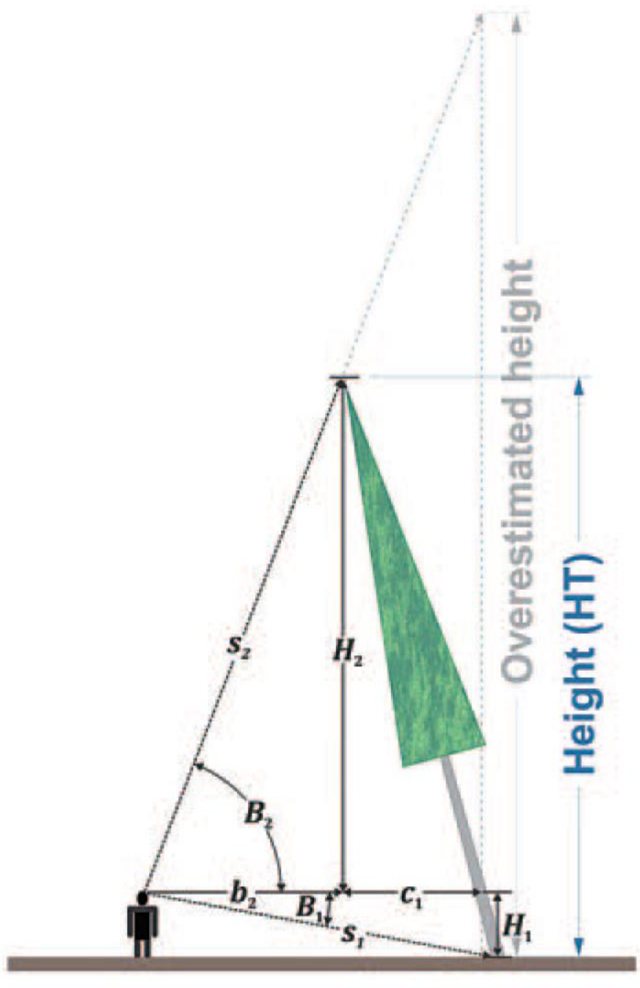

Figure. Demonstration of height measurement of a leaning tree, "Height (HT)" Height should be measured from the oblique perspective of the reader, not the human figure in the diagram, and sighted with the hypsometer drawing a horizontal line (blue horizontal line) from the tree top to a point over the tree base (reinterpreted from Bragg 20142)

[2] Bragg, D.C., 2014. Accurately measuring the height of (real) forest trees. *Journal of Forestry*, *112*(1), p.51.

