Quantification Guidance for Use with Forest Carbon Projects

This document provides guidance for quantifying a Forest Project's onsite carbon stocks and carbon in harvested wood products, both for purposes of estimating a project's baseline as well as providing ongoing estimates of onsite project carbon stocks throughout the project life.

The quantification guidance is organized into the following sections:

1. Reporting Requirements for Forest Carbon Pools
2. Guidance for Estimating Carbon in Forest Carbon Pools
   - Use of Sampled Data
   - Requirements for Estimating Carbon in Standing Live and Dead Trees
   - Use of Regression Equations
   - Forest Vegetation Stratification
   - Quantification of Carbon in Live Trees from Project Data
   - Adjustments to Standing Live and Standing Dead Trees for Missing Volume and Decay
   - Requirements of Estimating Lying Dead Wood Carbon
   - Requirements for Estimating Soil Carbon Emissions and Soil Carbon Quantification for Avoided Conversion Projects
   - Onsite Carbon Stocks Affected by Site Preparation Activities with Reforestation Projects
   - Total Onsite Carbon Stocks and Calculation of the Confidence Deduction
     - Applying a Confidence Deduction to Sampled Estimates
     - Applying a Confidence Deduction to Non-Aggregated Projects
     - Applying a Confidence Deduction to Aggregated Projects
   - Requirements for Calculating Carbon in Harvested Wood Products

Reporting Requirements for Forest Carbon Pools

Onsite forest carbon pools are broadly grouped into living biomass, dead biomass, and soils. Living biomass includes biomass in live trees and shrubs and herbaceous understory (live non-Tree biomass). Onsite dead biomass includes biomass in dead trees, Lying Dead Wood, and Litter. Offsite dead biomass includes harvested wood products.. For standardized reporting, all estimates of forest carbon stocks must be provided in terms of tonnes (metric) of CO_2 – equivalent (CO_2e) on a project and a per acre basis. Unless otherwise required in the referenced biomass equations, the following conversion formulae shall be used:

Base Unit	Conversion		Final Unit
Biomass	.5 * biomass	=	Carbon
Carbon	3.67 * carbon		CO_2e
Tons	0.90718474 * tons		Metric Tons (MT) or Tonnes
Hectares	0.404686 * hectares		Acres

Reporting requirements vary for each of the carbon pools. The estimates for the pools that are derived from sampling must meet the quality standards described later in this appendix. **Error! Reference source not found.** displays the reporting requirements for each of the carbon pools.

Table A.1. Reserve Requirements for Carbon Pool Categories and Determination of Value for Pool

<table>
<tr><th>Category</th><th>Carbon Pool</th><th>Forest Management</th><th>Reforestation</th><th>Avoided Conversion</th></tr>
<tr><td rowspan="2">Living biomass</td><td>Live Trees</td><td colspan="3">Required</td></tr>
<tr><td>Shrubs and Herbaceous Understory</td><td>Not allowed</td><td>Any removals as part of site preparation must be quantified</td><td>Not allowed</td></tr>
<tr><td rowspan="6">Onsite Dead Biomass</td><td rowspan="2">Standing Dead Trees</td><td colspan="3">Required for adherence to Natural Forest Management criteria and for project reporting.</td></tr>
<tr><td></td><td>Any trees removed as part of site preparation must be quantified</td><td></td></tr>
<tr><td rowspan="3">Lying Dead Wood</td><td colspan="3">Required for adherence to Natural Forest Management.</td></tr>
<tr><td colspan="3">Not allowed for crediting.</td></tr>
<tr><td></td><td>Lying Dead Wood Removed as part of site preparation must be quantified</td><td></td></tr>
<tr><td>Litter</td><td colspan="3">Not allowed</td></tr>
<tr><td rowspan="2">Soil</td><td rowspan="2">Soil</td><td colspan="3">Required for emissions reporting associated with management activities.</td></tr>
<tr><td colspan="3">Optional for reporting of project benefits in Avoided Conversion projects only.</td></tr>
<tr><td>Offsite Dead Biomass</td><td>Harvested Wood Products</td><td colspan="3">Required</td></tr>
</table>

Guidance for Estimating Carbon in Forest Carbon Pools

This section describes requirements for the development of values for the forest carbon pools described in Table A1. Project Operators must develop an inventory methodology that is included in the Project Design Document. Project Design Documents submitted to the Reserve must include the required provisions identified in this section as part of their quantification methodologies. Flexibility is allowed in the development of sampling methodologies by Project Operators beyond the requirements outlined in this document.

Use of Sampled Data

All inventory methodologies must be based on randomized or systematic sampling and include the minimum quality parameters described in this section for each carbon pool. Inventory methodologies must describe the process for locating sample plots. Sample plot locations may be monumented in such a way to assist in relocating them for quantification and verification purposes. Plot monument strategies that incorporate Global Positioning Systems (GPS) along with additional navigational strategies at close range to plot centers (that direct verifiers to the precise plot location) that are resistant to weather, wildlife, and other environmental factors can substantially reduce verification costs. Project Operators are advised to consider the verification guidance (Section 10 of the Forest Project Protocol) associated with verification of sampled carbon pools (the sequential sampling guidance for verification in particular) prior to settling on a strategy to monument plot locations or not.

Forest inventories are forever in flux due to forest growth, harvest, and natural disturbances. Therefore, inventories of carbon pools must either be updated or remeasured at a frequency commensurate with the anticipated or actual changes in the specific carbon pools so that sample plots and forest stratification reflect current conditions. Any plot data that is updated to reflect current conditions with the use of predicted (modeled) increments of height and diameter data will be used during site verifications to compare against verifiers field measurements using the sequential sampling techniques described in the verification section. This provision ensures that plot measurements and update processes are accurate. Estimates from sampled pools must meet a minimum confidence standard of +/- 20% at the 90% Confidence Interval. It is acceptable to calculate the descriptive statistics, including confidence intervals, using plot data that have been updated to a current date. Discounts for uncertainty are applied to project estimates when confidence standards are below +/-5% at the 90% Confidence Interval. This is described in greater detail below.

Requirements for Estimating Carbon in Standing Live and Dead Trees

It is required that both Standing Live and Standing Dead Trees be sampled. It is acceptable, but not required, to combine Standing Live and Dead Trees during sampling such that descriptive statistics, including confidence statistics, address the combined pools. Whether combined or not, tree data must be coded so that mean estimates can be interpreted independently for Standing Live and Standing Dead pools to allow monitoring of standing dead trees compared to requirements in the Natural Forest Management Section (Section 3.11) of the Forest Project Protocol (FPP).

Inventory methodologies must include a description of how the sampled data will be archived and the analytical tools that will be included in the analysis of carbon stocks. The tree lists that are developed from inventory sampling and used to expand inventory estimates to the project level must be available for verification review. It is acceptable for the tree list to be presented and reviewed in an electronic format, such as in a database or spreadsheet application. Table A.2 displays the requirements that all project inventory methodologies must include for Standing Live and Dead Trees.

