



Virginia Conservation Forestry Program
Rich Mountain

Project Design Document

For 2002 – 2011 Reporting and Initial Verification
Under the Climate Action Reserve's
Forest Project Protocol 3.2

Prepared by
Greg Meade, The Nature Conservancy
Tim Robards, PhD, CF, Spatial Informatics Group

Submitted for Verification February 2, 2012
Revised March 28, 2013

Contents

1. Introduction	6
2. Project Overview.....	7
a. Project Type: Improved Forest Management	7
b. Project Location and Geographic Boundaries.....	7
c. Project Area Definition	10
d. Legal Constraints on Harvesting	10
e. Project Activity and Start Date	10
f. Existing Land Cover and Land Use	13
g. Forest Vegetation Types	13
h. Site Classes	13
i. Land Pressures and Climate Zone Classification	13
j. Shape Files.....	14
3. Sustainable Harvesting and Natural Forest Management Practices	14
a. Sustainable Harvesting Practices	14
b. Natural Forest Management.....	14
i. Native Species	14
ii. Composition of Native Species.....	16
iii. Distribution of Age Classes	16
iv. Structural Elements	17
v. Onsite Standing Live Carbon Stocking.....	17
4. Onsite Carbon Inventory Methodology	17
a. Inventory Design	18
b. Stratification.....	19
c. Strata Descriptions	19
d. Field Procedures	20
e. Inventory Update Process.....	20
f. Confidence Deduction and Error Calculation	20
5. Baseline Modeling.....	21
a. Common Practice Calculation	21
b. Determine if Project Area's Initial Standing Live Carbon Stocks are Above or Below Common Practice	22

i. Backdating Process.....	23
ii. Common Practice Calculation Results.....	23
c. Estimate Baseline Carbon Stocks, Taking Into Account Financial and Legal Constraints on Harvesting in the Project Area.	25
i. Legal Constraints	25
ii. Financial Constraints	25
iii. Growth Modeling	27
iv. Baseline Harvest Schedule	27
d. Baseline Carbon Stocks for Required and Optional Carbon Pools in the Project Area for a 100 Year Modeling Period.....	29
e. Comparison of Project Minimum Baseline (MBL) with Carbon Stocks on Forest Owners Other Lands Within Logical Management Unit (LMU).	32
6. Project Activity Harvest Modeling (2011 Forward) and Initial Reporting Period	32
a. Project Activity Modeling, 2011 Forward	32
b. Initial Reporting Period 2002-2011.....	35
7. Calculation of Reversal Risk Rating and Contribution to the Buffer Pool	39
a. Financial Risk.....	39
b. Management Risk	40
i. Management Risk I: Illegal Removals of Forest Biomass	40
ii. Management Risk II: Conversion of Project to Alternative Land Uses.....	40
iii. Management Risk III: Over-Harvesting	40
c. Social Risk	41
d. Natural Disturbance Risk.....	41
i. Natural Disturbance Risk I: Wildfire	41
ii. Natural Disturbance Risk II: Disease or Insect Outbreak.....	42
iii. Natural Disturbance Risk III: Other Episodic Catastrophic Events	42
e. Summarizing the Risk Analysis	43
APPENDICES	44
Appendix A: Analysis of The Nature Conservancy Management Practices in accordance with Section 3.10.1 of the Climate Action Reserve v3.2 Forest Project Protocol.....	44
Appendix B: Inventory Methodology Used for 2011 Data Collection.....	48
Appendix C: Modeling Plan for the Rich Mountain Carbon Project	65
Appendix D: Biomass Equations and Calculation Methods	69

Appendix E: Volume Equations for the United States outside of California, Washington, Oregon, Alaska, and Hawaii.	71
Appendix F: Equation Reference and Equation Coefficients by Species used in the Rich Mountain Biomass Calculations and Species Substitutions	74
Appendix G: Complete CRM Methodology and Species Specific Biomass Coefficients	76
References	84

List of Tables:

TABLE 1: U.S.F.S. FIA CUBIC FEET OF GROWTH DESCRIPTION OF CLASS TYPES.....	13
TABLE 2: SPECIES COMPOSITION BY BASAL AREA PER ACRE	15
TABLE 3: STRATA INFORMATION FROM THE 2011 INVENTORY.....	21
TABLE 4: SAMPLING ERROR WITHOUT STRATIFICATION USING A SIMPLE RANDOM SAMPLE FORMULA.....	21
TABLE 5: SAMPLING ERROR WITH STRATIFICATION USING THE RESERVE ASSESSMENT AREA/FOREST TYPES.....	21
TABLE 6: COMMON PRACTICE CALCULATION FOR THE RICH MOUNTAIN FOREST CARBON PROJECT	22
TABLE 7: DIAMETER INCREMENTS USED TO BACK DATE THE INVENTORY DATA	24
TABLE 8: ACRES CONSTRAINED TO 50% RETENTION DUE TO RIPARIAN ZONE.....	25
TABLE 9: THE FOLLOWING WOOD PRODUCTS MIX WAS ESTIMATED FROM THE BASELINE SIMULATION	27
TABLE 10: ACRES ALLOCATED TO PRESCRIPTIONS, BY STRATA, FOR THE BASELINE.....	27
TABLE 11: REGENERATION FOR NON-FORESTED RANGELAND.....	28
TABLE 12: CARBON TONNES (CO ₂ E) REPORTED FROM THE BASELINE HARVEST SCHEDULE. STOCKS ARE REPORTED FOR THE YEAR INDICATED AND HARVESTED AMOUNTS ARE FOR THE MID-DECADE HARVESTS	28
TABLE 13: INCLUDED AND OPTIONAL GREENHOUSE GAS ASSESSMENT BOUNDARIES	31
TABLE 14: SILVICULTURAL PRESCRIPTIONS MODELED FOR PROJECT ACTIVITIES.....	33
TABLE 15: ACRES ALLOCATED TO PRESCRIPTIONS, BY STRATA, FOR THE PLANNED PROJECT ACTIVITY	33
TABLE 16: ESTIMATED CARBON FOR THE PROJECT ACTIVITY OVER THE NEXT 12 YEARS. ONSITE CARBON INCLUDES LIVE AND STANDING DEAD TREE POOLS.....	34
TABLE 17: ANNUAL GHG REDUCTIONS/REMOVALS NET OF DISCOUNTS AND SECONDARY EFFECTS (TONNES CO ₂ E)	35
TABLE 18: RICH MOUNTAIN FOREST CARBON PROJECT'S ANNUAL REPORT FOR 2002 TO 2011	37
TABLE 19: ADDITIONAL BUFFER CONTRIBUTION REQUIREMENTS OF FOREST CARBON PROJECTS PER EXHIBIT G IN THE PROJECT IMPLEMENTATION AGREEMENT	39
TABLE 20: SUMMARY OF RISK ANALYSIS FOR RICH MOUNTAIN FOREST CARBON PROJECT.....	43

List of Figures:

FIGURE 1: RICH MOUNTAIN CARBON PROJECT BOUNDARIES AND LOCATOR MAP.....	8
FIGURE 2: RICH MOUNTAIN CARBON PROJECT ASSESSMENT AREAS	9
FIGURE 3: RICH MOUNTAIN FOREST CARBON PROJECT AERIAL MAP DISPLAYING CANOPY COVER	12
FIGURE 4: RICH MOUNTAIN CARBON PROJECT INVENTORY POINT LOCATIONS - 2011.....	19
FIGURE 5: HEIGHT-DIAMETER FUNCTIONS FOR TOTAL HEIGHT (THT) AND MERCHANTABLE HEIGHT (BHT) WITH ACCOMPANYING EQUATIONS.....	24
FIGURE 6: HARVEST SITE NOTIFICATIONS WITHIN 20 MILES OF PROJECT.....	26
FIGURE 7: BASELINE HARVEST SCHEDULE AND CARBON POOLS	29
FIGURE 8: PROJECT ACTIVITY PROJECTED CARBON FOR 100 YEARS.....	35

1. Introduction

The Climate Action Reserve (Reserve) is a non-profit organization with a mission to “Promote the reduction of greenhouse gas emissions by pioneering credible market-based policies and solutions”. As part of that mission the Reserve has developed several rigorous carbon offset project protocols, including one for forest projects. Reserve protocols are considered to have high standards in all aspects, including additionality and permanence. Verified offsets are assigned a unique serial number and are traceable, thus preventing fraud by double sale or other means. The Forestry Protocol contains provisions for three types of projects: Improved Forest Management (IFM), Avoided Conversion, and Reforestation.

The Nature Conservancy (TNC) was founded in 1951, works around the globe, and is the largest conservation organization in the world, with millions of acres preserved for future generations. Closer to the project location, TNC has been active since the early 1990’s with the opening of the Clinch Valley Program Office in Abingdon, Virginia. The Clinch Valley program area covers over 2,200 square miles in Southwest Virginia and Northeast Tennessee. The program area has been designated as one of The Nature Conservancy’s Last Great Places, and hosts an unparalleled array of life. The streams are home to over 19 rare fish species and 43 varieties of freshwater mussels, including 28 globally rare species. The rich temperate forests teem with a diversity of life, while the intricate network of caves and karst systems snaking through the limestone bedrock hold a remarkable array of endemic species.

For all these reasons the Conservation Forestry Program was conceived to allow for unique partnerships that would keep forestland in sustainable production while protecting the conservation value and water quality of the region. For properties enrolled in the program, The Nature Conservancy takes ownership of the timber resource, makes management decisions, while the fee landowner receives an annual payment based on the value of the resource. This arrangement protects the enrolled properties from unsustainable timber harvests, provides income to the landowners, and also serves as a demonstration forest for local foresters, loggers, and landowners. To date the Conservation Forestry Program has enrolled approximately 22,000 acres, including the 5,750 acre Rich Mountain property.

The Nature Conservancy contracted with Forecon Inc. to perform the necessary forest inventory required for a full carbon project development document under the Reserve Forest Protocol v3.2. Additionally, Tim Robards with Spatial Informatics Group performed the growth and yield modeling, and biometric conversions.

2. Project Overview

a. Project Type: Improved Forest Management

The Rich Mountain Forest Carbon Project, an Improved Forest Management project as defined by the Forest Project Protocol (FPP) v3.2, will produce GHG reductions by managing the project forest for increased carbon sequestration and stocking when compared to baseline for the assessment area as defined within FPP v3.2 Appendix F. Baseline is defined as the common practice average carbon stocks on private lands within the project's FIA Assessment Area or initial project carbon stocks if lower. This project area is made up of 4 assessment areas, all within the Allegheny and North Cumberland Mountains Supersection. This project area falls within four assessment areas, Cove Forests, Mixed Hardwoods, Northern Hardwood, and Oak Hickory, all of which are within the Allegheny and North Cumberland Mountains Supersection.

b. Project Location and Geographic Boundaries

The Rich Mountain Project is located in Russell and Washington Counties in Southwest Virginia. The project area is within a larger fee ownership of the Stuart Land & Cattle Co. Inc. This project is part of the longest continuously operated cattle operation in America, commencing in the late 1700's. The Little River, a major tributary to the Clinch River, divides the project roughly in half. Approximate coordinates of the project midpoint are in degrees, minutes, seconds: 36°53'41.51"N, 81°53'50.64" W.

Figure 1 displays a map of the Rich Mountain boundaries, topography, roads, watercourses, and lat/long location.

Figure 2 displays a map of the Rich Mountain Project Assessment Areas.