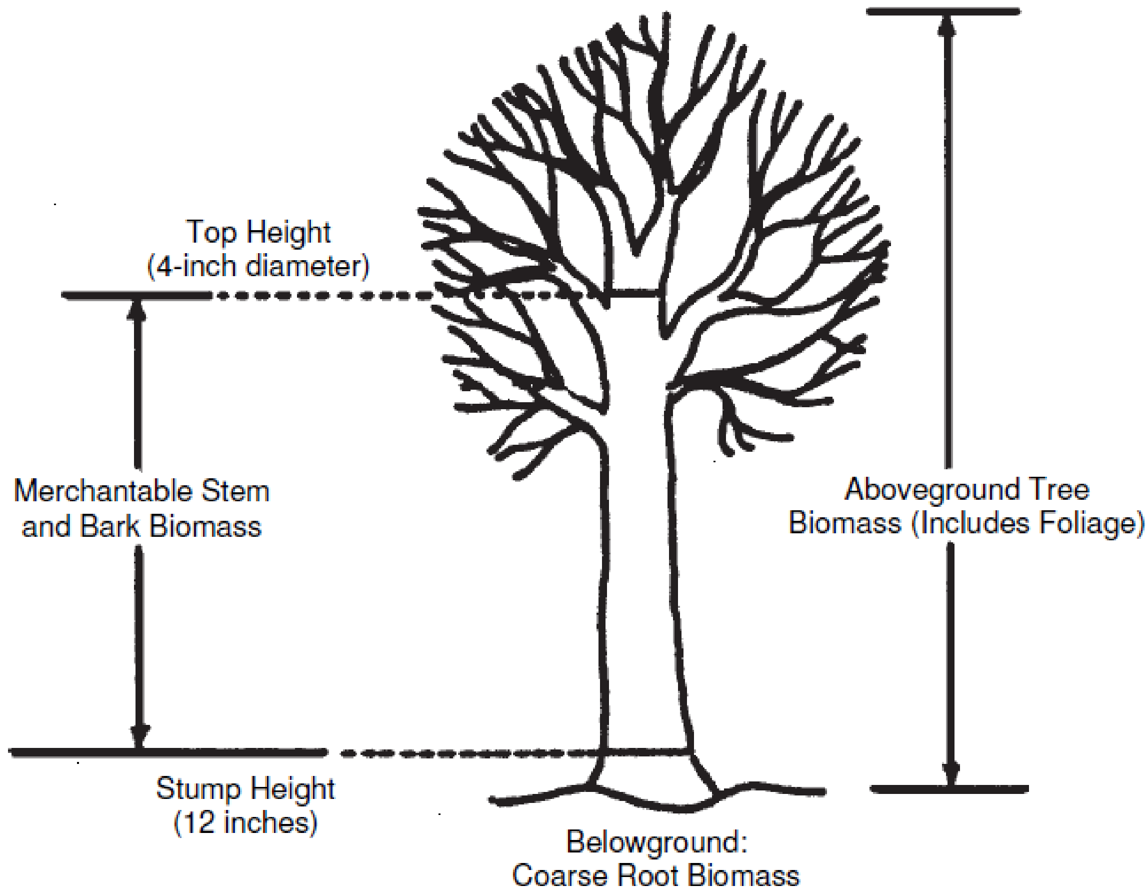

Figure 3. Illustration of aboveground biomass components and merchantable bole height (from Jenkins et al 2004[3])

Height (whether total height or bole height) must represent the original without-defect height of the sound tree. When tops are missing, height must be reconstructed by referencing heights of comparable trees, nearby.

[3] Jenkins, J.C.; Chojnacky, D.C.; Heath, L.S.; Birdsey, R.A. 2004. A comprehensive database of biomass regressions for North American tree species. Gen. Tech. Rep. NE-319. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 45 p.

Measurement of Standing Dead Wood

In the same plot used first to sample standing live trees each standing dead tree ≥ 12.7 cm (5") dbh and ≥ 4.6 m (15 feet) height, the following will be recorded:

- Azimuth from plot center to tree
- Species, if softwood, otherwise if hardwood leave undetermined
- Dbh in cm (to within 0.1 cm)
- Total height in m (to within 1 m) (see below)
- Visual appraisal of percent defect in each of three sections (top, middle and bottom thirds) of the merchantable stem to a 4" top
- Qualitative assignment of decay class

The same guidance for live trees applies to the above. For assignment of decay class, the following five categories (Table 1) will be used[4]. Note that for standing dead trees, height (whether total height or bole height) must represent the original without-defect height of the sound tree, and that for snags for instance, must be reconstructed by either (1) referencing heights of comparable sound trees nearby (giving careful consideration as to whether the dead tree was suppressed, and consequently would have had a lower height than its neighbors), or (2) measuring the length of fallen parts of the crown to add to snag height. On the data sheet, it is important to document whether phantom heights were used or whether reconstruction from a fallen top was used to determine total height.

[4] From Climate Action Reserve 2012. Quantification Guidance for Use with Forest Carbon Projects, referencing Woudenberg, S.W., Conkling, B.L., O'Connell, B.M., LaPoint, E.B., Turner, J.A., Waddell, K.L., 2010. The Forest Inventory and Analysis Database: database description and users manual version 4.0 for phase 2. US Department of Agriculture, Forest Service Gen. Tech. Rep. RMRS-245, 339 pp.

Table 1. Description of decay classes.

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 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; less than 20 percent of the bark remains; sapwood is gone; heartwood is sloughing throughout.

Standing dead wood is defined as all dead trees emanating from the original stump which are standing at an angle of greater than 45° relative to the ground.

Boundary Issues

It is expected that boundary issues will be encountered at some plots in the field. Crews will consult maps and GPS readings to confirm the location of any boundaries (and potential of plot overlap) between strata or of the inventory area. Crew members shall mutually agree to the location of a boundary based on available maps or GPS coordinates.

Plots that overlap the project boundary ("boundary overlap") will be corrected using the walk through method [5], illustrated in Figure 4 below. On plots near a boundary, for trees between the plot center and the boundary, the distance from the plot center to the tree will be measured, then the same distance will be measured continuing along the same path (away from the plot center). If at the end of the distance the observer is outside the boundary, the tree is counted twice for the

[5] Ducey, M.J., J.H. Gove, and H.T. Valentine. 2004. A Walkthrough Solution to the Boundary Overlap Problem. Forest Science, 50: 427-435.

plot. If the walk-through method is implemented, notation will be made on the data sheet as to which trees were counted twice.