Table A.2. Requirements for sampling Standing Live and Standing Dead Trees

Species	1. All trees sampled must include a species identifier. The inventory methodology must provide a crosswalk between any codes used to identify a species and the species name the codes represent. 2. Since all trees contain carbon, the inventory methodology must indicate that the sample methodology will include all species present within the project area.
Diameter at Breast Height (DBH) Measurements	1. Inventory estimates must include all trees 5 inches DBH and larger. It is acceptable that inventory methodologies include trees with DBHs less than 5 inches. 2. The location of the measurement of DBH must follow US FIA sampling guidelines (See link from the Forest Protocol Resources Website). 3. Measurement precision must be no greater than the nearest inch.
Height	1. Inventory methodologies must describe whether all trees on sample plots are measured for height or whether a subset of the sample plot heights is measured and regression estimators are developed for unmeasured heights. 2. Inventory methodology must describe whether height measurements describe the tree's total height or some other top height measurement (regression estimators, or published form equations, may also be used to estimate top heights from a partial height or vice versa). Where regression estimators are used for tree heights, the inventory methodology must describe the populations from which the regression estimators were acquired. 3. The sampling precision for tree heights (when measured) must be stated in the inventory methodology. Stated acceptable precision for measured heights not to be greater than +/- 10 feet. 4. The inventory methodology must include a description of the maximum angle accepted for measuring tree heights. The stated maximum acceptable slope to the measured height shall not exceed 120%.
Weight (Plot Area and Forest Strata)	1. All methodologies must describe the sample plot areas used to determine which trees are included for measurement. 2. All tree lists must include a field(s) that displays the weighting of each sampled tree in order to expand the sampled tree to a per acre value. 3. Where inventories are stratified, the governing rules for stratification and stratification methodology must be described. The process for updating forest strata must be described. 4. Where inventories are stratified, stratum areas must be provided at verification with maps and tabular outputs.
Status	1. Each sampled tree must be identified as live or dead. 2. Dead trees must be coded with the decay status so density adjustments can be made. Decay class descriptions and density adjustments are provided below.

Biomass Equations	1. All projects must calculate the biomass in each tree using the biomass equations provided by the Reserve (See link from the Forest Protocol Resources website). 2. The project's inventory methodology must include a list of the equations and cite the version of the Reserve's equation file from which they were copied.
Deductions for Missing Biomass	1. Both live and dead trees may have cavities, broken-tops, or other deformities that reduce the biomass in the trees. Therefore, the inventory methodology must include a description of how deductions are estimated to account for missing biomass. The Reserve has provided guidance below that is acceptable. Alternative methods that address deductions for missing biomass are subject to approval by the Reserve.

Sampling methodologies and measurement standards should be consistent throughout the duration of the Forest Project. If new sampling methodologies are incorporated during the project life, they must be approved by the Reserve. Sampling methodologies and measurement standards will be evaluated for their statistical validity. Additionally, uncertainties in estimates associated with modifications to sampling methodologies may require reconciliation to project data and/or baseline estimates and shall be conducted at the Reserve's sole discretion. The application of a revised sampling methodology can only occur as part of a site verification.

Use of Regression Equations

It is acceptable to develop carbon inventories using regression estimators to estimate tree heights. Project Operators must keep in mind that plots or (sub) populations will be randomly selected for verification and that regression estimators should be used where a high level of certainty can be developed from the estimators. Failure to do so will result in increased effort and cost to meet the standards of verification.

An example of using regression estimators is provided on the Reserves Forest Project Protocol Resource webpage.

Forest Vegetation Stratification

Stratification is not required, but it may simplify verification and possibly lower the costs of verification. Where forest vegetation is stratified, inventory methodologies must describe the guidelines used for stratification. Traditional stratification decisions are usually based on species composition, forest stem size (DBH or height), and density. It is important that the stratification be relevant to sampling forest carbon. The minimum polygon size to which the stratification guidelines apply must be included in the methodology. A map of current forest strata must be included in the Project Design Document. The methodology must also include the process guidelines for updating forest strata for disturbance and growth events.

Quantification of Carbon in Live Trees from Project Data

All projects must use the appropriate biomass equations for the Assessment Areas the project is located in. The required biomass equations are found on the Reserve's Forest Protocol Resource Page\Biomass Equations webpage. The calculation of CO_2e for each tree must be conducted in a manner that provides project estimates for:

- Whole trees (roots, stump, bark, bole, top, and branches), used to provide project totals and estimates of harvest emissions, considering the bole only proceeds to Harvest Wood Products estimates)
- Above-ground portion (stump, bark, bole, top, and branches) used to compare project data to Common Practice statistics for Improved Forest Management projects.
- Bole portion, for inclusion in calculations of carbon stored in Harvested Wood Products.

Projects outside of California, Oregon, Washington, Alaska, and Hawaii use estimators for non-bole portions of the tree referred to as Component Ratio Method (CRM). The CRM method must be used to compute the various portions of the tree mentioned above. The Reserve has provided both the U.S. Forest Service instructions for using the CRM method and a truncated version that provides the same outputs for the required estimates above, but provides calculation efficiencies in bypassing steps that produce non-required outputs, such as stumps. The guidance is found on the Reserve's Forest Protocol Resource\Biomass Equations webpage.

Projects in California, Oregon, Washington, Alaska, and Hawaii must use the biomass equations provided on the Reserve's Forest Protocol Resource\Biomass Equations webpage to calculate the above-ground portion of the trees. The Cairn's equation (Cairns, Brown, Helmer, & Baumgardner, 1997) must be used to calculate CO_2e in the below-ground portion of the trees. The Cairn's equation is:

$$BBD = \exp(-0.7747 + 0.8836 * \ln(ABD))$$

Where:

BBD = below-ground biomass density of standing live trees in tonnes per hectare
ABD = above-ground biomass density of standing live trees in tonnes per hectare

This estimate must be converted from biomass in tonnes per hectare to CO_2e in tonnes per acre using the conversions identified earlier in this guidance.

Adjustments to Standing Live and Standing Dead Trees for Missing Volume and Decay

Both Standing Dead Trees and Standing Live Trees may be missing portions of the tree as the result of physical and biological disturbances. Tree volumes need to be adjusted for missing parts to produce an improved estimate of the tree's biomass. Calculating CO_2e in Standing Dead Trees raises additional challenges since they may be in stages of decay such that density equations in standard biomass equations for live trees do not provide an accurate estimate. The guidance in this section provides a standardized method to account for volume and density adjustments.

The first step is to estimate the gross volume in the tree as if it were whole, using the volume equations (the first step in the biomass and carbon calculations) provided on the Reserve's Forest Protocol Resource page. The tree's biomass is then adjusted based on the tree's 'net' volume and adjusted density estimates for Standing Dead Trees. To standardize, the above-ground portion of the tree is divided into four parts; top, middle, bottom (visually estimating the original disposition of the tree when it was alive and vigorous), and below ground portion. It is assumed that the below ground portion is intact and complete. The standardized percentages assumed to be in each portion of the tree are shown in Table A.3.

Table A.3. Assumed percentages of volume in each portion of the tree.

Tree Portion	Percent of Tree's Volume
Top 1/3	5%
Middle 1/3	20%
Bottom 1/3	50%
Below Ground	25%

An ocular estimate is made of the portion remaining in each section of the tree during field sampling. Deductions from gross volume are made for anything that reduces the tree's gross volume, including breakage and cavities. The percentage remaining in each third is then summed to calculate the net volume remaining in the tree.

The tree's density must be adjusted to account for the varying states of decay in the remaining portion of the tree. Because standing dead wood does not have the same density as a live tree, a density reduction must be applied. The standardized guidance accounts for five density classes for standing dead wood, which must be recorded during the field sampling. The five decay classes, described in Table A.4 are qualitative based on the physical characteristics of the dead tree (USDA 2007, Woundenberg et al. 2010).

Table A.4. Decay Classes

Decay Class	Description of Condition of Standing Dead Wood
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.

The density identified for each species in the biomass equations posted on the Reserve's website must be modified for decay classes 2 – 5 using the reductions factors displayed in Table A.5[1], which are multiplied by the densities provided in the biomass equations.