Figure 1: Rich Mountain Carbon Project Boundaries and Locator Map

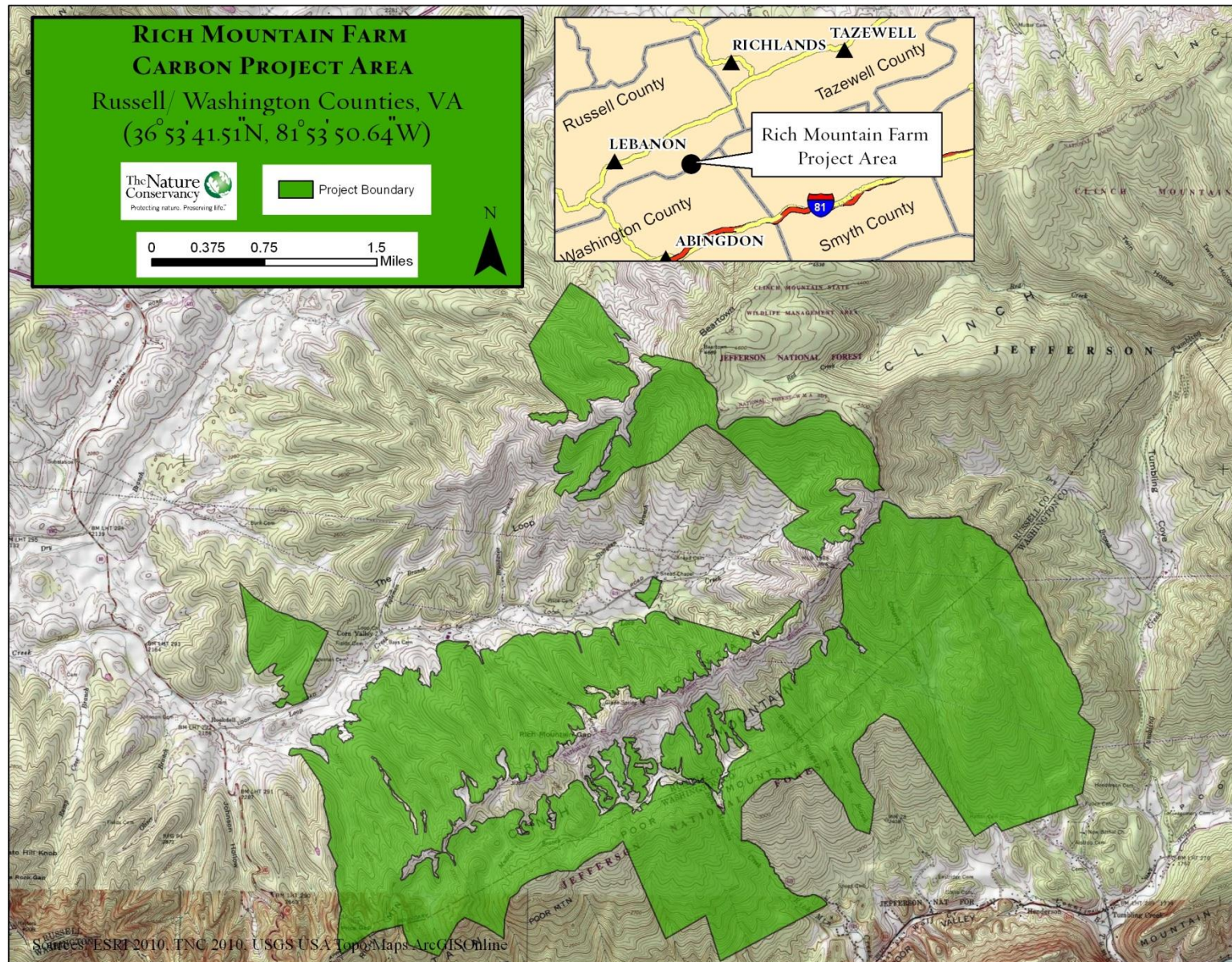
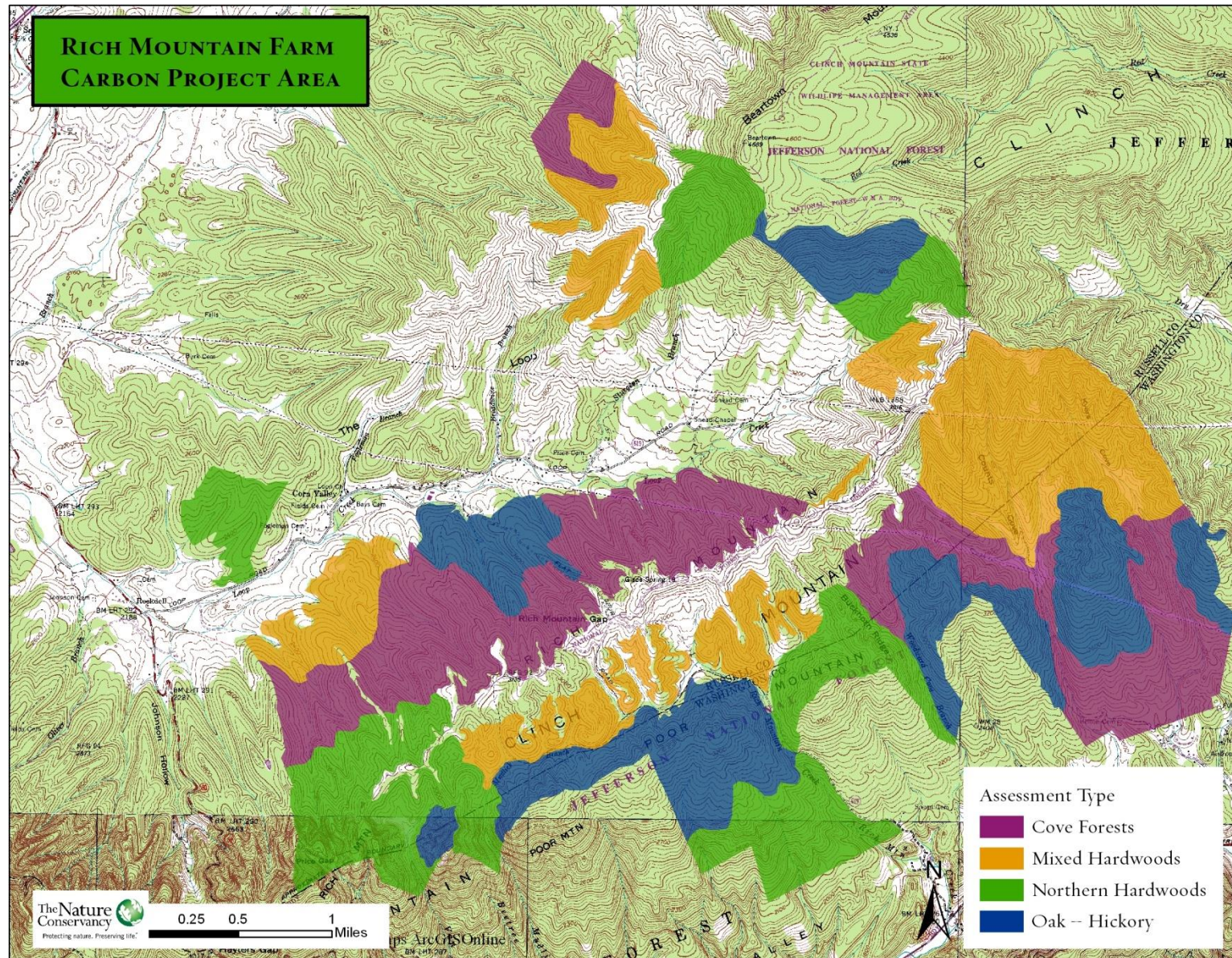


Figure 2: Rich Mountain Carbon Project Assessment Areas



c. Project Area Definition

The project area is defined as the 5,750 acres that TNC controls through the Forest Management Easement (FME) dated June 20, 2002.

The project is located on private, non-tribal land.

d. Legal Constraints on Harvesting

The state of Virginia has limited regulation of forest operations, and there are no local ordinances that restrict harvesting activities. The only state limitation on this project is that water quality cannot be impaired by sedimentation during or immediately following a timber harvest. This is commonly referred to as the Virginia Silvicultural Water Quality Law, and can be found in the Code of Virginia § 10.1-1181.1. The law allows for timber harvesting within riparian areas if done with care, and the normal practice is to harvest half of the volume in the riparian buffer, which is usually 50' on each side of a perennial or intermittent stream. TNC will meet or exceed this or any newly established legal requirement. This legal constraint is examined more closely in the Baseline Modeling section 5.c.i beginning on Page 18.

e. Project Activity and Start Date

The Rich Mountain Forest Carbon Project is viable due to TNC's management, both the philosophical approach and implementation on the ground. TNC has established the following goals for the property:

- Protect and enhance water quality, rare species and representative natural communities, soil quality, and other forest resources;
- Produce valuable forest products including high-quality sawtimber;
- Generate income for the fee landowner and contribute to the overall economic health of the local economy;
- Maintain positive relations through ongoing communication with adjacent property owners and the residents of the local communities;
- Relate our management of Rich Mountain to the management of the greater forest system in which it occurs

By focusing on the conservation of the forests and the long rotations needed to produce high-quality sawtimber TNC is practicing forestry quite differently than the common approach for the region, thus allowing for considerable carbon sequestration above and beyond common practice. For example, a common harvesting regime in the region is to make repeated entries into stands on a 15 year +/- interval and to remove the best quality trees in the stand at that time. This is commonly referred to as High Grading, and over several entries seriously degrades the forest to a point that sound forest management becomes cost prohibitive. Under TNC's management carbon stocks have increased by 25% since the project began in 2002. According to our baseline, fully described in Section 5, the project started well below common practice for the assessment areas and now eight years later is considerably over common practice, a clear demonstration that TNC's management will result in additional carbon sequestration.

Since TNC took ownership of the forest resource several intermediate harvests have been implemented as well as a few regeneration harvests. The removals have been in accordance with Forest Stewardship Council (FSC) management standards, and have been well below the net growth rate for the property, as measured cumulatively over our management history. Additionally TNC has hosted several educational events on Rich Mountain.

No fertilization of any type has been applied on the project since our ownership, and there will be none in the future.

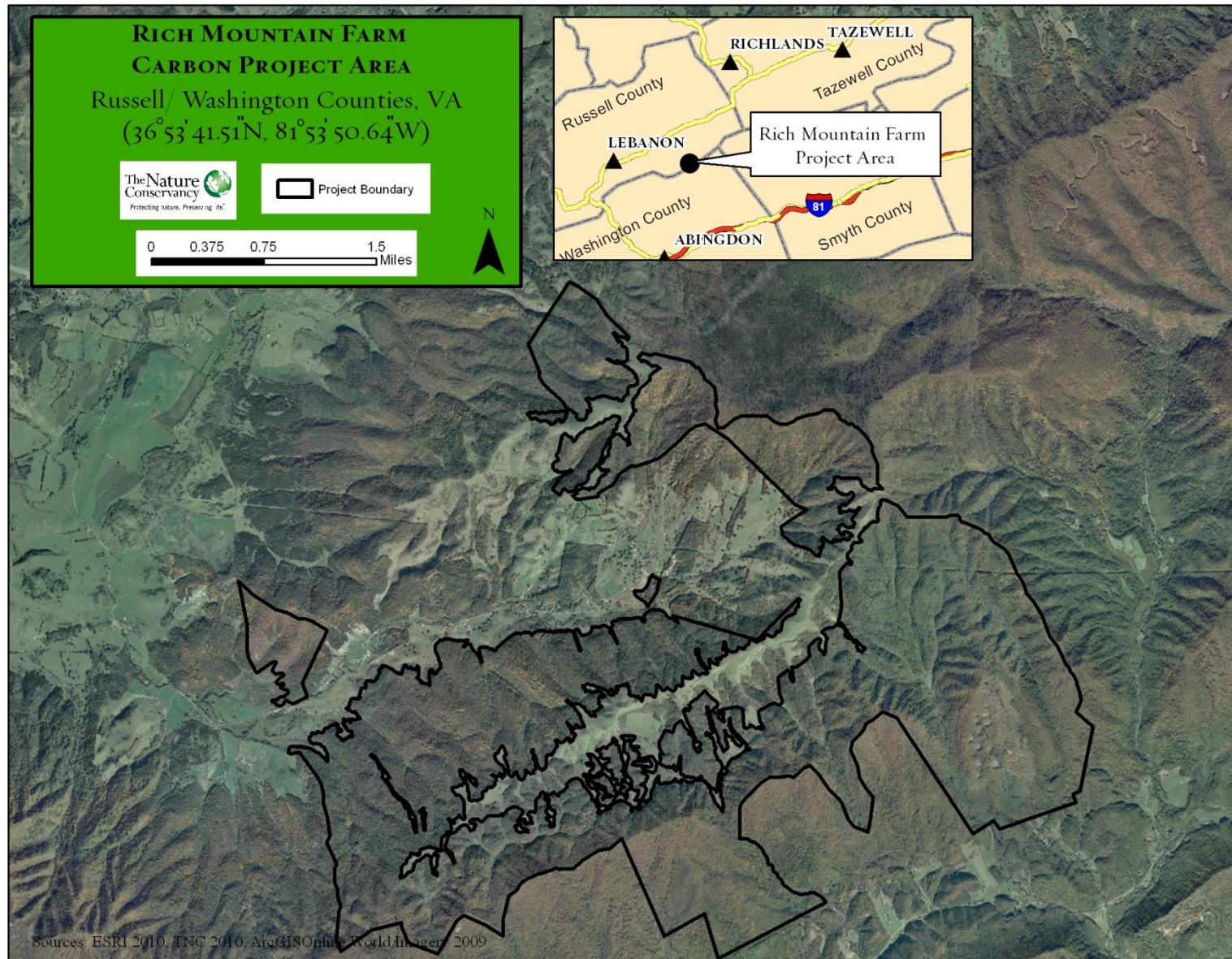
This project area has not been a part of any other Forest Carbon Registry previously.

The Project Start date has been established as June 20, 2002, the date that the Forest Management Easement (FME) was recorded in the Russell and Washington County Courthouses. The forest carbon offset project will be eligible under CAR rules to receive CRTs for 100 years, and it is anticipated that the project will seek verification of credits for the entire crediting period.

Monitoring and reporting for the project is required from the first issuance of CRTs and will continue for 100 years past the last issuance of credits. This effectively means that the project could last for 200 years if CRTs are issued for the full 100 year crediting period.

An improved forest management project must also meet a canopy cover threshold to be an eligible project. Canopy cover should exceed 10% on the entire project area and as seen in Figure 3 the canopy cover of the Rich Mountain project is well above this threshold. The aerial photography used for Figure 3 was taken in 2009.