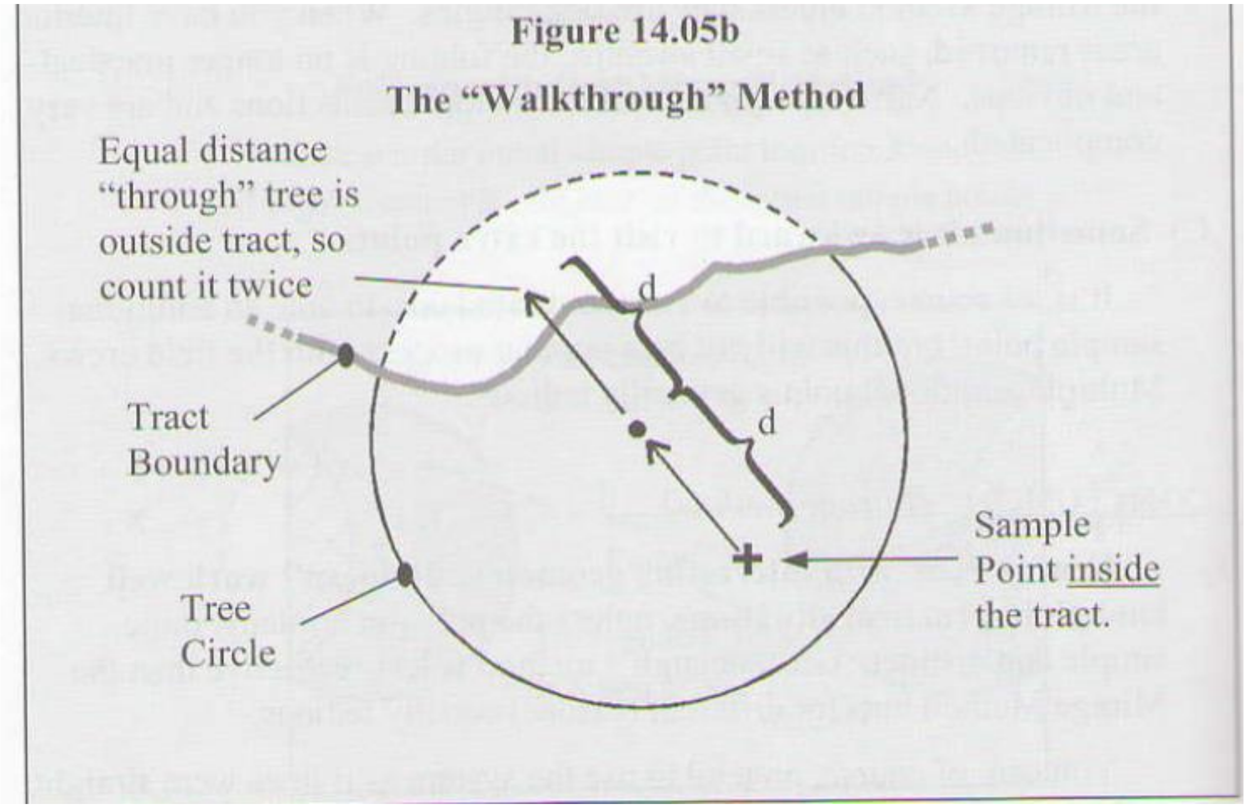

Figure 4. Diagram of walk through method (Iles 20036)

2C. Stratification rules (pre and post sampling)

An initial feasibility study was conducted in 2012 to obtain basic information on the project and to establish the best method of approaching the full inventory. In advance of this field visit, aerial imagery was obtained to determine the likely composition of the forests within the project area. The data collected during the on-site feasibility study was used to identify the existing forest types, and was compared with aerial imagery to establish three strata boundaries based on forest type.

[6] Iles, K. 2003. A Sampler of Inventory Topics. Kim Iles and Associates, Ltd.

The project area delineation, and stratification, were based on the property's 2002 Forest Management Plan[7], a 2012 timber type map[8] prepared by The Brigman Company and a time series of satellite imagery from Google Earth.

Based on visual appraisal of aerials and satellite images, roads, logging decks, food plots, 300' buffer along western border of property, saltmarsh and remaining areas of open water were delineated and excluded from the project area (documented in "timber type.pdf"). The buffer along the west side of the property provides compliance with the North Carolina Best Management Practices Neuse River Basin 'Riparian Buffer Rule' of 50' feet on each side of waterbody[9]. Generally, non-forest area exclusions were delineated down to ~ 1 acre in size (beyond this point it was not feasible to delineate), which matches the USFS FIA forestland definition. Any non-forest areas smaller than this (e.g. small wet openings in a forest matrix) still are defined as forest land per the USFS FIA definition, and are included in the project area – importantly, they are part of the sample population and are represented in inventory stock estimates.

Stands delineated in the 2012 timber type map were combined into three strata to represent broad forest types/biomass carbon classes for use in the forest carbon inventory design, as described below:

> Stratum 1 Hardwoods = hardwoods (mostly black gum, sweetgum and red maple), some minor pine component, estimated ~35 years old.
>
> Stratum 2 Mixed (understocked) pine = 7-15 years old pine (mostly loblolly and pond pine), understocked, naturally-regenerated, many areas with dense shrub understory impeding recruitment. Much of this area subject to a severe burn ca. 20 years ago.
>
> Stratum 3 Pine = 20-35 years old pine (mostly loblolly, with minor pond and longleaf pine component), planted and naturally-regenerated.

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[7] Plaster, A.L. May 10, 2002. Comprehensive Forestry Services. A Forest Management Plan for Lukens Island Hunting Club, Inc.

[8] Green Assets. September 5, 2012. A timber type map of Lukens Island Tract, Carteret County, NC.