[1] Harmon et al, 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.

Table A.5. Average density reduction factors for Standing Dead Wood for hardwoods and softwoods by decay class.

Softwoods		Hardwoods	
Decay Class	Reduction Factor	Decay Class	Reduction Factor
2	1.0	2	.8
3	0.92	3	.54
4	0.55	4	.43
5	0.29	5	.22

An example of field data that has all of the required elements for calculating the Standing Dead Tree's CO2e is shown in Table A.6.

Table A.6. An example of the data attributes needed to calculate CO_2e in Standing Dead Trees.

Tree Number	Species (type)	Status	DBH (Inches)	Height* (Feet)	Percent Remaining			Decay Class
					Top 1/3 of tree	Middle 1/3 of tree	Bottom 1/3 of tree	
1	Hardwood	Dead	16	95	0%	50%	100%	3
*Estimated height prior to death								

As an example of the application of the volume deductions, using the data from Table A.6 above, a tree with a total gross volume of 200 (cubic feet) would have an estimated net volume as shown in Table A.7.

Table A.7. Example of Calculating Net Volume in a Tree.

A tree with an assumed volume of 200 cubic feet is adjusted for net volume based on field observations displayed in Table A.6 and the standardized estimates of volume distribution by tree portion as shown below.			
Tree Portion	**Percent of Tree's Volume**	**Gross Volume (Cubic feet)**	**Net Volume (Cubic feet, based on Table X that displays percent remaining)**
Top 1/3	5%	10	0
Middle 1/3	20%	40	20
Bottom 1/3	50%	100	100
Below Ground	The root portion of the tree is estimated to have 25%	50	50
Total Volume		200	170

The density of the tree must be adjusted based on its decay class. After the tree's volume is adjusted for missing parts of the tree, the conversion to biomass must be determined using the reduction factor from Table A.5. *Average density reduction factors for Standing Dead Wood for hardwoods and softwoods by decay class*. An example is provided in Table A.8.

Table A.8. Example of adjusting the biomass calculation using density adjustment factors from Table A.5.

Tree Net Volume (from Table A.7 above)	Density of Live Tree (bole portion) from Biomass Equations (value is assumed)	Density Reduction Based on Decay (from Table A.5. Average density reduction factors for Standing Dead Wood for hardwoods and softwoods by decay class.) for a hardwood with a decay class '3'.	Adjusted Density (calculated by multiplying the density of live trees by the reduction factor)	Calculated Biomass (calculated by multiplying the adjusted density by the tree's net volume)
170	.46	.54	.25	42.5

Requirements for Estimating Lying Dead Wood Carbon

All projects must either maintain an inventory of Lying Dead Wood for the Project Area or monitor harvested areas according to the guidance in this section to ensure the project meets the conditions identified in Section 3.11.2 (Natural Forest Management) of the FPP. Lying Dead Wood is not eligible for crediting due to the high variability associated with estimating Lying Dead Wood, which produces estimates with unacceptable levels of uncertainty for crediting. Project Operators are required to include the status of Lying Dead Wood with each monitoring report.

Project Operators that choose to meet the monitoring requirement by maintaining an inventory of Lying Dead Wood must meet the following requirements:

1. Inventory plots or transects used to provide the Lying Dead Wood estimate must be no older than 12 years.
2. Data collected for Lying Dead Wood must include the estimated species, adequate data to estimate volume, and decay class, as defined by Table A.9 below, to estimate the density of the piece of Lying Dead Wood to determine biomass.
3. The sampling methodology must be included in the Project Design Document. The Reserve is not prescriptive with regards to the sampling design, other than adhering to general statistical principles of randomness. Fixed area plots and line transects, among other sampling methodologies, are acceptable.
4. The inventory sampling confidence in the estimate of Lying Dead Wood must be at +/-30% @ 1 Standard Error.

Project Operators that choose to meet the monitoring requirement through monitoring of harvested areas must meet the following requirements:

1. A harvested area is any area where commercial removal of forest vegetation has occurred.

2. A map of all areas harvested during the last reporting period must be submitted with the annual monitoring report and must include the harvest date.
3. All harvested areas must be monitored within one year of the harvest date.
4. Fixed area strips shall be randomly located on compass bearings chosen by the Project Operator (but maintained consistent within each harvest area). A recommended width of the fixed area strip is 66 feet (1 chain), which will require monitoring in each of the 33 foot areas on either side of the center line. 10 square chains equals one acre. Project Operators can determine the width of the strip that best suits the vegetation conditions present in the harvested area.
5. A map shall be produced that displays the location of the fixed area strips on the harvested areas. The width of the strip shall be documented for each strip.
6. The minimum area monitored shall be 5% of each harvested area.
7. Data collected within the fixed area strip must include the estimated length of the piece of lying dead wood, the average diameter of the lying dead wood, the estimated species, and the decay class as defined by Table X below.

Lying Dead Wood density must be adjusted to account for the state of decay. Because Lying Dead Wood does not have the same density as a live tree, a density reduction must be applied. The standardized guidance accounts for five density classes for Lying Dead Wood, which must be recorded during the field sampling. The five decay classes are qualitative based on the physical characteristics of the dead tree (USDA 2007, Woundenberg et al. 2010).

Table A.9. Decay Class Descriptions of Lying Dead Wood.

Decay Class	Description of Condition of Lying Dead Wood
1	Sound, freshly fallen, intact logs with no rot, no conks present indicating a lack of decay, original color of wood, no invading roots, fine twigs attached with tight bark.
2	Sound log sapwood partly soft but can't be pulled apart by hand, original color of wood, no invading roots, many fine twigs are gone and remaining fine twigs have peeling bark.
3	Heartwood is still sound with piece supporting its own weight, sapwood can be pulled apart by hand or is missing, wood color is reddish-brown or original color, roots may be invading sapwood, only branch stubs are remaining which cannot be pulled out of log.
4	Heartwood is rotten with piece unable to support own weight, rotten portions of piece are soft and/or blocky in appearance, a metal pin can be pushed into heartwood, wood color is reddish or light brown, invading roots may be found throughout the log, branch stubs can be pulled out.
5	There is no remaining structural integrity to the piece with a lack of circular shape as rot spreads out across ground, rotten texture is soft and can become powder when dry, wood color is red-brown to dark brown, invading roots are present throughout, branch stubs and pitch pockets have usually rotten down.

The density identified for each species in the biomass equations posted on the Reserve's website must be modified for decay classes 2 – 5 using the reductions factors displayed in Table A.10[2], which are multiplied by the densities provided in the biomass equations.

Table A.10. Average density reduction factors for Lying Dead Wood for hardwoods and softwoods by decay class.

Softwoods		Hardwoods	
Decay Class	Reduction Factor	Decay Class	Reduction Factor
2	0.87	2	0.74
3	0.70	3	0.51
4	0.40	4	0.29
5	0.29	5	0.22

An adjusted density coefficient for the downed logs is calculated by multiplying the density coefficient provided with the biomass equations on the Reserve's Webpage by the reduction value in the table above. The adjusted density value is multiplied by the volume estimate in the Lying Down Wood to determine the biomass.

[2] Harmon et al, 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.

Requirements for Estimating Soil Carbon Emissions and Soil Carbon Quantification for Avoided Conversion Projects

All projects must estimate the soil carbon emissions associated with project management practices. Avoided Conversion projects are eligible (optional) to report the baseline soil carbon emissions the project activity is avoiding. This section provides guidance for estimating soil CO_2e within the project boundaries, and quantifying emissions associated with project activities.