Figure 3: Rich Mountain Forest Carbon Project Aerial Map Displaying Canopy Cover



f. Existing Land Cover and Land Use

The Project Area includes 5,750 acres with the majority of the project area being in forest cover for the past 100 years or longer. Commercial timber harvesting has long been practiced in the project area as evidenced by decaying stumps, logging roads, and residual timber damage from past operations.

g. Forest Vegetation Types

The project area is dominated by mixed Appalachian Hardwoods, and may be further defined by the 4 assessment areas that occur on the project:

Oak-Hickory, Northern Hardwood, Cove Hardwood, and Mixed Hardwood

h. Site Classes

Appendix F in the FPP describes how to assess the site class for Project Areas. The Reserve stratifies the 7 U.S. Forest Service Timber Type Classes into High (Types 1-3), and Low (Types 4-7). The U.S.F.S. determines the Type Class by the growth potential of the site as measured in cubic feet per year. From the U.S.F.S. Field Inventory Analysis handbook (Woudenberg 2004) the Types are described in Table 1:

Table 1: U.S.F.S. FIA Cubic Feet of Growth Description of Class Types

Class Type	Cubic Feet of Growth/Acre/Year
1	225+
2	165-224
3	120-164
4	85-119
5	50-84
6	20-49
7	0-19

Using U.S.D.A. soil maps (Adkins 2007; Hatch & Thomas 2006), for the project area, which provide cubic foot growth potential, the site class was determined to be low for the entire project, as defined by the Reserve.

i. Land Pressures and Climate Zone Classification

In the area surrounding the project the predominant land use is commercial forestry and agricultural production. Some dispersed rural residential development pressure exists along public road frontage and near population centers.

The Climate Zone for the project area is Zone 6.

j. Shape Files

Several Shape Files generated in ArcView have also been distributed to the Verifying Body and the Reserve. The shape files are in the .shp format and include files that geographically describe the following:

- Project Boundary
- Assessment Area Delineation
- Inventory Point Locations

3. Sustainable Harvesting and Natural Forest Management Practices

a. Sustainable Harvesting Practices

Since commercial harvesting has been employed on the project and will continue to be judiciously implemented, it is necessary for the project to satisfy the FPP section 3.10.1 – Sustainable Harvesting Practices. Three options are given to satisfy this requirement. Option 3 was chosen for the Rich Mountain project. Under this option the Forest Owner must demonstrate within the entire Assessment Area that the forest owner is practicing uneven-aged silviculture. To meet this standard, the canopy cover must exceed 40% on any forest land within the assessment area, as measured on any 20 acres, owned by the Forest Owner.

TNC used geographical information systems (GIS) tools to analyze the total forest ownership within the entire Allegheny and North Cumberland Mountain Supersection. Over 60 properties owned by TNC were analyzed and 10 occurrences of canopy cover of less than 40% **and** equal to or larger than 20 acres were discovered. Upon closer examination, 9 of the 10 are agricultural lands, abandoned agricultural lands, or scrub/barren cover types, clearly not the result of even aged timber harvesting. One 20 acre forest opening was discovered on a preserve that is a relic of the previous owner's management, not the result of TNC management. Thus it was concluded that the Rich Mountain Project meets the Sustainable Harvesting Practices as outlined in FPP 3.10.1. The full analysis and methodology, including a map of the 10 occurrences, can be found in Appendix A.

b. Natural Forest Management

Several components make up the Reserve requirement for Natural Forest Management.

i. Native Species

As stated in Table 3.2 of the FPP the project must consist of at least 95% native species based on the sum of carbon in the standing live pool. This assessment shall be conducted using the estimate of basal area per acre for Improved Forest Management projects. 100% of the project is comprised of native species based on our 2011 inventory. Below is a table summarizing the basal area for the project.

Table 2: Species Composition by Basal Area per Acre

Species	Basal Area per Acre	Percent of Total
Basswood	1.48	1.7%
Beech	0.13	0.2%
Birch	1.20	1.4%
Black Cherry	4.71	5.4%
Black Locust	11.96	13.7%
Black Oak	0.33	0.4%
Black Walnut	2.10	2.4%
Blackgum	0.37	0.4%
Buckeye	3.19	3.6%
Butternut	0.10	0.1%
Chestnut Oak	9.05	10.3%
Cucumber	0.51	0.6%
Elm	0.93	1.1%
Hemlock	0.20	0.2%
Hickory	5.88	6.7%
Magnolia	0.11	0.1%
Miscellaneous Hardwood	1.55	1.8%
Miscellaneous Softwood	0.07	0.1%
Red Maple	4.65	5.3%
Red Oak	6.85	7.8%
Red Spruce	0.19	0.2%
Sassafras	0.84	1.0%

Scarlet Oak	0.64	0.7%
Sourwood	0.40	0.5%
Sugar Maple	9.72	11.1%
Virginia Pine	0.29	0.3%
White Ash	11.27	12.9%
White Oak	2.69	3.1%
White Pine	0.37	0.4%
Yellow Poplar	5.76	6.6%
Grand Total	87.54	100%

ii. Composition of Native Species

The FPP requires that no single species comprise more than the given basal area for standing live carbon under the “Composition of Native Species” in the Assessment Area Data File. For the Rich Mountain Project the Composition of Native Species ranges from a low of 60% to a high of 70% depending on the assessment area. As can be seen in Table 2 above, no single species represents higher than 60% of the project basal area per acre. In fact, over 31 species are represented in the basal area numbers. Four Species are slightly above 10% of the stocking for the project, Sugar Maple, Chestnut Oak, Black Locust, and Ash.

iii. Distribution of Age Classes

The criteria for meeting the Age Class Distribution requirements are identical to Sustainable Harvesting Practices requirements, thus the Rich Mountain project meets these criteria as well.

Additionally the FPP states that Forest Projects must manage the distribution of habitat/age classes and structural elements to support functional habitat for locally native plant and wildlife species naturally occurring in the Project Area. One of the measures of this is the same criteria as Sustainable Harvesting Practices, which the project meets, however a description of the general approach is also provided below.

The project area is managed under Forest Stewardship Council (FSC) standards, which has several standards targeted at maintaining ecologically functioning forests, to include wildlife diversity and viable populations. TNC meets that criterion several ways:

- Maintains large reserve areas where no management occurs.
- Practices uneven aged management to the greatest extent possible, focusing on 1-2 acre openings in the forest, replicating what naturally occurs.

- Extending the typical rotation age, therefore broadening the distribution of age classes over a longer period in the managed stands.

iv. Structural Elements

The FPP requires that standing and lying dead wood be retained in sufficient quantities. The criterion for assessing this varies depending on if salvage logging has occurred on the project within the previous year. There has been no salvage logging within the previous year, or during TNC's nearly eight year management history of the property. Projects with no salvage logging must meet the higher of the two following standing dead wood criteria:

- One metric ton of carbon per acre, or 5,750 tonnes of standing dead wood for the Rich Mountain Project; or
- 1% of standing live carbon stocks, which is 6,899 standing tonnes of dead trees as measured in CO₂e.

Of the two criteria, the 5,750 tonnes of standing dead wood is the higher. The current calculated standing dead wood on the Rich Mountain Forest Carbon Project is 15,020 tonnes of CO₂e, which converts to $(15,020/3.67)$ 4,092 tonnes of carbon. While the current standing dead wood meets one of the criteria above (1% of standing live) it fails to meet the higher criterion: one metric ton of carbon per acre (5,750 tonnes of carbon). This is a reflection of past management and harvesting practices. While TNC's management practices have significantly boosted onsite live stocking, dead wood changes show a more gradual transition as natural mortality occurs over time. TNC recognizes the value of standing and lying dead wood and has made significant changes from standard practice in how timber sales are administered to allow for additional dead wood, both lying and standing, to remain onsite. For example, all standing deadwood is to remain standing during a timber harvest, unless safety is an issue. Additionally, some large diameter trees are marked to leave during harvest sale planning to provide for habitat and eventually dead wood. As a result of these specific actions and the longer rotations prescribed in overall management philosophy, dead wood, both standing and lying, will significantly increase over the life of the project.

v. Onsite Standing Live Carbon Stocking

The FPP requires that standing live carbon stocking be maintained and/or increased during the life of the project. The project activity modeling (Section 6) predicts that will in fact be the case with this project. This will be monitored over the life of the project by incorporating new inventories and disturbances into the model, with appropriate changes made to the harvest schedule to ensure compliance with this requirement.

4. Onsite Carbon Inventory Methodology

Forest Projects must include a robust inventory based on field data. Living tree, standing dead, and harvested wood products are required to be included in the methodology. Optional pools were not included in this project due to the Reserve's current policy of not allowing those until further notice. The FPP provides guidance for project developers as they assemble the inventory methodologies.

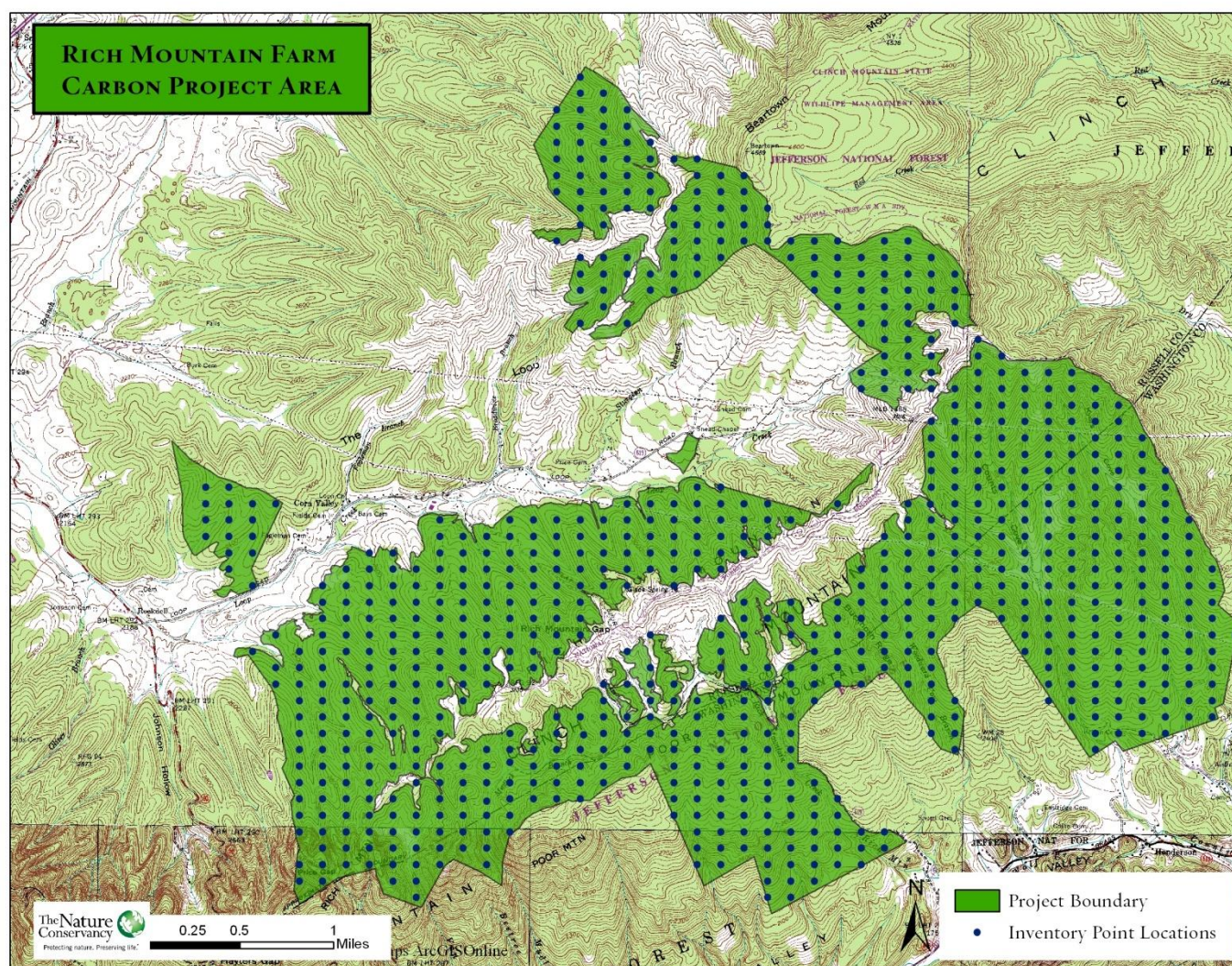
TNC hired Forecon Inc. to gather the field data required for this project through direct sampling across the entire property. This inventory was conducted in April 2011, and is the basis for reporting GHG emission reductions to the

Reserve for initial verification and for reporting years 2002-2011. After initial verification TNC plans to have the project verified annually, along with the required monitoring. Field verifications will be conducted at a minimum every six years, with desktop verifications being conducted in the interim years.

a. Inventory Design

Forecon Inc. was able to utilize existing information to aid in inventory planning and preparation. Existing stand maps from historic inventories along with harvest boundaries played a role in preparation. In April 2011, 817 variable radius plots (20 BAF) were taken across the project on a 7 chain by 10 chain grid (462' x 660'). The grid was generated within ArcView and the exact latitude/longitude positions were transferred to hand held GPS units for field navigation. The inventory plot locations were determined in the field based on the accuracy limits of the GPS units. When the GPS unit indicated that the cruiser was within the GPS accuracy limit of the center point the marked center point would be placed on the ground. By using this method the plot center was randomly selected by the GPS unit based on proximity to the latitude/longitude of the plot center created in ArcView. See Figure 4 for a map of the inventory point locations for the baseline inventory. A shape file containing inventory point locations has been provided to the Verifier and the Reserve.