[9] Sourced at: http://ncforestservice.gov/water_quality/bmp_manual.htm

Stratum	**Stands (as identified in the 2012 timber type map)**
1 Hardwood	H+I
2 Mixed pine	D+J+L
3 Pine	A+B+C+E+F+G+K

Strata designations will be maintained and updated over time, if necessary, as new data from future inventories becomes available

Stratum	**Acreage**
Hardwood	645.51
Mixed Forest with Pine	1,746.08
Mature Pine	1,743.29

Figure 6 shows a map of the project area, including the three strata and the inventory plots.

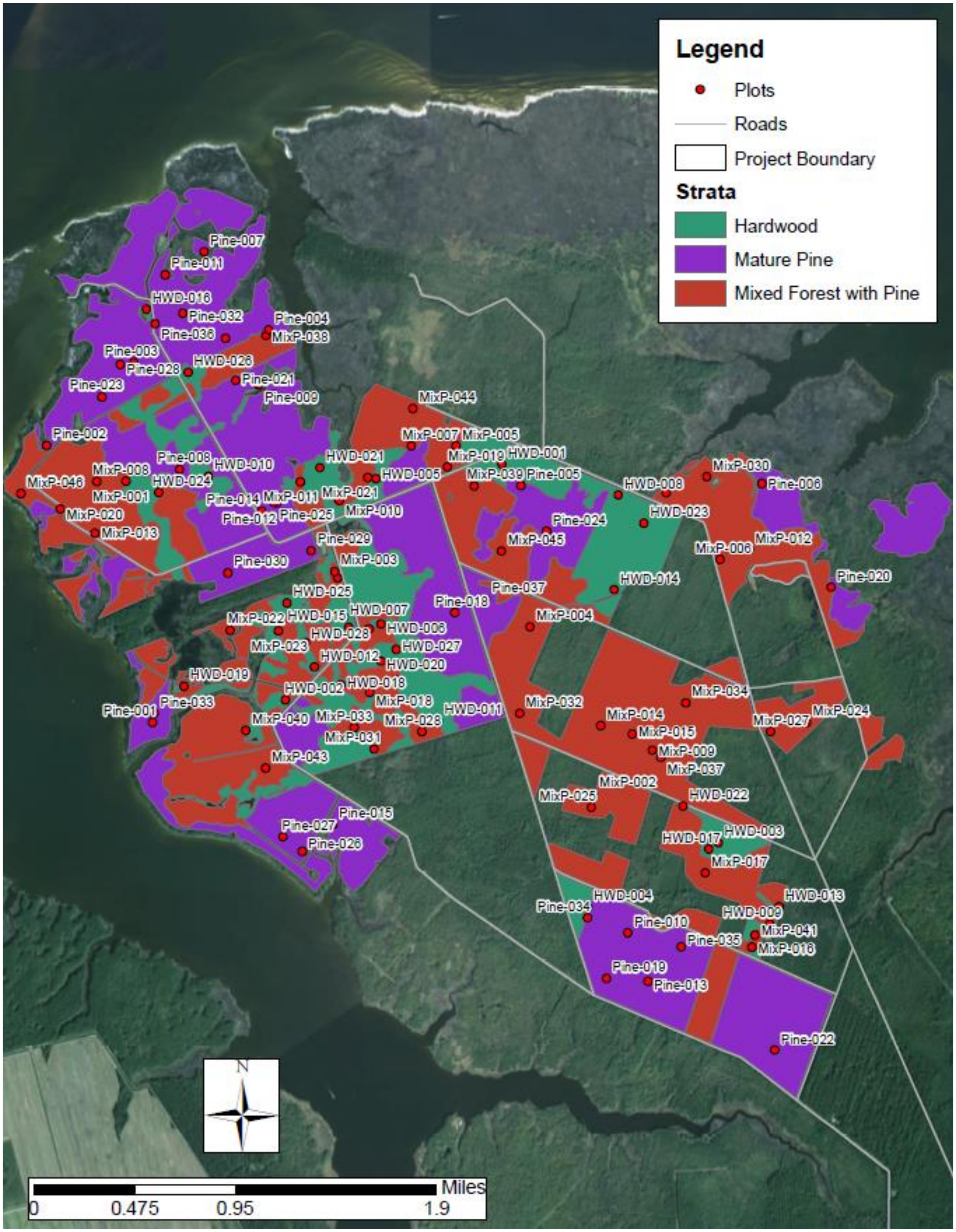

Figure 6. Project map with strata and inventory plot locations

3. Documentation of all analytic methods and biomass equations used to translate field measurements into volume or biomass carbon estimates

Standing Live and Dead Trees (AC-1 and AC-3)

Biomass was calculated in accordance with guidance provided in the COP. Professional Foresters with Southern Palmetto Environmental Consulting (NC License Number 1433) oversaw all reports referencing carbon stocks.

Modeling approach to de-grow Lukens inventory data back to April 29 2015 start date:

Inventory data were de-grown to a 29 April 2015 start date via the procedures below. Diameter and height of dead trees were assumed to be constant from the date of measurement (June and late September/early October 2015) to 29 April 2015.