No direct sampling of soil carbon is required for projects that are reporting soil carbon emissions only as part of project management practices. Rather, the estimate of emissions is based on soil carbon estimates from United States Geological Survey (USGS) data for project sites and comparing the data to standardized guidance to assess emissions based on management activities

For Avoided Conversion projects, the project benefit is determined by comparing the project soil carbon estimate (from sampling) to the standardized estimate of emissions associated with the activity. Currently, only Avoided Conversion projects that demonstrate a risk of conversion to agriculture (grazing not included) are eligible to report soil carbon benefits associated with the avoided conversion activity. Conversion risks to housing, development, golf courses, etc. are not currently eligible.

To summarize, Table A.11 provides the two different approaches to quantifying soil carbon benefits and/or emissions.

Table A.11. Soil Carbon quantification methods by Project Type

Project Description	Project Type Identification	Method to Estimate Project Soil Carbon (CO_2e) Stocks	Method to Estimate Project Effects on Soil Carbon (CO_2e)
Project will provide benefits by avoiding soil carbon emissions associated with conversion to agriculture (Avoided Conversion).	1	Soil carbon sampling required at project initiation	Initial avoided conversion effects estimated through standardized guidance.
			Follow guidance in 2-2
		Follow guidance in: 2-1a, 2-1d, 2-1e, 2-1f	Ongoing project effects estimated through default estimates of soil carbon emissions.
			Follow guidance in: 2-1a, 2-1d, 2-1e, 2-1f
Project is reporting management-related emissions	2	Use of United States Geologic Survey data	Project effects estimated through default estimates of soil carbon emissions.
		Follow guidance in 2-1a, 2-1b, 2-1c, 2-1f	Follow guidance in 2-2

Step 2-1: Developing an Estimate of Soil CO_2 –e within the Project Boundaries

Step 2-1a. Identify soil orders present within project (**Project Types 1 and 2**)
Project Operators must determine the soil orders present in their project area and the area each soil order represents. Where Natural Resource Conservation Service (NRCS) soil data is available on the NRCS website (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx), projects must use this data. Where NRCS data is either unavailable or believed to be in error at the project site, Project Operators may present the soil orders and area represented by each order with an official letter from a local NRCS representative stating that the portrayal of the soil orders by the Project Operator is accurate. The letter must state why existing data is either absent on the NRCS website or why the data is not accurate.

On the NRCS website mentioned above, users must create an Area of Interest (AOI), using the website tools, that approximates the project boundaries. To determine the soil order, users select the soil reports tab, select land classifications, and select “Taxonomic Classification of Soils”. This report provides a taxonomic classification of each of the soils in the AOI. The last four letters of the soil descriptions correspond to the soil order. For example, a soil classified as Xerochrepts is in the Inceptisol order. Table 5 below displays the soil orders associated with the last four letters in the soil descriptions:

Table 5. Soil Orders

Soil Order	Last Four Letters in Soil Description
Alfisol	-alfs
Andisol	-ands
Inceptisol	-epts
Mollisol	-olls
Spodosol	-ods
Ultisol	-ults
Histosol	-ists

Step 2-1b. Obtain Soil Organic Matter Values (**Project Type 2**)

Select the tab entitled ‘Soil Properties and Qualities’, then select ‘Soil Organic Matter’ and within the advanced options, select ‘Weighted Average. For the aggregation method, select ‘Higher’ as the tie break rule, and designate ‘0-30 cm’ for the soil depth. Next, click ‘View Ratings’ to review the organic matter percentage for each soil type in the AOI. Convert the number from the rating to decimal percent by dividing by 100.

Step 2-1c. Obtain the Soil Bulk Density Values (**Project Type 2**)

Soil bulk density estimates are determined by first selecting the ‘Soil Properties and Qualities’ tab, the ‘Bulk Density’ tab next, followed by the ‘On-third Bar’. Specify the ‘Weighted Average’ method and soil depth (0-30cm, unless otherwise noted). Select ‘View Ratings. The ratings will provide bulk density values for each soil type in the AOI. If the bulk density values are not available in the database, determine whether the soil orders are qualified as sandy, loamy, or clay using the ‘Surface Texture’ value in the Soil Properties and Qualities tab and then apply default values of 1.2 g/cm^3 for clay soils, 1.6 g/cm^3 for sand soils, and 1.4 g/cm^3 for loam soils.

Step 2-1d. Sample for Soil Organic Matter (**Project Type 1**)

Soil carbon estimates are based on sampling soil organic matter for the project. Materials needed include:

- Rubber Mallet
- Square spade (for removing organic material from core site)
- Soil Probe
- Compass
- Trowel and/or sturdy knife (for cleaning soil off of outside service of probe)
- Plastic bags (1 bag for each soil core)
- Marking Pen
- Measuring Tools (meters and centimeters)

Step 2-1di. Identifying the Plot Locations

Plots must be located randomly or systematically with a random start in each of the soil orders that occur on the project site. An adequate number of plots is needed to ensure the overall estimate of soil carbon meets or exceeds the minimum confidence levels stated in the FPP (+/-20% @ 90% confidence interval). It is acceptable to use the same, or a subset of, plot locations as used for biomass sampling, so long each soil order is sampled and the overall soil carbon estimate achieves the confidence standards stated above

Step 2-1dii. Identify Four Random Locations at each Plot and Extract Soil Organic Matter Samples

2-1dii-1. Select a random number by glancing at a watch's second hand (or digital version). Multiply this number by six to derive a compass bearing to use for the soil sample locations. Following the determined compass bearing, measure 10 meters from the plot center and establish each of the four soil sample locations. Minimal spatial adjustments (<2 meters) can be made to avoid rocks and roots from impacting the ability to sample. If obstacles cannot be avoided within 2 meters, an additional sample location must be selected using the method described above.

2-1dii-2: For each sample location, insert a soil core probe (minimum diameter ½") into the soil at the sample location to a depth of 30cm. A rubber mallet may be used to facilitate penetration. If the probe will not penetrate to the required depth, the probe must be removed, wiped free of soil, and inserted in an alternate location with a 2m radius from the sample location. If repeated efforts result in difficulties achieving full penetration, an additional sample location must be chosen as described in 2-1dii-1. If full penetration is not achieved within two efforts to locate a satisfactory sampling location, the sample must be taken from the initial sample location and the depth recorded.

2-1dii-3: Soil must be extracted carefully from the probe to avoid losing any of the soil collected. Should any soil be lost, the sample must be rejected and a new sample location selected as described above. The extracted soil is placed in a sealable plastic bag. Label the bag with the plot number followed by the letter "SOM", indicating the sample is a 'Soil Organic Matter sample (not a bulk density sample).

2-1dii-4: The soil organic matter samples must be sent to a laboratory with expertise in analyzing soil carbon and physical properties within 106 hours of the acquisition of the samples from the plot sites. The laboratory must receive instructions that the samples are to be heated to over 1000 degrees Celsius. This heat will burn off the carbon and a detector is to be used to measure the amount of carbon dioxide produced and reported as a percent of the volume sampled.