Figure 4: Rich Mountain Carbon Project Inventory Point Locations - 2011



b. Stratification

Pre-data collection stratification was not attempted. The data was however stratified into assessment areas post collection. The assessment area stratification was developed based on the sample plot information along with observations made in the field by Forecon Inc. Changes in assessment type were delineated on the inventory maps in the field and transferred into ArcView for final calculations. In either case the project meets the statistical requirement for a zero confidence deduction. More explanation is available in the Error and Confidence Deduction section, 4.f.

c. Strata Descriptions

It was found that a simple stratification by assessment area within the project slightly decreased the sampling error.

The following assessments areas are included in the project:

- Cove Forests

- Mixed Hardwoods
- Northern Hardwoods
- Oak-Hickory

An Assessment area map was developed and included as Figure 2 on Page 9.

d. Field Procedures

In Appendix B the complete methodology utilized by Forecon Inc. can be found. This includes the field measurement procedures and plot monumentation.

e. Inventory Update Process

The FPP requires that the inventory update process be described as part of the initial verification. For the purposes of this project updates will be required for growth, harvests, and disturbances.

Forest growth along with planned project harvesting activity will continue to be modeled by the USFS FVS growth model, and will serve as the basis of emissions and monitoring reports between new inventory periods. FVS modeling data appears to be accurate, so no local changes are expected. Disturbances such as fire, insect and disease damage, or any other unplanned occurrence will be updated as follows. As soon as possible the disturbed area will be inspected, mapped, and described in detail. Included in the detail will be cause, impact on carbon stocks, and extent. Affected areas will be re-inventoried and the new data will replace the original data in the modeling runs to provide the most accurate estimates of carbon stocks.

Modeling runs will be updated when harvesting activities and disturbances cumulatively combine for a 5% or greater change in project level carbon stocking.

The FPP allows for the use of field inventory data up to 12 years old. For programmatic reasons a complete inventory will be conducted every 10 years, thus ensuring that all modeling is completed with data within the requirement. The next scheduled inventory will take place in 2021/2022.

f. Confidence Deduction and Error Calculation

The inventory was post-stratified for the purposes of calculating the confidence interval. As shown in the following tables the sampling error at the 90% confidence level was less than the 5 percent threshold for a deduction. The bound was calculated by multiplying the standard error by a t-value of 1.645. These calculations were carried out in accordance to the guidance found in the FPP Appendix A.4 – Applying a Confidence Deduction.

Table 3: Strata information from the 2011 inventory

Strata	No. of Plots	Carbon (CO ₂ /acre)			Acres	Carbon (CO ₂) Total
		Average	Std. Dev.	Std. Error		
1	216	97.3	63.09	4.29	1,572.7	153,003.5
2	219	83.4	52.10	3.52	1,543.5	128,703.3
5	195	84.6	63.66	4.56	1,328.4	112,411.3
6	181	113.2	68.41	5.08	1,270.8	143,863.8
NF	4	0.0	0.00	0.00	31.7	-
Total	815				5747.2	537,981.9

Table 4: Sampling error without stratification using a simple random sample formula

Mean	n	StdDev	StdError	Bound	SamplingError
93.577	815	61.910	2.169	3.567	3.81%

Table 5: Sampling error with stratification using the Reserve assessment area/forest types

Total	n	StdDev	StdError	Bound	SamplingError
537,981.9	815		12,391.10	20,383.37	3.79%

5. Baseline Modeling

The Reserve requires project developers to conduct a series of steps to determine the Project's Baseline. For an IFM project on private land the outline to accomplish this can be found in section 6.2.1 of the FPP and is summarized below:

- Determine the Common Practice Level of above-ground standing live carbon stocks applicable to the Project Area.
- Determine if the Project Area's initial *above-ground* standing live carbon stocks are above or below Common Practice.
- Estimate baseline above-ground standing live carbon stocks, taking into account, financial and legal constraints on harvesting in the Project Area, as well as the minimum baseline level applicable to the Project Area, as defined in the guidance for Step d, below. The minimum baseline level will depend on whether initial above-ground standing live carbon stocks are above or below Common Practice. In no case will the minimum baseline be lower than the limits of the modeled financial restraints and legal requirements.
- Determine the baseline carbon stocks over 100 years for all required and optional carbon pools in the Project Area.
- The FPP also requires that the Project Developer compare the minimum baseline level, calculated in Steps a-d above, to carbon stocking on other lands within the same logical management unit (LMU).

a. Common Practice Calculation

Assessment Areas are defined by the Reserve in the FPP in Section 11 – Glossary of Terms as:

A distinct forest community within geographically identified ecoregions defined by the Reserve that consists of common regulatory and political boundaries that affect forest management. The size of the Assessment Areas is determined by efforts to achieve optimal statistical confidence across multiple scales using U.S. Forest Service Forest Inventory and Analysis Program (FIA) plots for biomass.

The Rich Mountain Project has been found to be within the Allegheny and North Cumberland Mountains Supersection, based on project shape files and shape files of the Supersections provided by the Reserve.

According to Appendix F of the FPP, *Determining a Value for Common Practice*, Acreage within each Assessment Area of the Supersection must be identified for any contiguous area of 20 acres or more. This was accomplished as part of the forest inventory process and the map is displayed as Figure 2, on Page 8. Once the project acreage is allocated to the proper Assessment Area, a site determination must be made as High or Low if necessary for the Assessment Areas of the project. As described in Section 2h of this document the entire Project Area was determined to be a Low site class. Based on the acreage in each Assessment Area and the Low site class Table 6 was constructed to identify Common Practice for the Rich Mountain Project.

Table 6: Common Practice Calculation for the Rich Mountain Forest Carbon Project

Strata ID	Strata Name	CAR Common Prac. Aboveground CO ₂ e (t./ac.)	Acres
1	Allegheny & North Cumberland Mountains, Cove Forests	91	1573
2	Allegheny & North Cumberland Mountains, Mixed Hardwoods	52	1544
5	Allegheny & North Cumberland Mountains, Northern Hardwoods	87	1328
6	Allegheny & North Cumberland Mountains, Oak-Hickory	93	1271
NF	Open/Unproductive/Nonforest	87	32

Common practice was calculated using the weighted averages of the Reserve's assessment areas, which coincide with the strata. The weighted average common practice was **80.12** tonnes/acre of above-ground standing live carbon stocks in CO₂e. Note that the 32 acres identified in the table as NF were distributed to the appropriate Assessment areas to arrive at the weighted average for those acres. The acreage was kept separate to allow for more accurate modeling to occur based on actual stocking; however it was included in the common practice calculation.

Appendix F of the FPP states that a project must be over 90% contained in a single Assessment Area to be eligible. Per personal communications with Reserve Staff, the FPP is incorrect regarding the 90% requirement, thus the Rich Mountain Project is eligible per the weighted average approach to Common Practice outlined above.

b. Determine if Project Area's Initial Standing Live Carbon Stocks are Above or Below Common Practice

The inventory data was stored in a combination of 2-Dog software format in MS Access and in MS Excel. The data was processed in MS Excel (Rich Mountain Inventory Carbon Estimate.xls, and provided to the Reserve and Verifier) to estimate the confidence interval and provide an estimate of the carbon pools for the 2011 inventory. This estimate was used as a quality check against the estimates derived from the FVS growth simulator software.

i. Backdating Process

The project start date is June 20, 2002. In order to produce a baseline estimate and project the project activity for the first seven years of the project, it was necessary to backdate the 2011 inventory to the start date. Since the growing season of 2002 was the first year's growing season, the inventory was backdated to the beginning of 2002. The backdate process used the following steps in MS Excel:

- 1) Decrement each tree diameter annually (Husch et al. 1993) using the average inside bark diameter increment, by species group, and the predicted bark ratio for the given tree size and species (Keyser 2010).
- 2) Annually decrement each tree total and merchantable height by calculating the difference in height from the height-diameter function and subtracting that from the respective height. Missing heights were input using separate functions for total and merchantable height. A project specific height-diameter function was developed for this project using a subset of the inventory data that captured total height, merchantable height (4" top), and diameter for 20% of the trees sampled. Species were not found to be a significant variable. The relationship can be seen in Figure 5 below.
- 3) Add tree records to the plots in each year where harvest occurred. Harvest stand tables were estimated from the cut reports.

ii. Common Practice Calculation Results

This resulted in a starting inventory that was below common practice; therefore equation 6.6 in the FPP was used to calculate the Minimum Baseline Level (MBL). Equation 6.6 is $MBL = \text{MAX}(\text{MAX}(\text{HSR}, \text{ICS}), \text{MIN}(\text{CP}, \text{WCS}))$, where HSR is the high stocking reference, ICS is the initial above-ground standing live carbon stocks, CP is the common practice, and WCS is the weighted average carbon stocks for the logical management unit. The WCS is equal to the ICS because the entire project is a logical management unit (see Section 5.e). CP is also higher than ICS rendering that part of the equation not applicable for this project. The HSR is also equal to the ICS since the project start date and the date of acquisition are the same. For the Rich Mountain Project this leaves the equation $MBL = \text{MAX}(\text{ICS}, \text{ICS})$ which equals ICS. Therefore the $MBL = \text{ICS}$.

$$\begin{aligned} MBL &= \text{MAX}(\text{ICS}) = \text{MAX}(50.46) \\ &= 50.46 \text{ tonnes/acre CO}_2\text{e} \end{aligned}$$

The MBL will be used for the baseline harvest schedule.

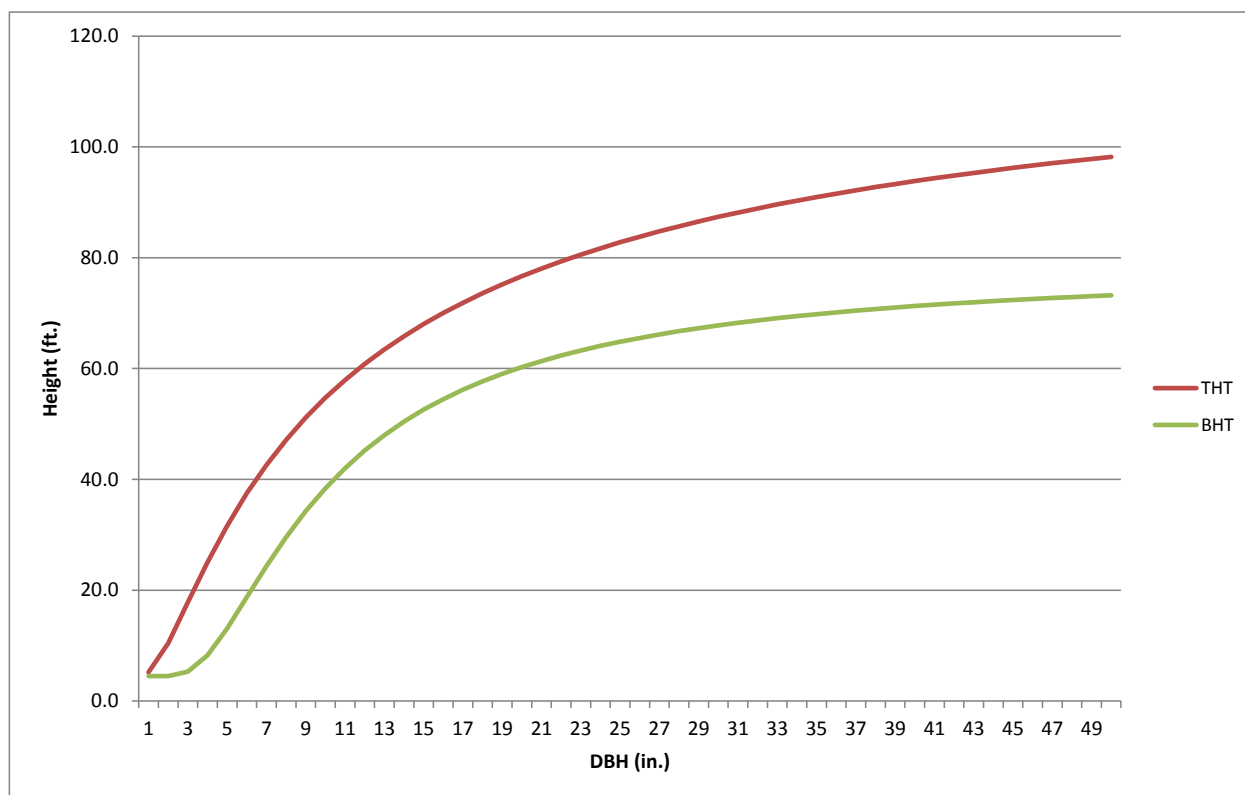
*Note that financial constraints and legal requirements must be modeled and included in the establishment of the MBL. The MBL cannot be lower than limits imposed by financial and legal constraints. In this case the modeling did not lower the MBL.