1. Inventory data were entered into FVS-SN and grown for 5 years with no management (with "NoTriple" keyworded to track individual trees and permit cross-referencing to raw inventory dataset).
2. For each live tree (ascribed a unique identifier), annual diameter and height growth was derived assuming linear growth during the 5-year projection interval (i.e. for dbh, annual growth calculated as dbh at end of 5-year interval minus dbh at beginning of 5-year interval, reported in the FVS Treelist output, divided by 5). This linear extrapolation of the FVS model should be valid for the short < 1 year time interval applied here.
3. For each live tree, diameter and height data, as measured, were de-grown referencing the annual rates derived in step 2 above. For trees measured in June 2015, annual rates were multiplied by 0.25 (1.5 months / ~ 6 month annual growing season) and for trees measured in late September/early October annual rates were multiplied by 0.833 (5 months / ~ 6 month annual growing season). Estimated growth in the intervening period between measurement and project start date was subtracted from the measured values of dbh and height.
4. Initial carbon stocks and harvested wood products were recalculated using the de-grown data.

Gross cubic foot volume of stem wood (VOLCFGRS) was calculated using equations referenced by "Woodall et al 2011[10]".

For volume and biomass estimation, unidentified standing dead hardwoods were assigned a species corresponding to the hardwood species having the highest relative basal area for that

[10] Woodall, Christopher W.; Heath, Linda S.; Domke, Grant M.; Nichols, Michael C. 2011. Methods and equations for estimating aboveground volume, biomass, and carbon for trees in the U.S. forest inventory, 2010. Gen. Tech. Rep. NRS-88. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 30 p.

stratum (black gum in the hardwood and pine stratum, and sweet gum in the mixed forest with pine stratum).

For all trees, VOLCFGRS was then adjusted to deduct any portion observed missing (referencing defect assessments for the top, middle and bottom thirds of the merchantable stem volume of inventory trees), to produce sound cubic foot volume of stem wood (VOLCFSND). Deductions for defect were incorporated by multiplying VOLCFGRS by weighted average overall percent sound (1 – recorded percent defect) referencing the proportions of merchantable stem volume represented in each of three assessed thirds.

Tree Portion	Softwoods Percent of Tree Biomass[11]	Hardwoods[12] Percent of Tree Biomass
Bottom 1/3	49%	47%
Middle 1/3	31%	32%
Top 1/3	20%	21%

VOLCFSND and dbh were then used to produce estimates of biomass using the Component Ratio Method, per Woodall et al 2011, and referencing coefficients consolidated in the ARB database "Biomass Coefficients for Use with the Component Ratio Method." Root biomass was calculated using guidance provided by ARB as found on the ARB website (http://www.arb.ca.gov/cc/capandtrade/protocols/usforest/usforestprojects_2014.htm). In summary, root biomass (DRYBIO_BG) is calculated as the product of root biomass calculated using Jenkins ratios (root_biomass_Jenkins) and an adjustment factor (AdjFac).

Deductions for defect of standing dead wood applied the same procedures outlined above for standing live. Wood density of standing dead wood was adjusted by multiplying by species-specific density reduction factors (DRF), corresponding to a given decay class, referenced from Harmon et al 2011[13], and then a structural loss adjustment (SLA) factor applied (Domke et al 2011[14]; table below).

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[11] Estimated for Loblolly Pine, from Table 67 of Wahlenberg, W.G., 1960. Loblolly pine. *School of Forestry, Duke University, Durham, NC*.

[12] Estimated for Black Gum and Sweetgum applying Girard form class reported in Table 39 of Wenger, K.F., 1984. Forestry handbook (Vol. 84, No. 1). John Wiley & Sons.

[13] Harmon, Mark E.; Woodall, Christopher W.; Fasth, Becky; Sexton, Jay; Yatkov, Misha. 2011. Differences between standing and downed dead tree wood density reduction factors: A comparison across decay classes and tree species. Res. Pap. NRS-15. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 40 p.

[14] Domke, Grant M., Christopher W. Woodall, and James E. Smith. 2011. Accounting for density reduction and structural loss in standing dead trees: Implications for forest biomass and carbon stock estimates in the United States. Carbon balance and management 6.1: 1-11.

Decay Class (as assessed in the field)	Top	Bark	Bole	Stump	Roots
1	1	0.92	1	1	1
2	0.5	0.66	1	1	0.95
3	0.2	0.39	1	1	0.8
4	0.1	0.21	1	1	0.65
5	0	0	1	1	0.5

Biomass was converted to carbon applying a carbon fraction of 0.5, and carbon converted to carbon dioxide equivalent (CO2e) applying a conversion factor of 3.664. All estimates of carbon dioxide equivalent per unit area are converted to metric tons (1000 kg) per acre.

An excel spreadsheet ("Lukens 2015 inventory BACKWARD rev18Jul2016.xlsx") was created to perform these calculations for each plot.

Carbon in In-Use Forest Products (AC-7)

In-use Forest Products were modeled based on conversion rate and inventory data.