Step 2-1e. Sample for Bulk Density (**Project Type 1)**
Sampling for soil bulk density must be conducted on the project site. Materials needed include:

- Rubber Mallet
- Piece of wooden 2x4 approximately 1' to 2' in length
- Square spade
- Soil Core/Ring with known volume
- Trowel and/or sturdy knife
- Plastic bags (1 bag for each soil pit)
- Marking Pen
- Measuring tools (meters and centimeters)

Step 2-1ei. One random location 4 meters from each plot center must be selected for soil data collection to dig a soil pit to a depth of at least $30cm^3$. The measure of depth must be below the organic layer (branches, leaves, moss, etc.). The sides of the pit can be made straight using the trowel or the study knife. Random selection is achieved through the use of the second hand method described in Step 2-1dii-1. Adjustments to the location of the pit can be made using the adjustments allowed for difficulties associated with inserting soil probes described in 2-1dii-2.

Step 2-1eii. Two samples will be taken from the soil pit. The sample is taken by centering the soil ring at a depth of 7.5cm and the second is taken by centering the ring at a depth of 22.5cm. The ring is inserted perpendicular to the pit face. The location of each insertion must be into undisturbed soil, as occurs during the process of extracting the soil rings. The soil pit can be expanded to ensure that undisturbed soil is sampled.

2-1eii -1: For each of the samples the sharp end of the ring is pushed in, without twisting, as far as possible with the hands.

2-1eii -2: The piece of wood is placed over the ring and gently hammered evenly into the soil. If strong resistance is encountered, an alternate location may be found within the pit, or a new pit located using the guidance described above.

2-1eii -3: Using the trowel or sturdy knife, soil is removed around the outside of the ring to allow for extraction of the ring without losing soil. The surfaces of the ring should be cleaned and cut flus to the surface of the ring. Small losses during extraction and cleaning (up to 2 cm^3) can be restored by filling the void with soil from the pit site and smoothing. Samples must be rejected if soil losses from the ring occurring during extraction and cleaning are greater than $2cm^3$.

2-1eii -4: The soil from both ring samples is placed in one sealable plastic bag and labeled with BD and the plot number.

2-1eii -5: The bulk density samples must be sent to laboratory with expertise in analyzing soil carbon and physical properties within 106 hours of the acquisition of the samples from the plot sites. Bulk density instructions sent with the samples shall describe that the samples are to be dried at 105 degrees centigrade for at least 48 hours and that all portions of the sample are to be retained (including rocks). The laboratory shall present the results of the analysis of bulk density estimates as g/cm^3, displaying dry weight over total sample volume.

Step 2-1f. Calculate the Total Soil CO_2 per Acre (**Project Types 1 and 2)**

Use Equation 2 (below) to calculate the soil CO_2 per acre:

Equation 2. Soil CO_2e per acre

$$\begin{aligned}&\text{Soil } CO_2e = \\ &\text{Organic Matter Value (Steps 1b or 1d)} \times 0.58 \text{ (Conversion of Organic Matter to Carbon)} \\ &\qquad \times \text{Bulk Density Value (Steps 1c or 1e)} \times \text{SoilDepth Sampled (30 cm)} \\ &\qquad \times 40{,}468{,}564.224 \text{ (Conversion of } 1\text{cm}^2 \text{to 1 acre)} \times 10^{-6} \text{ (Conversion of 1 gram to 1 metric ton)} \\ &\qquad \times 3.67 \text{(Conversion of Carbon to } CO_2)\end{aligned}$$

An example is provided in Table 6 below.

Table 6. Example Calculation

Organic Matter from Steps 7-1b or 7-1d	Conversion of Organic Matter to Carbon	Bulk Density (g/cm3) from Steps 7-1c or 7-1e	Soil Depth Sampled 30 cm	Conversion of 1 cm^2 to 1 acre 1 acre = 40,468,564.224 cm2	Conversion of 1 gram to 1 metric ton Carbon	Conversion of 1 Metric Ton Carbon to 1 Metric Ton CO_2	Estimated Metric Tons CO_2 per Acre
	*	*	*	*	*	*	=
0.05	0.58	1.2	30	40,468,564.224	0.000001	3.67	155.05

Step 2-2. Quantify the project effects on soil CO_2e (Project Types 1 and 2)

Project effects are calculated using the standardized guidance below. Avoided Conversion projects must use the standardized guidance for purposes of estimating project benefits. Soil carbon emissions resulting from management activities are determined where the activity, or set of activities, leads to a net loss of soil carbon across the entire project. Net emissions can occur across the project area in a sustainably managed forest where emissions from management activities are not restored during the rest, or growth cycle, of the stand. The default values provided are derived from scientific literature and address the high-end estimates of net emissions associated with management activities, except in the case of conversion where it is more conservative to underestimate the emissions associated with the avoided activity. The background documentation for the default values is found on the Reserve's website under 'Forest Resources'.

Default emission values are provided as percentages for each soil order, based on harvesting intensity, site preparation intensity, and the frequency of disturbance. Project Operators must report their soil carbon emissions by grouping the total acres in each permutation, or class of soil order, harvesting intensity, site preparation intensity, and frequency of disturbance, rather than reporting on an individual stand basis. An example of reporting classes of management activities is provided below, following the descriptions of the management activities.

Net carbon emissions are estimated as the difference between soil carbon stocks (CO_2e) in the soil prior to the management activity and the soil carbon stocks (CO_2e) in the soil immediately prior to the subsequent harvest event for each harvested stand. Index values are provided for both harvesting intensity and site preparation intensity that, when combined, classify the harvesting intensity for the stand. The index value for harvesting intensity is derived from both the amount of biomass removed during harvest and the soil disturbance associated with the biomass removal. The index value for site preparation is based on the amount of soil disturbance associated with site preparation activities.

For each stand harvested in a given reporting year, Project Operators must determine the harvesting intensity using the guidance below. For Avoided Conversion projects, the guidance is used below to assist in determining baseline conditions and applied to the project rather than individual stands. First, the index value is determined for the stand based on the amount of biomass removed during harvest, based on guidance in Table 7.

Step 2-2a. Harvesting Intensity

The Harvesting Intensity value is calculated using a factor for the amount of biomass removed and the amount of soil disturbance that occurs removing the biomass. Both values are added together to calculate the harvesting intensity. The value for disturbance related to biomass removal is determined using Table 7 below:

Table 7. Determination of Biomass Removal Index

Biomass Affected by Harvest		
Percentage Pre-Harvest Above-Ground Biomass Removed	Silviculture Activities Generally Associated with Level of Biomass Removed	Biomass Removal Index
<10%	Sanitation Salvage	0
10 – 50%	Selection, Thinning	0
51% - 80%	Rotation harvest with biomass remaining in tree tops, seed/shelterwood and/or leave trees, and dead wood	1
> 80%	Rotation harvest with whole tree harvesting and little retention	2
Not a Silvicultural Activity- There is no intent to follow up with efforts to regenerate forested conditions		
100%	Conversion – only relevant to assessment of Avoided Conversion baseline	10

Step 2-2b. Soil Disturbance from Harvesting Activities

The second value considered for determining the harvest intensity is based on the level of soil disturbance associated with biomass removal. Soil disturbance within the harvested stands boundary may be the result of skidding logs, tree falling, and harvesting equipment. The disturbance may be extensive or minimized, depending on site-specific conditions and care taken during harvesting operations. The soil disturbance index is based on the amount of mineral soil (below the organic layer, including litter and duff) exposed due to harvest activities. The determination of the amount of mineral soil disturbance is from ocular inspection of harvested stands. Table 8 below is used to determine the Soil Disturbance Index from harvesting

Table 8. Determination of Soil Disturbance Index.

Percent of Mineral Soil Exposed during Harvest	Soil Disturbance Index
<5%	0
5-20%	2
20-40%	3
40-60%	4
>60%	5

Step 2-2c. Determining the Harvesting Intensity Class

The values for the biomass removal index and the soil disturbance index are summed together to determine the Harvesting Intensity Class. Table 9 below displays the Harvesting Intensity Classes for the sum of the biomass removal and soil disturbance indexes.