The diameter increments, by species group are shown in the Table 7 below.

Table 7: Diameter increments used to back date the inventory data

Species	10-yr inside bark diameter increment (in.)
Red maple	1.87
Red oak	1.99
Sugar maple	2.11
White oak	2.47
Yellow-poplar	3.04
Misc. hardwoods	2.04

Figure 5: Height-diameter functions for total height (THT) and merchantable height (BHT) with accompanying equations



Equation 1 & 2: Height-diameter functions for total height and merchantable height

Equations:

1: Total Height (THT) = $4.5 + \text{Exp}(4.7976 - 5.1240 * \text{DBH}^{-0.7645})$

2: Merch Height (BHT) = $4.5 + \text{Exp}(4.3039 - 22.7101 * \text{DBH}^{-1.4636})$

c. Estimate Baseline Carbon Stocks, Taking Into Account Financial and Legal Constraints on Harvesting in the Project Area.

An analysis of any financial and legal constraints is required in the development of the Project's Baseline.

i. Legal Constraints

Legal Constraints were fully explored in Section 2.d, and the results were accounted for in the Project Baseline modeling by restricting the riparian acreage of each assessment type to 50% volume retention. The acreage was calculated using watershed shapefiles and the Assessment Area shape files developed in the timber inventory process. Results of the constrained acreage is seen below in Table 8.

Table 8: Acres constrained to 50% retention due to riparian zone

CAR Assesment Type	Acreage
Oak - Hickory	25.7
Northern Hdwd	61.8
Mixed Hdwd	83
Cove Hdwd	109.6

ii. Financial Constraints

The Project demonstrates there are no substantial financial constraints based on the following:

1. The Project Area is in an area accustomed to timber harvesting. To demonstrate this data was obtained from the Virginia Department of Forestry of all logging jobs in the area surrounding the project. The data covered the time period from July 1, 2009 to March 1, 2012, or 20 months. The data indicates that there were 188 harvested sites with a cumulative acreage of 8,139 that commenced during this period within 20 miles of the project. This can be viewed in Figure 6 below.
2. The Project Area has been harvested in the past. While under TNC control 609 MBF of sawtimber has been harvested.

**RICH MOUNTAIN FARM
CARBON PROJECT AREA**

Russell/ Washington Counties, VA

The Nature Conservancy
Protecting nature. Improving life.

0 2.5 5 10 Miles

**Rich Mountain Farm
Project Area**

NORTON
SAINT PAUL
LEBANON
BRISTOL
Tazewell
Smyth

Rich Mountain Farm
Carbon Project Area

Logging Sites (2009-2012)

20-mile Project Area Buffer

Carbon Project Area

Sources: VDOT 2011, Forest 2010, NCS 2009, ArcGIS Software World Industry, 2009

iii. Growth Modeling

The Southern Variant of the Forest Vegetation Simulator (Keyser 2010) was used to model forest growth, mortality and harvest over time. FVS is a Reserve approved growth model for these applications. FVS is an individual tree growth model that will accept direct input of the 2011 inventory data, and will model volume, stocking, and basal area over time with harvesting inputs. The individual tree diameters provided by FVS is the basis of the calculating individual tree biomass as fully explained in Appendix C. Simulations were conducted in 5-year increments with harvests simulated mid-decade.

A minimum harvest level of 2,000 board feet per acre was required to ensure that modeled harvests were economical.

iv. Baseline Harvest Schedule

The baseline harvest schedule allocated acres to silvicultural prescriptions with the objective of having the 100-year average aboveground live tree pool be equal to or greater than the minimum baseline level (MBL) of 50.46 tonnes/acre CO₂e. Consideration was given to financial, legal, and regulatory constraints by ensuring that at least 50 percent cover was retained in riparian zones. This was accomplished by restricting acres to commercial thinning or no harvest silviculture for the required number of acres in each strata. For the baseline modeling, common and legal harvesting practices were assigned to strata. The results of the constraints and modeling assumptions are given in Table 8, 9 and 10.

Table 9: The following wood products mix was estimated from the baseline simulation

Species Group	Merch Category	Proportion
Hardwood	Sawtimber	45.63%
Hardwood	Pulpwood	53.67%
Softwood	Sawtimber	0.41%
Softwood	Pulpwood	0.30%
Total		100.00%

Table 10: Acres allocated to prescriptions, by strata, for the baseline

Strata	Silvicultural Prescription	Acres	Subtotal (Acres)
CAR-1: Cove Hardwoods	Clearcut	1,463.1	
	Single Tree Selection	109.6	1,572.7
CAR-2: Mixed Hardwoods	Thin	1036.577	
	Single Tree Selection	507.0	1,543.5
CAR-5: Northern Hardwoods	Clearcut	1,266.6	
	Single Tree Selection	61.8	1,328.4
CAR-6: Oak-Hickory	No Harvest	-	
	Clearcut	1,245.1	
	Thin	25.7	1,270.8
Non-Forested	No Harvest	31.7	31.7
Total			5,747.2

With these assumptions the U.S.F.S. Forest Vegetation Simulator (FVS), Southern Variant was used to simulate the assumptions and harvesting practices.

Natural regeneration was modeled utilizing the sprouting feature of FVS, since these were primarily sprouting hardwoods. The non-forested stands were populated with a single cohort of early successional species in the first decade. Table 11 shows the per acre values by species. These species were selected to emulate the pioneer species established from adjacent stands at a density post initial stem exclusion.

Table 11: Regeneration for non-forested rangeland

Species	Trees Per Acre
Black locust	100
Ash	100
Yellow popular	100
Red oak	5
Red maple	5
Elm	100
Total	410

The results of the baseline harvest schedule used to calculate the MBL are shown in Table 12 and Figure 7 below. The static horizontal lines in Figure 7 represent 100 year averages for that carbon pool. Onsite carbon pools reported in Table 12 are graphically represented in Figure 7 by the bar graphs, the harvested carbon pools are represented by symbols in Figure 7.

Table 12: Carbon Tonnes (CO₂e) reported from the baseline harvest schedule. Stocks are reported for the year indicated and harvested amounts are for the mid-decade harvests

Year	AG Live Tree	BG Live Tree	Standing Dead	Cut-All	Cut-Merch
2002	288,584	55,763	14,970	343,731	184,024
2012	78,324	15,088	14,970	617	332
2022	98,180	18,890	14,970	1,174	637
2032	147,097	28,505	14,970	1,477	800
2042	265,855	51,856	14,970	1,950	1,059
2052	422,005	82,285	14,970	2,631	1,431
2062	576,513	112,048	14,970	2,281	1,246
2072	713,362	138,166	14,970	711,998	368,270
2082	184,695	35,327	14,970	2,056	1,133
2092	190,894	36,483	14,970	2,149	1,177
2102	224,785	43,196	14,970	-	-

Figure 7: Baseline Harvest Schedule and Carbon Pools

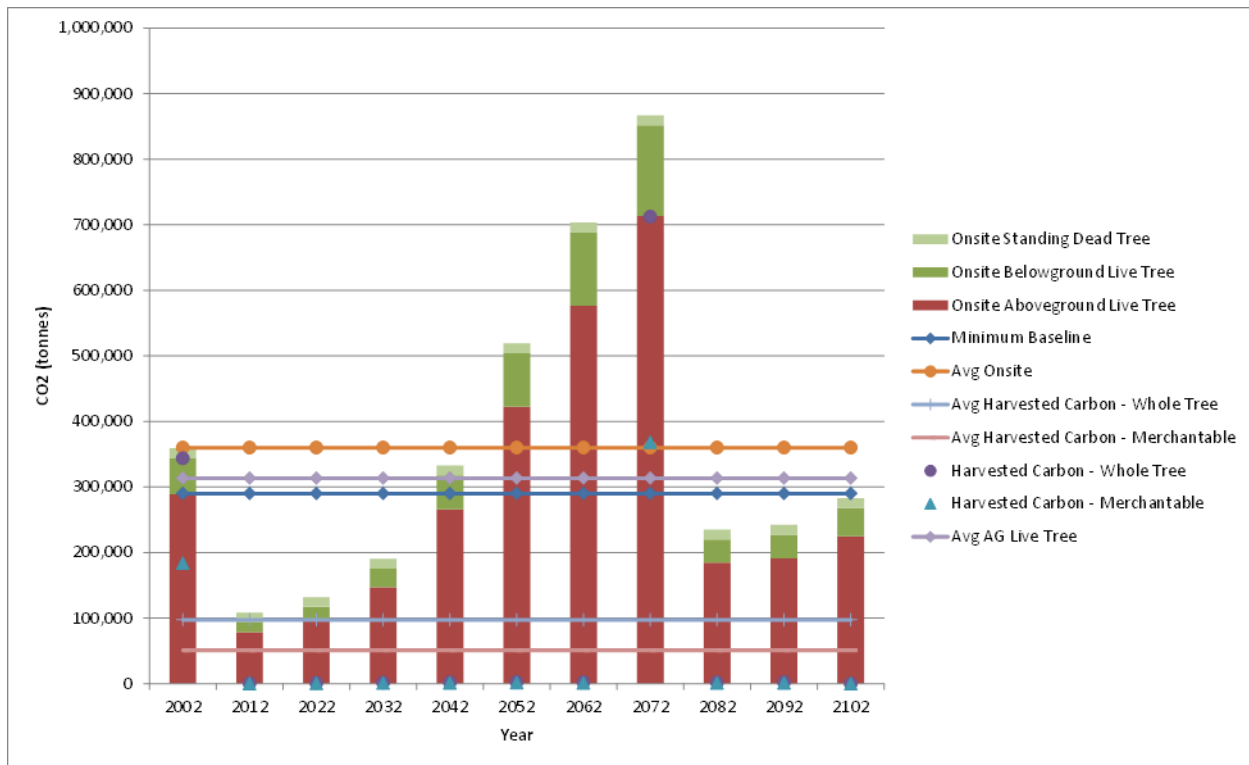


Figure 7 displays the total onsite and harvested CO2 tonnes per decade for the baseline harvest schedule. The pattern over time is largely a function of the periodicity of the even-aged harvests modeled. For example baseline scenario includes a large percentage of even aged management, implemented with clearcuts. These are largely harvested in year 1 and then grow until decade of 2072 at which time they are harvested again, therefore the spike in harvested wood products in that decade and the immediate decline in onsite carbon stocks. The harvest schedule meets all legal and economic feasibility tests and is a likely scenario under a no-carbon-project scenario. The key in Figure 7 explains each of the pools depicted. The harvested carbon pools are elevated in the decade before a drop in on-site carbon stocks, which is a function of the harvest schedule. The horizontal lines are the averages across the planning period, which are used in the CRT calculations.

Modeling the baseline stocking with legal and financial constraints yields an average onsite above ground standing live tree stocking of 313,415 total tonnes of CO2 for the 100 year baseline modeling scenario, or 54.53 tonnes CO2e per acre, which is above the MBL as required by the FPP.

d. Baseline Carbon Stocks for Required and Optional Carbon Pools in the Project Area for a 100 Year Modeling Period.

There are no optional carbon pools in the Rich Mountain Project. Standing live, standing dead, and in-use forest carbon are required pools. The in-use forest carbon pool is further divided into Harvested Live (HL) and Harvested Merchantable (HM), defined as HL being the total carbon in harvested trees, and HM as the carbon in the merchantable portion only of harvested trees. 100 year averages for standing live and standing dead are required for

project baseline calculations. The 100 year average harvested live and average harvested wood products developed in the baseline scenario is input into the Reserve's Calculation Worksheet and represented graphically in Figure 7. For the Rich Mountain Forest Carbon Project the required baseline pools are:

- Standing Live – 366,534 tonnes CO₂e
- Standing Dead – 14,970 tonnes CO₂e
- Harvested Live – 9,728 tonnes CO₂e
- Harvest Merchantable – 5,092 tonnes CO₂e

The following table further describes how each carbon pool was accounted for in the project.

Table 13: Included and Optional Greenhouse Gas Assessment Boundaries

Pool	Description	Type	Gas	Quantification Method	Additional Information
IFM-1	Standing Live Carbon	Reservoir / Pool	CO2	Baseline: Modeled based on initial field inventory and simulations. Project: Modeled through FVS and will be updated with periodic field inventory	See Modeling Plan, Appendix C for more details
IFM-3	Standing Dead Carbon	Reservoir / Pool	CO2	Baseline: Modeled based on initial field inventory and simulations. Project: Modeled through FVS and will be updated with periodic field inventory measurements	See Modeling Plan, Appendix C for more details
IFM-6	Soil Carbon	Reservoir / Pool	CO2	Not Included in project	Project does not employ site prep activities.
IFM-7	Carbon in in-use Forest Products	Reservoir / Pool	CO2	Baseline: Estimated from modeled harvesting volumes Project: Estimated from measured harvesting volumes	In-use Forest Products derived from Harvested Merchantable pools in the calculations
IFM-8	Forest Product Carbon in Landfills	Reservoir / Pool	CO2	Baseline: Estimated from modeled harvesting volumes Project: Estimated from measured harvesting volumes	Storage factors are given by CAR for each Assessment Area. Project specific calculations can be found in HarvestSchedule Workbook.
IFM-9	Biological emissions from site preparation activities	Source	CO2	Not Included in project	No site preparation activities will occur in project.
IFM-14	Biological emissions/removals from changes in harvesting on forestland outside Project Area	Source/ Sink	CO2	Baseline: N/A Project: The default 20% "leakage" factor was applied to the difference in harvest volume relative to baseline harvest volume, based on the whole tree harvested pool.	Project utilized the CAR provided CRT Calc workbook and can be found as a tab in the HarvestSchedule Workbook
IFM-17	Biological emissions from decomposition of forest products	Source	CO2	Baseline: Quantified as a component of calculating carbon stored for 100 years in wood products (IFM-7 & IFM-8) Project: Quantified as a component of calculating carbon	Based on calculations used for in-use wood products and carbon in landfill storage. Details can be seen on CAR provided CRT Calculation tab included in HarvestSchedule Workbook

e. Comparison of Project Minimum Baseline (MBL) with Carbon Stocks on Forest Owners Other Lands Within Logical Management Unit (LMU).