Modeling was employed to project harvests and inputs to harvested wood products in the baseline. To model management scenarios we applied the USFS Forest Vegetation Simulator Southern Variant (FVS-SN). Detailed FVS-SN model outputs were then converted to t CO2 estimates applying ARB estimation procedures (i.e. component ratio method).

All tree data entered into FVS was sourced from the back-modeled 2015 inventory. Measured tree heights were entered in the database for all trees (i.e. the initial dataset from which projections were modeled included no FVS-imputed heights). Standing dead trees were assigned FVS tree history codes of 8 or 9 (undetermined time of mortality). FVS damage codes were assigned as follows:

Code 96 (broken/missing top) assigned where field-estimated defect of top third of merchantable stem volume of the tree exceeded 50%

Code 25 (defect pulpwood and sawtimber volume) assigned where field-estimated defect was recorded for any portion of merchantable stem volume of the tree, and severity entered as 1-99 (99 = 100%) representing weighted average overall percent defect calculated from defect recorded for the top, bottom and/or middle thirds, referencing the same proportions of merchantable stem volume represented in each of the three assessed thirds (see above)

Location was assigned as 81103 (corresponding to Croatan National Forest, closest national forest to project area) and ecoregion 232Ib (Tidal Area). Site index for each stratum (stand in FVS) referenced NRCS data, assigned as follows:

Stratum/stand	**Site index of reference species**	**Reference species**
Hardwood	95	Sweetgum
Mixed Forest with Pine	97	Loblolly pine
Pine	97	Loblolly pine

Site indices from NRCS corresponded closely to site index estimates made from direct measurement data. Site index at base age 50 (SI50) was determined from tree measurements (dominant/co-dominant total height and age) taken in the project area, applying a coastal plain loblolly pine site index curve from Amateis and Burkhart (1985)15. Average site indices of loblolly pine for Mixed Forest with Pine and Pine strata were 104 and 94, respectively, feet total height at base age 50.

From initial onsite live tree stocks input to FVS-SN, we modeled a clearcut in year 1. The FVS "NoTriple" command was entered to avoid excessive tree records and speed processing.

Carbon in harvested wood products was calculated from FVS model CutList outputs by first calculating sound merchantable stem volume (inside bark) for each tree cut using the same equations and procedures referenced above for live trees. Merchantable volume was disaggregated into pulp and sawtimber by referencing fractions specified in the FVS CutList output (referencing FVS-SN Southern Region volume merchantability standards; Keyser 2008);

[15] Amateis, R. L. and H. E. Burkhart. 1985. Site Index Curves for Loblolly Pine Plantations on Cutover Site-Prepared Lands. Southern Journal of Applied Forestry, 9:166-169.

where merchantable volume was zero in the FVS CutList output, all carbon is assigned as pulp, assuming recovery of stems down to 5” dbh.

Because specific gravity data was unavailable for sweet bay (*Magnolia virginiana*) and redbay (*Persea borbonia*), calculations could not be processed and these species were excluded from harvested wood product calculations.

Parameter BChv, standing live stocks in t CO2 harvested prior to delivery to a mill (thus equivalent to standing live converted per the modeled schedule), was calculated and projected through the baseline conversion projection, detailed in spreadsheet "Lukens eq 6.1 calcs REV 18JUL2016.xlsx".

Volumes were converted to biomass by applying basic specific gravities referenced from the USFS Wood Handbook 2010. Specific gravity at zero percent moisture content was calculated from basic (green volume) specific gravity using eq. 4-11 from USFS Wood Handbook 2010 (p. 4-9). Biomass was converted to carbon applying a carbon fraction of 0.5, to produce metric tons C on a per acre equivalent basis. Harvest t C/acre (before delivery to mill) were summed for four categories: hardwood saw, hardwood pulp, softwood saw and softwood pulp. This represents Step C1 of ARB protocol Appendix C.

Biomass transformed to wood products was estimated applying mill efficiency values referenced from the ARB “Regional Mill Efficiency Data” Microsoft Excel database, for the Southeast (SE) region (which includes North Carolina), specified in the table below.

Species group	**Sawtimber**	**Pulp**
Hardwoods	0.609	0.591
Softwoods	0.636	0.553

This represents Step C2 of ARB protocol Appendix C.

End wood product classes following transformation were assigned based on a survey of mills nearest the project area, conducted November 2015. Based on the survey findings, the following assumptions are applied:

Volume component	**Expected mill destination; end wood product class/treatment**
Hardwood saw	no mills within 140 miles accept hardwoods; assumed to be piled and burned onsite
Hardwood pulp	no mills within 140 miles accept hardwoods; assumed to be piled and burned onsite
Softwood saw	to Weyerhauser lumber mill in New Bern, NC (80 mi distance); softwood lumber
Softwood pulp	to Canal Wood pulp mill in Morehead City, NC (50 mi distance); paper

Wood product amounts retained in storage for 100 years in in-use wood products were then calculated referencing 100-year average storage factors provided in the California Air Resources Board (ARB) Compliance Offset Protocol U.S. Forest Projects (Table C.2). This represents Step C3 of ARB protocol Appendix C. Results were summed across the hardwood/softwood/pulp/sawtimber categories and multiplied by 3.664 to obtain average t CO2 stored in in-use wood products over 100 years from wood harvested in baseline over the first 1.5 years of the project, scaled to align with the conversion rate applied in the baseline, equal to 6,685 t CO2. For the entire baseline period, 20,055.7 t CO2 will be stored in in-use wood products.