Table 9. Harvesting Intensity Classes based on Summing the Biomass Removal and Soil Disturbance Indexes

Harvesting Intensity Classes	
Harvesting Intensity Class	Sum of Biomass Removal and Soil Disturbance Indexes
Light - Medium	<3
High	3-4

Very High	5-7
Conversion	>7

Step 2-2d. Determining Site Preparation Classes
For each stand harvested the Project Operator must determine the Site Preparation Index using the guidance in Table 10.

Table 10. Site Preparation Classes and Descriptions of Management Activities

Site Preparation	
Site Preparation Class	Description
Very Light	Less than 5% surface area disturbance of soil below litter and duff due to ripping, grading, raking, etc.
Light	5% to 24% surface area disturbance below litter and duff due to ripping, grading, raking, etc.
Medium	25% to 59% surface area disturbance below litter and duff due to ripping, grading, raking
Heavy	60% to 100% surface area disturbance below litter and duff due to ripping, grading, raking
Conversion	Soils cleared of trees, stumps and other forest vegetation and prepared for agriculture, grazing, and/or development. No return to forest vegetation.

Step 2-2e. Determining the Frequency of Disturbance
The frequency of disturbance is determined as the time between harvest activities associated with the specific silviculture event that is being evaluated for soil carbon emissions. This value must indicate the number of years until the next harvest event will occur.

Table 11. Frequency of Disturbance Classification

Frequency of Disturbance	Years
Short	< 15
Medium	16 - 30
Long	31 - 45
Very Long	>45

Step 2-2f. Determining Emissions Associated with Management Activities
For each class of harvested stands, or stands that have received site treatment, a value is determined for each combination of Harvest Intensity, Frequency of Disturbance, Site Preparation, and Soil Order. A percent value is derived from Table 12 below based on the combination of the various classes.

Table 12. Estimated Net Carbon Loss

Harvesting Intensity	Frequency of Disturbance	Site Treatment	Estimated Net Carbon Loss by Soil Order						
			Alfisol	***Andisol***	***Inceptisol***	***Mollisol***	***Spodosol***	***Ultisol***	***Histosol***
Light - Medium	Short	Very Light	0%	0%	0%	0%	0%	0%	80%
	Medium		0%	0%	0%	0%	0%	0%	80%
	Long		0%	0%	0%	0%	0%	0%	80%
	Ex-Long		0%	0%	0%	0%	0%	0%	80%
High	Short	Very Light	Conifers 0% Hardwoods 20%	0%	8%	0%	10%	9%	80%
		Light	Conifers 5% Hardwoods 20%	5%	8%	5%	10%	9%	80%
		Medium	Conifers 10% Hardwoods 20%	10%	10%	10%	20%	11%	80%
		Heavy	Conifers and Hardwoods 20%	20%	20%	20%	41%	22%	80%
	Medium	Very Light	Conifers 6% Hardwoods 20%	0%	0%	0%	33%	24%	80%
		Light	Conifers 6% Hardwoods 20%	5%	5%	5%	33%	24%	80%
		Medium	Conifers 10% Hardwoods 20%	10%	10%	10%	33%	24%	80%
		Heavy	Conifers and Hardwoods 20%	20%	20%	20%	41%	24%	80%
	Long	Very Light	Conifers 0% Hardwoods	0%	0%	0%	31%	0%	80%

			20%						
		Light	Conifers 5% Hardwoods 20%	5%	5%	5%	31%	5%	80%
		Medium	Conifers 10% Hardwoods 20%	10%	10%	10%	31%	11%	80%
		Heavy	Conifers and Hardwoods 20%	20%	20%	20%	41%	22%	80%
	Very Long	Very Light	0%	0%	0%	0%	5%	0%	80%
		Light	0%	0%	0%	0%	10%	5%	80%
		Medium	0%	0%	0%)	0%	20%	11%	80%
		Heavy	0%	0%	0%	0%	41%	22%	80%
Very High	Short (<10 years)	Very Light	Conifers 6% Hardwoods 20%	6%	28%	6%	1%	6%	80%
		Light	Conifers 6% Hardwoods 20%	6%	28%	6%	10%	6%	80%
		Medium	Conifers 10% Hardwoods 20%	10%	28%	10%)	20%	11%	80%
		Heavy	Conifers and Hardwoods 20%	20%	53%	20%	41%	22%	80%
	Medium (11-30 years)	Very Light	Conifers 6% Hardwoods 20%	6%	6%	6%	0%	5%	80%
		Light	Conifers 6% Hardwoods 20%	6%	6%	6%	10%	6%	80%
		Medium	Conifers 6% Hardwoods	10%	10%	10%	20%	11%	80%

			20%						
		Heavy	Conifers and Hardwoods 20%	20%	20%	20%	41%	22%	80%
	Long (31-45 years)	Very Light	Conifers 6% Hardwoods 20%	5%	6%	6%	0%	6%	80%
		Light	Conifers 6% Hardwoods 20%	6%	6%	6%	10%	6%	80%
		Medium	Conifers 6% Hardwoods 20%	10%	10%	10%	20%	11%	80%
		Heavy	Conifers and Hardwoods 20%	20%	20%	20%	41%	22%	80%
	Ex-Long (>45 years)	Very Light	Conifers 6% Hardwoods 6%	6%	6%	6%	0%	6%	80%
		Light	Conifers 6% Hardwoods 6%	6%	6%	6%	10%	6%	80%
		Medium	Conifers 6% Hardwoods 6%	6%	6%	6%	20%	6%	80%
		Heavy	Conifers 6% Hardwoods 6%	6%	6%	6%	41%	6%	80%
Conversion	Conversion	Agriculture	30% (Doc10)	30%	30% (Doc10)	30% (Doc10)	30% (Doc10)	30%	80%
		Residential-commercial	0%	0%	0%	0%	0%(Doc11)	0%(Doc11)	80%

This percentage is multiplied by the soil carbon (CO_2 –e) estimate on a per acre basis and multiplied by the stand's acres to determine the emissions to report for each stand. The stand emissions are summed to determine the soil carbon emissions (CO_2 –e) reported annually. An example of the calculation is provided in Table 13 below.

Table 13. Example of Calculations for Annual Soil Carbon Reporting

Reporting Year			2012						
A	B	C	D	E	F	G	H	I	J
Stand ID	Soil Order	Soil Carbon (CO_2-e) Tonnes per Acre	Acres	Stand Soil Carbon (CO2-e) Tonnes	Harvesting Intensity	Disturbance Frequency	Site Preparation	Estimated Soil Carbon Loss %	Stand Soil Carbon Loss (CO2-e) Tonnes
	From Step 2-1	From Step 2-1		D*C	From Step 2-2	From Step 2-2	From Step 2-2	Table 12	I*E
1	Alfisol	85	595	50,575	Very High	Very Long	Heavy	6%	3,035
2	Alfisol	85	683	58,055	Light-Medium	Short	Very Light	0%	-
3	Alfisol	85	2,232	189,720	High	Long	Light	5%	9,486
Sum of Soil Carbon Emissions (CO2-e) Tonnes									12,521

Onsite Carbon Stocks Affected by Site Preparation Activities with Reforestation Projects

The removal of standing dead trees, brush, and downed logs associated with Reforestation Projects may constitute a significant quantity of emissions compared to the project benefits in the short term. Therefore, Reforestation Projects must estimate the biological emissions associated with site preparation activities prior to planting trees.