Section 6.2.1.1 of the FPP requires that MBL be compared to the other properties within an LMU. The FPP defines a LMU as all land that the Forest Owner and its affiliate(s) either own in fee or hold timber rights on, and which it or they manage as an explicitly defined planning subunit. LMUs are generally characterized by having unique biological, geographical, and/or geological attributes, are generally delimited by watershed boundaries and/or elevational zones, and contain unique road networks. In addition, an LMU must:

- Be a sustainable planning subunit as demonstrated by inventory reports and growth and harvest projections for the LMU.
- Demonstrate that the proportion of the LMU harvested in the past 10 years is within 20 percent of the annualized area or volume projected for harvest.
- Where uneven aged management is utilized, have between 33 percent and 66 percent of the forested stands exceeding the retention standards identified in the growth and harvest projections by a minimum of 25 percent basal area.

After reviewing the Reserve definition of an LMU, and considering how the Rich Mountain Project is managed it was determined that the project would be considered an LMU on its own. This is based on the following considerations:

- The management of the forest resource is guided by a tract specific legal document, the Forest Management Easement, which is unique to this property alone.
- Forest Inventories are carried out on this property independently of other properties.
- Rich Mountain has a unique management plan that does not include other properties.
- The allowable harvest is calculated independently for Rich Mountain.
- Rich Mountain is assigned its own Cost Center within TNC's accounting system, with revenues and costs being tracked independently of any other property.
- Annual payment calculations to the fee landowner of Rich Mountain are computed independently without influence of other properties.

Since the Rich Mountain Project was determined to be its own LMU, the calculations outlined in the FPP equations 6.7, 6.8, and 6.9 were not required for the baseline calculation.

6. Project Activity Harvest Modeling (2011 Forward) and Initial Reporting Period

a. Project Activity Modeling, 2011 Forward

The project activity was modeled to provide estimates of carbon stocks for the next ten years, when another inventory is scheduled. The backdating of the inventory provided the project activity estimates from 2004 to 2010. The acres allocated to the prescriptions were the manager's best estimate of planned activity over the next decade and are displayed in Table 13 below.

Note that the forecasted project activity to include silvicultural prescriptions and onsite carbon stocks are subject to change at TNC's discretion, within the flexibility afforded by the Project Implementation agreement.

Table 14: Silvicultural prescriptions modeled for Project Activities

Strata	Rx ID	Rx Description	Activity Trigger(s)	Residual Stocking	Species Retention Preferences	Frequency to Check Trigger	Minimum Post-Harvest Time
Oak-Hickory	OHREG	Regeneration	18" Average DBH	15	Red Oak, White Oak	10 yrs	70 yrs
	OHTHIN	Harvest w/Reserves	>120 BA	80	Red Oak, White Oak	10 yrs	20 yrs
		Thinning from below	<16" Average DBH				
Cove Hdws	CHREG	Regeneration	18" Average DBH	15	Yellow Poplar, Red Oak, Sugar Maple	10 yrs	70 yrs
	CHTHIN	Harvest w/Reserves	>130 BA	80	Yellow Poplar, Red Oak, Sugar Maple	10 yrs	20 yrs
		Thinning from below	<16" Average DBH				
Northern Hdws	NHREG	Regeneration	18" Average DBH	15	Sugar Maple, Black Cherry, NRO	10 yrs	70 yrs
	NHTHIN	Harvest w/Reserves	>130 BA	80	Sugar Maple, Black Cherry, NRO	10 yrs	20 yrs
		Thinning from below					
Mixed Hdws	MHREG	Regeneration	18" Average DBH	15	Red Oak, White Oak, Red Maple	10 yrs	70 yrs
	MHTHIN	Harvest w/Reserves					
		Thinning from below					
All	GRSEL	Group Selection	16" Average DBH	0		20 yrs	70 yrs
	GRTHIN	Avg 1-acre size	<60 Slope and good access				20 yrs

The following table shows the allocation of acres to the above prescriptions.

Table 15: Acres allocated to prescriptions, by strata, for the planned project activity

Strata	Silvicultural Prescription	Acres	Subtotal (Acres)
CAR-1: Cove Hardwoods	No Harvest	792.7	1,572.7
	Regeneration	160.0	
	Thin/Regeneration	420.0	
	Group Selection	200	
CAR-2: Mixed Hardwoods	No Harvest	1,143.5	1,543.5
	Regeneration	400.0	
CAR-5: Northern Hardwoods	No Harvest	567.4	1,328.4
	Regeneration	111.0	
	Thin/Regeneration	450.0	
	Group Selection	200.0	
CAR-6: Oak-Hickory	No Harvest	450.8	1,270.8
	Regeneration	145.0	
	Thin/Regeneration	475.0	
	Group Selection	200.0	
Non-Forested	No Harvest	31.7	31.7
Total			5,747.2

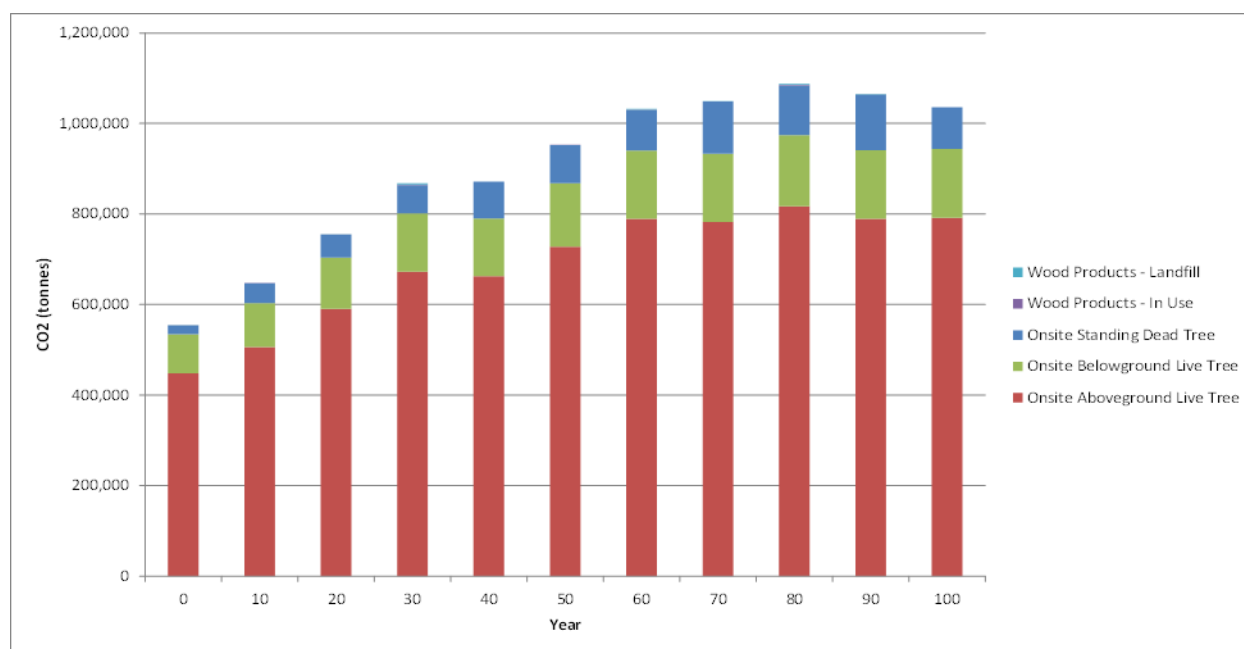
The harvest schedule multiplied the acreage allocations by the carbon yield streams obtained from the FVS simulations. The following table is the resulting annual estimate of onsite CO2 including above and belowground live and standing dead trees.

Table 16: Estimated carbon for the project activity over the next 12 years. Onsite carbon includes live and standing dead tree pools.

Year	Onsite CO2 (tonnes)
2011	566,508
2012	569,302
2013	577,363
2014	585,538
2015	593,829
2016	602,238
2017	610,766
2018	619,414
2019	628,185
2020	637,080
2021	649,473
2022	662,108

The 100-year projection of project activity is shown in Figure 8 below.

Figure 8: Project activity projected carbon for 100 years



b. Initial Reporting Period 2002-2011

Table 17 is the Reserve's Forest Project Calculations Worksheet, which is available on their website at:

<http://www.climateactionreserve.org/wp-content/uploads/2011/04/2011-Forest-Calc-Worksheet-4-2011.xls>

The calculations that support this worksheet can be found in the supplied Excel Worksheet titled: Harvest Schedule Rich Mountain.

A summary of the cumulative gross CRTs issued to the Project are presented below in Table 17.

Table 17: Annual GHG Reductions/Removals Net of Discounts and Secondary Effects (tonnes CO2e)

Year	CRTs
2002	7,294
2003	14,054
2004	14,238
2005	13,772
2006	28,996
2007	11,944
2008	10,754
2009	18,250
2010	34,331
2011	9,446

Note – The CRT numbers above correspond with Calc Row 33 on the CRT Worksheet provided by CAR. Due to rounding within the Worksheet the numbers may appear to be off by 1. The numbers in Table 18 are actual.

Table 18: Rich Mountain Forest Carbon Project's Annual Report for 2002 to 2011

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	Type of Project:	Data determined by Forest Owner at each verification													
	Improved Forest Management	Data determined by Forest Owner at time project is registered													
		Data calculated automatically													
Reporting Periods		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Start Date		20-Jan-02													
Reporting Period Begin Date			20-Jan-02	1-Jan-03	1-Jan-04	1-Jan-05	1-Jan-06	1-Jan-07	1-Jan-08	1-Jan-09	1-Jan-10	1-Jan-11	1-Jan-12	1-Jan-13	1-Jan-14
Reporting Period End Date			31-Dec-02	31-Dec-03	31-Dec-04	31-Dec-05	31-Dec-06	31-Dec-07	31-Dec-08	31-Dec-09	31-Dec-10	31-Dec-11	31-Dec-12	31-Dec-13	31-Dec-14
Reporting Date			3-May-02	3-May-02	3-May-02	3-May-02	3-May-02	3-May-02	3-May-02	3-May-02	3-May-02	3-May-02			
Calculating GHG Reductions/Removals for Onsite Carbon Stocks - All Project Types - all data should be entered as the end of the Reporting Period															
1	Actual Onsite Carbon Stock (tannar CO ₂ e)	371,876	382,716	400,317	418,101	433,535	464,051	479,541	493,842	515,638	553,515	566,508			
2	Confidence Deduction		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
3	Adjusted Actual Onsite Carbon Stock (adjusted for confidence deduction) (tannar CO ₂ e)		382,716	400,317	418,101	433,535	464,051	479,541	493,842	515,638	553,515	566,508	-	-	-
4	Increment in Actual Onsite Carbon Stock (tannar CO ₂ e)		382,716	17,600	17,784	15,434	30,516	15,491	14,300	21,797	37,877	12,992	-	-	-
5	Baseline Onsite Carbon Stock (tannar CO ₂ e)	371,876	371,876	371,876	371,876	371,876	371,876	371,876	371,876	371,876	371,876	371,876	371,876	371,876	371,876
6	Increment in Baseline Onsite Carbon Stock (tannar CO ₂ e)			-	-	-	-	-	-	-	-	-	-	-	-
7	Quantified GHG Reductions / Removals for Onsite Carbon Stock (tannar CO ₂ e)		10,140	17,600	17,784	15,434	30,516	15,491	14,300	21,797	37,877	12,992	-	-	-
Calculating Carbon Stored in Wood Products Including Market Effects and Leakage - All Project Types - all data should be entered as the end of the Reporting Period															
8	Actual Carbon in Trees Harvested for Wood Products (tannar CO ₂ e)		-	-	-	5,241	7,149	-	-	-	-	-			
9	Baseline Carbon in Trees Harvested for Wood Products (tannar CO ₂ e)		9,728	9,728	9,728	9,728	9,728	9,728	9,728	9,728	9,728	9,728	-	-	-
10	Actual Carbon in Harvested Wood Delivered to Mills (tannar CO ₂ e)		-	-	-	2,640	1,900	-	-	-	-	-			
11	Baseline Carbon in Harvested Wood Delivered to Mills (tannar CO ₂ e)		5,092	5,092	5,092	5,092	5,092	5,092	5,092	5,092	5,092	5,092	-	-	-
12	Actual Carbon Stored Long-term in Wood Products (tannar CO ₂ e) - Excl Landfill		-	-	-	458	327	-	-	-	-	-			
13	Actual Carbon Stored Long-term in Wood Products (tannar CO ₂ e) - Incl Landfill		-	-	-	1,045	747	-	-	-	-	-			
14	Baseline Carbon Stored Long-term in Wood Products (tannar CO ₂ e) - Excl Landfill		877	877	877	877	877	877	877	877	877	877	-	-	-
15	Baseline Carbon Stored Long-term in Wood Products (tannar CO ₂ e) - Incl Landfill		2,001	2,001	2,001	2,001	2,001	2,001	2,001	2,001	2,001	2,001	-	-	-
16	Diff Between Actual and Baseline Carbon in Harvested Wood (tannar CO ₂ e) - Excl Landfill		(877)	(877)	(877)	(419)	(550)	(877)	(877)	(877)	(877)	(877)	0	0	0
17	Difference Between Actual and Baseline Carbon in Harvested Wood (tannar CO ₂ e) - Incl Landfill		(2,001)	(2,001)	(2,001)	(956)	(1,254)	(2,001)	(2,001)	(2,001)	(2,001)	(2,001)	0	0	0
18	Difference in Actual and Baseline Carbon Stored in Wood Products (tannar CO ₂ e) - Landfill Adj		(2,001)	(2,001)	(2,001)	(956)	(1,254)	(2,001)	(2,001)	(2,001)	(2,001)	(2,001)	0	0	0
19	GHG Reductions / Removals for Carbon Stored in Wood Products (tannar CO ₂ e) at mill/transport		(1,601)	(1,601)	(1,601)	(764)	(1,003)	(1,601)	(1,601)	(1,601)	(1,601)	(1,601)	0	0	0
Calculation Other Secondary Effects - Reforestation Projects - all data should be entered as has occurred during Reporting Period															
20	Mobile Combustion Emission Factor (average tannar CO ₂ e per acre)														
21	Initial Site Prep Acres in Project Area (Acres)														
22	One-time combustion emissions associated with machinery use in site preparation (tannar CO ₂ e/acre)		-	-	-	-	-	-	-	-	-	-	-	-	-
23	Leakage Risk Percentage for Leakage from Shifting Cropland and Grazing Activities (%)			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
24	Secondary Effect emissions due to shifting cropland or grazing activities (tannar CO ₂ e)		-	-	-	-	-	-	-	-	-	-	-	-	-