Calculations are documented in the spreadsheet “Lukens HWP BSL PROJ REV 18JUL2016.xlsx”.

Forest Product Carbon in Landfills (AC-8)

As for in-use wood products above, modeling was employed to project inputs to harvested wood products in long-term storage in landfills in the baseline. The same modeling procedures and assumptions were applied.

Wood product amounts retained in storage for 100 years in landfills were calculated referencing 100-year average storage factors provided in the California Air Resources Board (ARB) Compliance Offset Protocol U.S. Forest Projects (Table C.3). This represents Step C4 of ARB protocol Appendix C. Results were summed across the hardwood/softwood/pulp/sawtimber categories and multiplied by 3.664 to obtain average t CO2 stored in landfills over 100 years

from wood harvested in baseline scaled to align with the 18-month conversion rate, of which the initial Reporting Period covers 6 months (one-third), equal to 5,930 t CO2. For the entire baseline period, 17,789.3 t CO2 will be stored in landfills.

Calculations are documented in the spreadsheet "Lukens HWP BSL PROJ REV 18JUL2016.xlsx".

Biological Emissions from Clearing Forestland outside Project Area (AC-13)

In the actual (project) case, the Avoided Conversion Discount (ACD) factor is calculated to be zero, because the fair market value of the alternative land use exceeds that of the current forested land use by more than 80%. Refer to Part VIII.D of the Initial OPDR.

Biological Emissions from Decomposition of Forest Products (AC-17)

Biological emissions from decomposition of forest products are already incorporated as a component of calculating carbon stored in in-use wood products and landfills (already incorporated in calculation of AC-7 and AC-8).

Baseline Carbon Stocks

The baseline scenario is a conversion of the project area to agricultural use. An appraisal was conducted of the land, indicating that the property's converted value would be approximately four times greater than its current forested value. The baseline is modeled and presented based on an 18-month conversion timeframe, as referenced in planning documentation in accordance with Section 6.3 of the COP, of which the initial Reporting Period covers 6 months (one-third). This rate of conversion is used to establish baseline carbon stocks and the uncertainty discount is zero (ARB COP US Forest Projects, adopted Nov. 14, 2014, table 6.3). The baseline harvest volume for the first Reporting Period is one-third of the on-site carbon stocks. The remaining carbon stocks would be harvested the following year, in accordance with the 18-month conversion timeframe. There are no further harvests in the baseline scenario, as the property would have been entirely converted for agriculture. A 100-year baseline projection can be found in "Lukens eq 6.1 calcs REV 5AUG2016.xlsx", and is also presented in OPDR Attachments H and I.

Actual harvest volumes will be minimal over the next 100 years. No harvests will occur within the first 10 years of the project. From year 11 to year 25, roughly 400,000 cubic feet will be harvested annually to improve species diversity in the project area. Anticipated annual growth is approximately 500,000 cubic feet, so there will be no net decrease in carbon stocks. Refer to "FVSOut_LukensR2mgt.xlsx" and "FVSOut_LukensR2nomgt.xlsx". From year 26 to 100,

minor thinnings may take place to encourage forest health and wildlife habitat, however harvest volumes will not exceed annual growth.

4. Quality Assurance / Quality Control (QA/QC) Plan

Includes procedures for internal review to ensure that standard operating procedures are being followed. The QA/QC plan must include procedures for assessing and ensuring the quality of collection, transfer and archiving of field data; procedures for data entry and analysis, and data maintenance and archiving; and any other relevant procedures to ensure quality and consistency in the collection and maintenance of data used to compile the offset project data reports.

Implementation of the monitoring plan will apply QA/QC procedures as outlined here to minimize errors in measurement, transcription and data entry, and to provide documentation and consistency in data archiving. This section covers procedures for: (1) collecting and recording reliable field measurements, and (2) documenting data entry.

Field Measurements

Field crews will be fully trained in all aspects of the field data collection and adhere to field measurement protocols. Each crew will be led by a professional forester/forest ecologist, and these leaders will be responsible for ensuring that all field protocols are followed to ensure accurate and consistent measurement. Pilot sample plots shall be measured before the initiation of formal measurements to appraise field crews and identify and correct any errors in field measurements. All borderline trees will be measured to the center of the tree.

To ensure accurate measurements, the height of diameter at breast height (1.37 m) will be confirmed using a pole cut to breast height. The hypsometer and DME will be calibrated per the procedures above. Field crews will have fine scale parcel maps for use in the field to interpret parcel boundaries and border trees.