For carbon pools that will be affected by site preparation, an inventory of the pools that will be affected must be conducted prior to any site preparation activities. For those carbon pools that are affected by site preparation, Forest Owners must provide an estimate of initial carbon stocks using one of the following alternatives:

- Measuring carbon stocks using 20 randomly placed sample plots located in the portion of the Project Area containing the greatest amount of biomass in the pool or pools that will be affected. The portion of the area sampled shall be calculated. The estimate derived on a per acre basis shall be applied to the balance of the project area.

- Stratifying (classifying) the Project Area into similar densities and measuring stocks within the affected carbon pools using 20 randomly located sample plots per density class.

- Measuring the affected carbon stocks based on a systematic grid system across the Project Area.

Summing up the Onsite Carbon Stocks and Calculating the Confidence Deduction

Annual reporting is conducted by summing the carbon stocks present at the end of the reporting period in all of the relevant carbon sources, sinks, and reservoirs for the project. Certain reported pools are sampled and the mean estimate is used for annual reporting. The number reported for the sampled pools is adjusted based on the confidence in the estimate of the carbon. The sampling error is calculated for each of the sampled pools at the 90% confidence interval and subsequently calculated as a percentage of the mean, using the following steps:

> **Step 1.** Calculate the mean and the standard error of the inventory estimate (for each pool or combined pools where applicable, such as with standing live and dead wood).
> **Step 2.** Multiply the standard error by 1.645.
> **Step 3.** Divide the total inventory estimate by the result in (2) 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.

Carbon Pool	**Source of Data**	**Project Type(s)**	**Required / Optional?**	**Mean CO_2 equivalent Tonnes per Acre**	**Sampling Error at 90% Confidence Interval (Percent of Mean)***	**Sampling Error as a Percentage of the Carbon Pool Estimate**
Data Derived from Sampling						
				Example Data		
Standing Live Trees	Sampled within the project boundaries.	All project types	Required	95	6	6.32%
Standing Dead Trees	Sampled within the project boundaries.	All project types	Required	6	2	33.33%
Soil Carbon	Sampled within the project boundaries	Avoided Conversion	Optional	65	8	12.31%
				Sum of Reported Pools	Calculation of Combined Sampling Error	Calculation of Combined Sampling Error as a Percentage
Summarizing Sampled Data				□all reported pools from sampling)	$U_S = \frac{((U_1*R_1) + (U_2*R_2) + ... + (U_n*R_n))^{.5}}{\lvert R_1 + R_2 + ... + R_n \rvert}$ Where: U_S = percentage uncertainty of the sum U_i = percentage uncertainty associated with pool *i* R_i = removal (emission) estimate for pool *i*	Combined Sampling Error/Sum of all Reported Pools from Sampling used to Determine the Confidence Deduction
Summary of Example Data from Sampled Pools				166	10.20	6.14%
Data not Derived from Sampling						

Soil Carbon Emissions	Standardized Guidance	All Projects	Required	-5 (Example)	NA – Not subject to sampling error	NA – Not subject to sampling error
Pools effected by Site Preparation	Sampled within project boundaries	Refores tation	Required	-5		
Sum of Onsite CO_2 equivalent Tonnes				156	NA	NA

The per-acre unit must be expanding to the project area based on the number of acres in the project. The sum of onsite CO_2 equivalent tonnes for the project is input into the calculation worksheet for annual reporting.

Applying a Confidence Deduction to Sampled Estimates
Any forest carbon inventory derived from sampling will be subject to statistical uncertainty. Where statistical confidence is low, there is an increased risk of overestimating a project's actual carbon stocks and therefore a higher risk of over-quantifying GHG reductions and removals. To help ensure that estimates of GHG reductions and removals are conservative, Forest Owners are required each year to apply a confidence deduction to the inventory of actual onsite carbon stocks. A confidence deduction is *not* applied to the forest carbon inventory when it is used to model baseline carbon stocks. Confidence deductions are applied, where appropriate, to estimated onsite forest carbon stocks each reporting period.

Applying a Confidence Deduction to Non-Aggregated Projects

The target sampling error for the combined inventory estimates for non-aggregated projects is +/-5% of the mean at the 90% confidence interval. Projects that cannot meet this target level are still eligible, but may have to take a "confidence deduction" that reduces their net reported carbon stocks.

The process for calculating the combined sampling error at the 90% confidence interval is shown above. The combined sampling error must be compared to the table below to determine the confidence deduction for the reporting period in which a site verification has occurred. The confidence deduction shall not be modified in the interim years between site verifications. The percent deduction from the table below is input into the calculation worksheet which calculates the net reported onsite stocks.

Table X. 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 $1/10^{th}$ percentage
20% or greater	100%

Applying a Confidence Deduction for Aggregated Projects

The target sampling error for the combined inventory estimates for aggregated projects is on a sliding scale up to +/-20% of the mean at the 90% confidence interval. The scale is based on the number of projects participating within the aggregate. Project Operators enrolled in an aggregate may submit project inventories with reduced sampling requirements based on the statistical principle that the targeted standard error (+/-5% of the mean at the 90% confidence level) is achieved across the entire aggregate.

The target sampling error for the participant Project Operator ranges between 7%-20% of the mean at the 90% confidence level based on the total number of projects in the aggregate as shown in Table 1 below.

Table 1 - Target sampling error at the 90% confidence level for projects participating in an aggregate.

Number of Participating Projects in the Aggregate	Target Sampling Error (TSE)
2	7%
3	8%
4	9%
5	10%
6	11%
7	12%
8	13%
9	14%
10	15%
11	16%
12	17%
13	18%
14	19%
15+	20%

For projects in an aggregate, confidence deductions are determined according to Table 2 (using the appropriate TSE from Table 1).

Table 2 - Inventory confidence deductions for participating projects in an aggregate.

Actual Sampling Error at 90% Confidence Level	Confidence Deduction
If between 0% and TSE%	0%
If greater than TSE% and not greater than 20%	(Actual sampling error – TSE %) to the nearest 1/10%
If greater than 20%	100%

The confidence deduction must be updated each time the project is subject to a site-visit verification but must remain unchanged between verification site visits. If increased sampling over time results in a lower confidence deduction at the time of a site-visit verification, the lower deduction may be applied to inventory estimates in all previous years. The Reserve will issue CRTs in the current year for any increase in quantified GHG reductions and removals in prior years associated with the new (lower) confidence deduction. Conversely, if a loss of qualified sampling plots results in a higher confidence deduction, this higher deduction must also be applied to inventory estimates in all previous years. Any resulting decrease in creditable GHG reductions and removals for prior years will be treated as an avoidable reversal, and must be compensated for by retiring CRTs in accordance with Section 7.3.2.

Requirements for Calculating Carbon in Harvested Wood Products

A portion of the carbon in harvested trees continues to be sequestered for long periods of time as wood products. Standardized guidance is provided to account for forest carbon that remains sequestered in harvested wood products. The protocol bases the accounting of harvested wood products on the average amount of carbon sequestered over a 100-year period. The 100-year period is consistent with the Forest Project Protocol's definition of permanence. The average amount of carbon remaining sequestered over the 100-year period is determined by calculating the amount of carbon delivered to the mills, the portion of the carbon that is converted to wood products using a coefficient that estimates the mill's efficiency, and determining the wood product classes manufactured by the mill, as different wood products have different decay rates.