Table 18 - Continued

A	B	C	D	E	F	G	H	I	J	K	L	M	N
25	Other Secondary Effect Emissions for Reforestation Projects (tanner CO ₂ e)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Calc Rev	Calculating Other Secondary Effects - Improved Forest Management Projects												
26	Difference Between Actual and Baseline Carbon in Trees Harvested for Wood Products (tanner CO ₂ e)		(9,728)	(9,728)	(9,728)	(4,487)	(2,579)	(9,728)	(9,728)	(9,728)	(9,728)	(9,728)	-
27	Other Secondary Effect Emissions (shifting activities/materials) IFM Projects (tanner CO ₂ e)		(1,946)	(1,946)	(1,946)	(897)	(516)	(1,946)	(1,946)	(1,946)	(1,946)	(1,946)	-
Calc Rev	Determining the Uncertainty Discount Factor and Calculating Other Secondary Effects - Avoided Conversion Projects												
28	Appraised Fair Market Value of Anticipated Alternative Land Use of Project Area (000\$)												
29	Appraised Fair Market Value of the Current Forested Land Use of Project Area (000\$)												
30	Avoided Conversion Discount Factor		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
31	Quantified GHG Reductions/Removals for On-site Carbon Stocks (tanner CO ₂ e)		10,840	17,600	17,784	15,434	30,516	15,491	14,300	21,797	37,077	12,992	-
32	Other Secondary Effect Emissions for Avoided Conversion Projects (tanner CO ₂ e)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Calc Rev	Quantified GHG Reductions and Removals												
33	Annual GHG Reductions/Removals Net of Discount and Secondary Effects (tanner CO ₂ e)		7,294	14,054	14,238	13,772	28,996	11,944	10,754	18,250	34,331	9,446	0
34	Cumulative GHG Reductions/Removals incl. net carryover reversals (tanner CO ₂ e)		7,294	21,348	35,586	49,358	78,355	90,299	101,053	119,303	153,634	163,080	163,080
35	Cumulative Negative Carryover from Prior Year (tanner CO ₂ e)		0	0	0	0	0	0	0	0	0	0	0
36	CRTs Issued = Net of Negative Carryover, less Buffer or adjust for Reversals (tanner CO ₂ e)		7,293	14,054	14,238	13,771	28,996	11,944	10,753	18,250	34,330	9,445	0
Calc Rev	Calculation of Buffer Pool Contribution - all data should be entered as end of Reporting Period												
37	Project Specific Reversal Risk Rating		20.2%	20.2%	20.2%	20.2%	20.2%	20.2%	20.2%	20.2%	20.2%	20.2%	0.0%
	CRTs from other Reporting Periods submitted to Buffer Pool		0	0	0	0	0	0	0	0	0	0	0
38	Buffer Pool Contribution (CRTs)		1,475	2,842	2,879	2,785	5,863	2,416	2,175	3,691	6,942	1,910	-
Calc Rev	Accounting for Reversals - all data should be reported as sum during Reporting Period												
39	Annual Reversals (tanner CO ₂ e)		-	-	-	-	-	-	-	-	-	-	-
40	Total "Avoidable Reversals" to be compensated by the Forest Owner (tanner CO ₂ e)		-	-	-	-	-	-	-	-	-	-	-
41	"Unavoidable Reversals" compensated by the Reserve from the Buffer Pool (tanner CO ₂ e)		-	-	-	-	-	-	-	-	-	-	-
Calc Rev	Compensating for Avoidable Reversals - all data should be reported as sum during Reporting Period												
42	"Avoidable Reversals" compensated by retirement of CRTs in the Forest Owner's Reserve Account (tanner CO ₂ e)		-	-	-	-	-	-	-	-	-	-	-
43	"Avoidable Reversals" compensated by retirement of CRTs issued to other Forest Projects Registered with the Reserve (tanner CO ₂ e)		-	-	-	-	-	-	-	-	-	-	-
44	Carryover "Avoidable Reversals" which need to be compensated by Forest Owner (tanner CO ₂ e)		-	-	-	-	-	-	-	-	-	-	-
Calc Rev	CRTs Issued to Account Holder - following verification												
45	Annual CRTs Issued to Account Holder		5,818	11,212	11,359	10,956	23,133	9,528	8,578	14,559	27,388	7,535	-
46	Vintage I - Calendar year of Reporting Period start date (Vintage)		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
47	Portion of CRTs in first vintage in Reporting Period		5,818	11,212	11,359	10,956	23,133	9,528	8,578	14,559	27,388	7,535	-
48	Vintage II - Calendar year of Reporting Period end date (Vintage - if different from start date vintage)		-	-	-	-	-	-	-	-	-	-	-
49	Portion of CRTs in second vintage Reporting Period		-	-	-	-	-	-	-	-	-	-	-
50	Cumulative CRTs Issued to Account Holder		5,818	17,020	28,389	39,375	62,508	72,036	80,614	95,173	122,561	130,096	130,096

7. Calculation of Reversal Risk Rating and Contribution to the Buffer Pool

Each forest project must calculate its reversal risk rating by following the guidelines in Appendix D of the FPP. Risk ratings are calculated for several categories to include: Financial, Management, Social, and Natural Disturbance. The Reserve provides worksheets that enable the project developer to calculate the appropriate risk rating in each category. The provided worksheets are included below. The table references are taken directly from the Reverse Protocol, Appendix D.

a. Financial Risk

Table D.2. Financial Risk Identification

Applies to all projects		
Identification of Risk	Contribution to Reversal Risk Rating	
	PIA only	PIA combined with Qualified Conservation Easement or Qualified Deed Restriction or on public lands
	5%	1%
Default Financial Risk	5%	1%

Contributions to the buffer pool based on financial risks include not only the worksheet identified as Table D.2 in the FPP, but also an additional contribution based on Exhibit G in the Project Implementation Agreement (PIA). Exhibit G has the following table to explain the additional contribution.

Table 19: Additional Buffer Contribution Requirements of Forest Carbon Projects per Exhibit G in the Project Implementation Agreement

Risk Category	PIA with "Subordination Clause Type 2"	PIA with "Subordination Clause Type 1"
Financial Failure	10%	2%

The Rich Mountain Project will only use a PIA between the project developer and the Reserve, so the default reversal risk rating is 5% according to table D.2. An additional 2% is added as a result of Exhibit G in the PIA.

Additionally the Rich Mountain Project is assessed a supplementary 2% Financial Failure risk factor due to the ownership type. In a memo from the Reserve dated November 11, 2010, TNC was notified that an additional contribution would be required since the Forest Owner is not the fee owner.

b. Management Risk

Management risk is comprised of three separate risk ratings as detailed below.

i. Management Risk I: Illegal Removals of Forest Biomass

Table D.3. Risk of Illegal Removals of Forest Biomass

Applies to all projects	
Identification of Risk	Contribution to Reversal Risk Rating
United States Default Harvesting Risk	0%

The Rich Mountain Project is within the United States, thus the default illegal harvesting risk of 0% is used.

ii. Management Risk II: Conversion of Project to Alternative Land Uses

Table D.4. Risk of Conversion to Alternative Land Use

Applies to all projects	
Identification of Risk	Contribution to Reversal Risk Rating
With Qualified Conservation Easement or Qualified Deed Restriction that explicitly encumbers all development rights	0%
Without Qualified Conservation Easement or Qualified Deed Restriction	2%

With a PIA only the Rich Mountain Project's default risk for conversion to alternative land use is 2%

iii. Management Risk III: Over-Harvesting

Table D.5. Risk of Over-Harvesting

Applies to all projects	
Identification of Risk	Contribution to Reversal Risk Rating
With Qualified Conservation Easement or Qualified Deed Restriction that explicitly encumbers timber harvesting associated with project stocks	0%
Without Qualified Conservation Easement or Qualified Deed Restriction	2%

With only a PIA on the Rich Mountain Project the default 2% risk for overharvesting is applied to the project.

c. Social Risk

Applies to all projects	
Identification of Risk	Contribution to Reversal Risk Rating
United States Default Social Risk	2%

The social risk is identified as 2% since the project is within the United States.

d. Natural Disturbance Risk

i. Natural Disturbance Risk I: Wildfire

Table D.7. Natural Disturbance Risk I – Wildfire

Applies to all projects	
Identification of Risk	Contribution to Reversal Risk Rating
For the Assessment Area the project is located in, determine long-term fire risk potential from fire history perimeter maps (at least 30 years) – enter rate as an annualized percentage.*	X%
If fuel treatments have been implemented for the Project Area, reduce the value above by the appropriate % as indicated below.**	(X%) x Y%

Based on input received from Reserve staff, a more accurate, site specific wildfire risk rating was calculated for the project area using Virginia Department of Forestry data. One of The Virginia Department of Forestry's primary functions since it was established in 1912 has been to control and suppress wildfires on private, state, and local government lands. Over time, the Department has collected data about the incidence and severity of those wildfires across the state. To calculate a site specific risk of wildfire, regional data, for the counties of Washington, Russell, and Washington counties, was obtained from the Department and analyzed in comparison with state-wide wildfire data. For the regional-specific data that was available, an average of 1992 acres burned annually. According to 2010 FIA data, these three counties have a combined 540,759 acres of private, state, and local government forestland. Therefore, the results indicate that an average of .38% of all private, state, and local government lands burned annually during this time period. Note that 5 of the included years spanned the 1930s and 1940s, when burned acres were considerably higher than in more modern times. With the increased use of technology, increased numbers of fire departments and trained wildland firefighters, and greater public awareness generally regarding wildfires, most are extinguished before reaching more than 10 acres in size. The inclusion of the historic years increases the average considerably compared to the most recent 15 years of data. However to ensure an aggressive prediction of wildfire, the older data was included.

Since additional analysis was desired to further strengthen our understanding of the risk of a wildfire reversal, statewide data were analyzed for an additional 33 years for a total historic analysis of 55 years. To accomplish this analysis, a comparison of the relationship of regional and state-wide fire data was conducted.

For the 22 years during which both regional and state-wide data were available, an average of 6% of the total statewide burned acreage could be attributed to the three county area (Washington, Russell, Washington counties). The maximum annual contribution of wildfire acres burned from the three county area to the statewide total during that 22 year period was 15%. This figure was applied to the state wide data from 1961-1994 to calculate an aggressively high number of potential acres burned annually (15% of the average annual state-wide acreage burned). For this time period, the average annual regional acreage burned was 1,370 acres, resulting in a wildfire occurrence rate of .25%. The calculated weighted average of 22 years with 1992 acres each and 33 years of 1,370 acres each equals 1,619 acres burned annually. This results in a wildfire occurrence rate of .30% annually.