Periodically, each crew will re-measure sample points measured by another crew. The sample point re-measured may be selected opportunistically. After returning from the field, point level estimates of total (above and belowground live and standing dead) tCO_2/acre will be calculated and compared. The difference in estimates should not exceed 20%. If the difference exceeds 20%, both crews will return to the sample point in question to re-measure the point, and identify and correct any procedural errors before continuing with the inventory.

Data Entry

All data will be recorded on the paper data sheet “Lukens data sheet.doc” All measurements will be repeated aloud in the field by both the crew member taking the measurement and the crew member recording the measurement to confirm that the value measured is correctly heard and

transcribed, and subsequently checked for legibility and completeness. In audible relay, both measurer and recorder will state the decimal point in the measurement taken. Prior to departing the sampling point, the recorder will provide the plot data sheet to another crew member for a data check. A second crew member will ensure all data has been collected and recorded appropriately. Data sheets will be reviewed daily to identify and clarify any vague or illegible records by two field crew members. Data from the field sheets will be transcribed to an Excel database (format following "Lukens 2015 inventory stats*.xlsx") nightly, and any anomalous outlier values of dbh or height identified using the data filter - sort function, and as necessary, flagged for re-confirmation/re-measurement. Transcribed data will be cross-checked against field data sheets, and corrected as necessary, opportunistically by another member of the data analysis team.

5. Description of data management systems and processes

Includes the collection, storage and analysis of inventory related data analytical methods to translate field measurements into volume and/or biomass estimates:

Data management begins in the field as data are being collected. Procedures listed above in the Quality Assurance / Quality Control section above documents the handling of data collected in the field, data entry and data entry checks. The process of transforming field data from the data sheet through the process of modelling and then yielding the final estimation of carbon stocks is an involved process with many steps. These steps include:

- Record data on field datasheet
- Put inventory data into excel
- Convert relevant excel data into FVS format
- Develop Tree Init and Stand Init tables for use in FVS
- Load MS access database
- Develop model using FVS Suppose interface
- Run models producing tree list as output tables
- Perform CRM and harvested wood product calculations in excel workbooks
- Estimate total emissions and reductions in excel workbook.

Finalized original electronic data spreadsheets will be saved and stored within the Green Assets office and backed up off-site weekly. Availability of original data spreadsheets will be limited to Green Assets' technical staff. When these data are required by the ARB or verification bodies, copies will be provided and the original version preserved. All records sufficient to allow for a verification will be retained for a minimum of 15 years.

6. A change log documenting any changes in the inventory methods or equations used to calculate carbon stocks

A project-specific "Change Log" will be established to document any changes in the inventory methods or equations used to calculate carbon stocks and will be maintained in a similar format to the original project field data spreadsheet.

7. Standard procedures for updating the forest carbon inventory, including documented procedures to account for:

a. Harvest

Landowner will be provided with a "Forest Activity" log to document any harvests which may occur. This log will specify the location, stratum, area within stratum harvested, as well as a description of the harvest type and associated documented volumes removed and their fate. Assessment of forest carbon stocks in harvested areas will utilize either timber mill tickets, appropriate FVS modeling results, or other industry standard methodology, and will occur within one year after harvest.

b. Growth

Growth will be documented upon required inventory updates, minimally on a 12-year interval. The inventory will be updated either via periodic re-measurement (no less frequently than every 12 years, but more often, as needed) or via growth and yield model projections of plot data. Re-measurements will follow all procedures outlined in this document and will require the re-measuring all sample plots. In the interim, and where no significant disturbance or harvest has taken place (confirmed via qualitative field assessments by the responsible forester) plot data may be updated through model projections using an ARB approved growth and yield model. Where growth and yield model projections of plot data are used to update the inventory, and where the FVS-SN model is used, all procedures for data entry and analysis as herein outlined will be adhered.

c. Disturbance

Disturbances will likewise be documented on the "Forest Activity" log. Notes relative to the anticipated or actual effect said disturbances will have on the carbon project will be maintained as well as any follow up procedures actually executed. Assessment of forest carbon stocks in disturbed areas will utilize either timber mill tickets, appropriate FVS modeling results, or other industry standard methodology, and will occur within one year after disturbance.

d. Incorporating new inventory and plot data, and retiring older sample plots

It is anticipated that the original plot points will be maintained and periodically sampled at no less frequently than every 12 years as required, and more frequently as needed to ensure accurate estimates are provided for monitoring reports and required verifications, e.g. in the case of harvest or disturbance, and specified above.

e. Modeling, as allowed under Appendix B within the California ARB COP U.S. Forest Projects, adopted Nov. 14, 2014

Modeling forest growth will be performed utilizing Forest Vegetation Simulator, Southern Variant. Calibration to local conditions will be performed, when necessary. When updating the forest carbon inventory through modeling, calibration will include, at a minimum, specification of site index by stratum, FVS location code and ecoregion.

f. Application of appropriate confidence deduction.

Application of a confidence deduction will be performed, as specified in Appendix A.4 of the COP.

Inventory methods and sampling procedures, once established, will be consistent over the life of the project. Any changes to inventory methods or calculations will be documented and justified in the change log.