An estimate of the average carbon remaining in use over the 100-year term is provided for each wood product class, which is the basis of baseline and annual reporting of harvested wood products. Furthermore, some wood products eventually end up in landfills where anaerobic conditions serve to reduce the rate of further decomposition. Since the amount of harvested wood products that end up in landfills and the actual decay rate of the wood products in landfills is highly uncertain, the accounting of harvested wood products in landfills is included only when it is conservative to do so. Conservative in this case means that if, in a given reporting year, the amount of harvested wood products in the baseline exceeds the amount of harvested wood products in the project activity, the carbon in landfills is reported. If there is more harvesting of wood products in the project case than in the baseline case, harvested wood products are not considered in either the baseline or the project case.

The Reserve has developed a spreadsheet tool to assist in the calculation of harvested wood products, which is available on the Reserve's website. The spreadsheet is titled Forest Calculation Worksheet and contains a tab for the accounting of harvested wood products. Project reporting of harvested wood products occurs on an annual basis. The volume of logs delivered to the mill in the baseline case remains static throughout the project life. However, the mill efficiencies and the wood product classes identified in a reporting period are applied to the baseline harvested wood products the same way they apply to the project harvested wood products. The intent of this policy is to provide the best comparison of project activity to baseline activity possible.

The spreadsheet is designed with default values for converting volumetric units from logs delivered to mills to cubic feet and the values of mill efficiencies to be used on a geographic basis. The annual reporting of carbon in trees harvested for wood products is based on the relative proportion of volume in trees harvested for wood products and volume delivered to the mill(s) in the baseline case. Therefore, the reporting of volume delivered to mills is essential to calculating the volume in trees harvested for wood products.

Mill efficiency estimates from the actual mills the project logs are delivered to can be used if data exists to support the claim in a form that can be verified. Users must identify the mill(s) the project logs are delivered to and input the volume that is manufactured into lumber, oriented strand board, non-structural panels, miscellaneous products and paper/pulp. Project Operators must provide an affidavit from the mill that the reported wood product classes are reasonable according to production records at the mill. Again, the wood product classes reported for a given reporting year apply both to the project and the baseline case which eliminates the calculation of project benefits or detriments based on comparisons of the decay rates of wood products alone.

Modeling Carbon Stocks

This protocol requires the use of certain empirical-based models to estimate the baseline carbon stocks and project stocks of selected carbon pools within the Project Area. These models may also be used to supplement assessments of actual changes in carbon stocks resulting from the Forest Project.

About Models and Their Eligibility for Use with Forest Projects

Empirical-based models are used for estimating existing values where direct sampling is not possible or cost-effective. They are also used to forecast the estimations derived from direct sampling into the future. Field measurements (standing live and dead trees) provide the base input data for these models. Project Operators should be careful to ensure that all required data inputs for the models are included in the inventory methodology.

The models that simulate growth projections have two basic functions in the development and management of a Forest Project. Models project the results of direct sampling through simulated forest management activity. These models, often referred to as growth and yield simulation models, may project information regarding tree growth, harvesting, and mortality over time – values that must ultimately be converted into carbon in an additional step. Other models may combine steps and estimate tree growth and mortality, as well as changes in other carbon pools and conversions to carbon, to create estimated projections of carbon stocks over time.

Models are also used to assist in updating inventory plots so that the plots can represent a reporting year subsequent to their actual sample date. The model simulates the diameter and height increment of sampled trees for the length of time between their sampled date and the reporting year. Plot data can be projected for the length of time the projection method is expected to accurately reflect actual forest growth. Inaccurate updating of plot data can lead to the inability of a project to be verified. Verifiers are directed to randomly select plots or stands for verification. Project Operator estimate deviations from verifier's measurements will result in verification failure. Hence, it is recommended to update plots at least every 12 years.

The following growth models have been approved:

- CACTOS: California Conifer Timber Output Simulator
- CRYPTOS: Cooperative Redwood Yield and Timber Output Simulator
- FVS: Forest Vegetation Simulator
- SPS: Stand Projection System
- FPS: Forest Projection System
- FREIGHTS: Forest Resource Inventory, Growth, and Harvest Tracking System
- CRYPTOS Emulator
- FORESEE

A Forest Owner may update inventory plot data for estimating diameter and height growth by incorporating data obtained from sample plots, as in a stand table projection. An example of an appropriate method of applying a stand table projection is as follows:

- The Project Area is stratified into even-age management and uneven-age management.
- Diameter increment shall be based on the average annual increment of a minimum of 20 samples of radial growth for diameter increment for each 8" DBH (Diameter at Breast Height) class, beginning at 0 – 8" DBH for each management (even-age or uneven-age)

type. The average annual increment shall be added for each year according to the plot's sample date.

- Height increment is based on regression curves for each management type (even-age or uneven-age) developed from height measurements from the same trees the diameter increment data was obtained. The estimated height shall be determined using the regression estimators for the 'grown' diameters as described above.

The Reserve may include additional models following approval of a state forestry authority (i.e. a state agency responsible for oversight of forests) who will acknowledge in writing that the model:

- Has been peer reviewed in a process that: 1) primarily involved reviewers with necessary technical expertise (e.g. modeling specialists and relevant fields of biology, forestry, ecology, etc.), and 2) was open and rigorous
- Is parameterized for the specific conditions of the Project Area
- Limits use to the scope for which the model was developed and evaluated
- Is clearly documented with respect to the scope of the model, assumptions, known limitations, embedded hypotheses, assessment of uncertainties, and sources for equations, data sets, factors or parameters, etc.
- Underwent a sensitivity analysis to assess model behavior for the range of parameters for which the model is applied
- Is periodically reviewed (Prisley & Mortimer, 2004)

Using models to forecast carbon stocks

The use of simulation models is required for estimating a Forest Project's baseline carbon stocks. Models may also be required to forecast actual carbon stocks expected under the Forest Project (e.g. in conjunction with determining expected harvesting volumes or in updating forest carbon inventories).

Standing live tree information must be incorporated into the simulation models to project carbon stocks over time. If a model has the ability to convert biomass to carbon, it must include all the carbon pools required by this protocol. Standing dead trees must be assumed to be static over the baseline modeling. Exceptions to this rule are allowed if approved in writing by the Reserve prior to verification.

Projected baseline carbon stocks must be portrayed in a graph depicting time in the x-axis and carbon tonnes in the y-axis. Baseline carbon stocks must be projected forward from the date of the Forest Project's Start Date. The graph should be supported with written characterizations that explain any annual changes in baseline carbon stocks over time. These characterizations must be consistent with the baseline analysis required in Section **Error! Reference source not found.**.

Modeling Requirements

A modeling plan must be prepared that addresses all required forecasting of baseline carbon stocks for the Forest Project. The modeling plan shall contain the following elements:

1. A description of all silviculture methods modeled. The description of each silviculture method will include:
    a. A description of the trees retained (by species groups if appropriate) at harvest.
    b. The harvest frequency (years between harvests) for each silviculture method modeled.
    c. Regeneration assumptions.

2. A list of all legal constraints that affect management activities on the Project Area. This list must identify and describe the legal constraint, how the legal constraint affects the project area, and discusses the silviculture methods that will be modeled to ensure the constraint is respected.
3. A description of the site indexes used for each species and an explanation of the source of the site index values used.
4. A description of the model used and an explanation of how the model was calibrated for local use, if applicable.

Modeling outputs must include:

1. Periodic harvest, inventory, and growth estimates for the entire Project Area presented as total carbon tonnes and carbon tonnes per acre.
2. Harvest yield streams on modeled stands, averaged by silviculture method and constraints, which must include the period over which the harvest occurred and the estimated volume of wood (cubic feet in logs delivered to mills) removed.