Not only is the incidence rate of wildfires in Virginia relatively low, the intensity is generally low as well (Miller 2011). The Appalachian Hardwood Forests that dominant the project area are tolerant of fire, with fire mortality of live trees rare even when a fire does occur. A typical fire in this region would result in the leaf litter being consumed along with some dead and down material. Small diameter live trees (<5 inch DBH) may experience some mortality as well. It is a very rare fire event that would consume live trees over 5 inches in DBH.

If the project applies an overly conservative estimate that all the living trees will be consumed in every wildfire, the analysis points out that on average, the chance of a wildfire induced carbon stocking reversal is .30%. If this is rounded up to a 1% risk of reversal rating, an additional three fold margin of safety is built in.

Based on the detailed analysis conducted by TNC staff a Wildfire Reversal Rating of 1% is assigned. The underlying detailed calculations and raw data have been provided to the Reserve and the Verifier.

ii. Natural Disturbance Risk II: Disease or Insect Outbreak

Table D.8. Natural Disturbance Risk II – Disease or Insect Outbreak

Applies to all projects	
Identification of Risk	Contribution to Reversal Risk Rating
Default Risk Contribution from Disease or Insect Outbreak	3%

The assigned risk rating is 3%, per the worksheet above.

iii. Natural Disturbance Risk III: Other Episodic Catastrophic Events

Table D.9. Natural Disturbance Risk III – Other Episodic Catastrophic Events

Applies to all projects	
Identification of Risk	Contribution to Reversal Risk Rating
Default Risk Contribution from Other Catastrophic Events	3%

The assigned risk rating is 3%, per the worksheet above.

e. Summarizing the Risk Analysis

Table 19 below summarizes the assigned risk analysis by category for the Rich Mountain Project.

Table 20: Summary of Risk Analysis for Rich Mountain Forest Carbon Project

Risk Category	Source	Contribution %
Financial Failure	Default Risk and PIA Subordination Type	9
Illegal Forest Biomass Removal	Default for U.S. Projects	0
Conversion	Default risk for projects without qualified conservation easement	2
Over-Harvesting	Default risk for projects without qualified conservation easement	2
Social	Default for U.S. Projects	2
Wildfire	Detailed Analysis conducted by TNC staff	1
Disease or Insect Outbreak	Default Risk	3
Other Catastrophic Events	Default Risk	3

Overall Contribution to Buffer Pool is **20.22%** as calculated per the equation in FPP, Appendix D.5

$100\% - ((100-9\%) \times (100-0\%) \times (100-2\%) \times (100-2\%) \times (100-2\%) \times (100-1\%) \times (100-3\%) \times (100-3\%)) = 20.219\%$ which rounds up to 20.22%.

APPENDICES

Appendix A: Analysis of The Nature Conservancy Management Practices in accordance with Section 3.10.1 of the Climate Action Reserve v3.2 Forest Project Protocol.

In an effort to meet the Reserve's v3.2 Forest Project Protocol Sustainable Harvesting Practices TNC staff examined our land management practices within the project assessment area (Allegheny & North Cumberland Mountains).

This requirement requires the Forest Owner to accomplish this on all of their forest landholdings within the Assessment Area, not just the project itself. We do not have information at a fine enough scale to determine which Assessment Area each of our landholdings would fall in within the Supersection. This being the case we determined it was more reasonable to attempt to determine this within the whole Supersection, which would also result in a more conservative approach, thus meeting the requirement.

The first attempt to meet the protocol was through Option 1, which states: "Forest Owner must be certified under the Forest Stewardship Council, Sustainable Forestry Initiative, or Tree Farm System certification programs." The Nature Conservancy has a policy titled "Compatible Human and Economic Use" that addresses forest management on any property that is controlled or owned by the Conservancy. In short, the policy requires that all revenue generating forest management activities should be certified under a credible third party certification system as defined by the World Wildlife Foundation and World Bank. Currently the only system that meets that requirement is the Forest Stewardship Council (FSC) Certification. This policy has been in place since 2007, with renewed focus on getting the Conservancy's managed forest under FSC certification. In discussions with our Director of Certification Programs, Fran Price, no managed forestland within the Supersection could be identified that was not FSC certified. While this likely meets the intent of the protocol, the majority of our forestlands are preserves with no active forest management, and are not FSC certified. This being the case Option 3 was selected as the next attempt to meet the protocol.

Under Option 3 the Forest Owner must demonstrate uneven aged silvicultural practices by maintaining canopy cover averaging at least 40 percent across the entire forestland ownership for the projects Assessment Area(s). TNC staff devised a methodology to utilize ArcView GIS Analytical software to determine if the canopy cover requirements were met across the entirety of the forestland ownership within the Supersection. The Supersection was selected instead of Assessment Area, because the Assessment Area for each property owned is unknown and appropriate data to determine that is unavailable. By selecting the Supersection you are by default selecting every Assessment Area, thus ensuring compliance in the Projects Assessment Areas. Using the developed methodology 62 properties were identified for compliance checks to Option 3. Ten properties were flagged as having areas 20 acres or larger that had less than 40% canopy cover. Upon further investigation into all 10 cases reasonable explanations were found as to why there is a lack of canopy cover on these properties, such as hayfields, swamps, bogs, and abandoned fields. See attached table for more details on each occurrence. After this detailed analysis and follow up investigation we are confident that our project meets the Sustainable Harvesting Practices requirement within the protocol.

Methodology for Canopy Cover Analysis

The Nature Conservancy has considerable experience with Geographic Information Systems (GIS) and access to many data sources. This experience along with knowledge of the Reserve's v3.2 Sustainable Harvesting Practices requirements led TNC staff to develop the following methodology to gauge compliance.

TNC maintains extensive spatial information on all its properties. Among that information are shape files that can be used with other data sets to analyze a variety of data. Chris Bruce, TNC Virginia Chapter's Geographic Information Systems Manager, devised an analysis to determine within the Allegheny and North Cumberland Mountains Supersection if TNC is meeting the Sustainable Harvesting Practices requirement; specifically, Option 3 that ensures that the project developer maintains at least 40% canopy cover across all ownerships within the Supersection as measured on any 20 acres.

The analysis relied primarily on three data shapefiles, the Allegheny and North Cumberland Mountains shape file, the National Landcover Data shapefile, and a TNC property shapefile, which included all TNC owned and managed properties, included those purchased within the past 5 years. Using these shapefiles we were able to determine any areas within the Supersection that are larger than 20 acres and have less than 40% canopy cover. Our initial analysis identified 17 separate occurrences where this was the case. After closer examination, several of the occurrences were on the same properties, and after consolidation the final number of properties that required further investigation was 10. The managing TNC staff for each preserve was identified and interviewed regarding the lack of canopy cover on the preserves. See Table A1 and Figure A1 below outlining our findings.

Table A. 1: TNC Preserves That Have < 40% Canopy Cover in Contiguous Blocks of 20 or more Acres

Preserve Name	Acres with < 40% Canopy Cover	Number of Occurrences	State	Reason for Canopy Openings	TNC Harvesting
Moosic Mountain Barrens	155	3	PA	Natural vegetation is shrub/scrub	No
Licking Creek South Preserve	43	2	MD	Abandoned Ag Lands	No
Sideling Hill Creek Preserve	56	1	MD	Ag Lands and Reforested Ag Lands	No
North Cherry Creek Bog	34	1	MD	Abandoned Ag Lands	No
The Glades	65	1	MD	Peat Bog, Been Reforested	No

Preserve					
Cranesville Swamp Preserve	191	5	WV/MD	Agricultural Production, Abandoned Ag Lands, and Wetlands	No
Bear Rocks	308	1	WV	Natural Vegetation is Shrub/Barrens	No
Warm Springs Mountain	20	1	VA	Timber Harvest performed prior to TNC Ownership	No
Upper Clinch River	23	1	VA	Abandoned Ag Lands	No
Cleveland	65	1	VA	Abandoned Ag Lands	No

Figure A. 1: Location and name of each TNC Preserve with an occurrence of 40% or less canopy cover on 20 or more acres.



Appendix B: Inventory Methodology Used for 2011 Data Collection

FIELDWORK INSTRUCTIONS AND CRUISING SPECIFICATIONS THE NATURE CONSERVANCY - CONSERVATION FORESTRY PROGRAM INVENTORY 2011

Cruise Design

- 1.) Sampling Method: **20 Basal Area Factor** Variable Radius Plot inventory, with point centers established on a systematic “line-plot” grid system.
- 2.) Statistical Standards of Inventory: The statistical accuracy target for this project is +/- 10% variance from the total sawtimber volume estimate (board feet) at a confidence interval of 90%, applied at the tract level. The two tracts considered for this project are Clifton Farms and Rich Mountain. An additional accuracy target is +/- 5% variance from the total biomass estimate at a confidence interval of 90%, applied at the carbon project level. There will be two projects considered for this target; Rich Mountain and Clifton Farms. The later of these targets is intended to comply with either the Climate Action Reserve (CAR) Improved Forest Management methodology (version 3.2) or the Voluntary Carbon Standard (VCS) “Methodology for Improved Forest Mgmt through Extension of Rotation Age”, VM 0003; under which a zero confidence deduction based on the biomass needs to be achieved.
- 3.) Sampling Intensity: The specified sample spacing is outlined by tract as follows:

Tract	Spacing
Rich Mountain	7 chain by 10 chain

- 4.) Data Collection: All data will be collected on hand held Pocket PC data recorders incorporated with Pocket Dog data collection software and Excel.

Mapping and Stratification

Forest stand type maps will be developed to stratify inventory information, and will assist in reaching the statistical standards. These maps will provide information relevant to forest cover types, timber size classifications, tree stocking, forested acres, roads, well sites or any other information pertinent to tract management. Stands will be developed by cruisers. Cruisers will delineate manageable units using the USFS stand types found in Appendix F of the CAR protocol.

Methodology

- 1.) The following forestry tools will be carried by each cruiser during the field inventory:
 - Hand compass
 - Recreational grade GPS unit
 - Diameter tape
 - 20 BAF prism
 - PDA loaded with Pocket Dog and Excel software

- Increment borer
 - Laser hypsometer
 - Clinometer
- 2.) All sample points will be located using a GPS. If GPS signal is insufficient or mapped point is not correlating to GPS location for some reason, cruiser will use compass and declination correction as shown on the USGS quadrangle maps to locate point centers as accurately as possible. Points located by compass will be indicated as such on field tally. At each point the cruiser will place a pin flag in the ground indicating plot center. Each pin flag will have the cruisers identification and point number clearly indicated. In addition, flagging will be hung at eye level above each sample plot.
 - 3.) Cruisers will adjust compasses for magnetic declination relevant to the tract.
 - 4.) Sample point locations will be located as accurately as possible in correspondence to the cruise map. In the event a point falls within 1 chain of a boundary line, the point will be moved back along the line of travel to a point 1 chain from the boundary. The cruiser will note any such adjustments to sample point location in the Comments section for that tally point.
 - 5.) At each sample point, beginning with the first tree north then proceeding in a clockwise direction, each tree greater than 1.00" dbh and falling within the 20 BAF variable radius plot will be measured and tallied. All borderline trees will be determined to be "in" or "out" by calculating the limiting distance of each borderline tree with slope corrections applied as necessary.

Limiting Distance for all borderline trees will be determined using the following method:

- a) Measure, from the uphill side, the diameter (dbh) of the borderline tree to the nearest 0.1" (inch) and mark the point at which the measurement was made with a paint stick.
- b) Measure to the nearest 0.1' (1/10th foot) the horizontal distance from the pith of the tree (at dbh) to point center.
- c) Calculate the limiting distance of the tree by using a lookup table of plot radii for trees of different diameters for a 20 Basal Area Factor prism. If the resulting distance is greater than the measured horizontal distance then the tree is "in" and will be recorded in the tally. Conversely, if the measured distance is greater than the calculated limiting distance then the tree is "out" and is not to be recorded.

NOTE: Adjustments to correct for slope when determining limiting distance of borderline trees will be made by sighting a clinometer or laser hypsometer on a point at eye level upon the tree in question and recording the percent slope. Determine the Slope Correction Factor from the conversion table and multiply this figure by the limiting distance of the tree to calculate the slope corrected limiting distance. Then, measure the distance, parallel to the slope, from the face of the tree to point center. If this measurement is less than the slope corrected limiting distance the tree is "in" and recorded in the tally. Conversely, if the measured distance is greater than the slope corrected limiting distance the tree is "out".

- 6.) The following information will be recorded on the PDA (using Pocket Dog) for all trees tallied at each sample point location. PLEASE NOTE: Items 'E' and 'F' will only be collected on every fifth plot. These plots will be delineated during the creation of the cruise maps, and will be the same plots that increment boring data and down & dead woody debris information will be taken (see NOTE under section 7: Text Data Fields as well as section 8B below).
 - A. Species (**SP**), from the specified Species Code List incorporated within each PDA unit for Pocket Dog.
 - B. Product Code (**PROD**) for each tree tallied is to be recorded as per the code list provided within the Data Processing section listed below.

- C. Diameter (**DBH**) measured at a point 4.5' above the ground (dbh) on the uphill side of the tree. Diameters will be measured with a diameter tape. All trees 1.00 inches dbh and larger will be recorded by One (1) inch diameter classes as follows:

<u>Diameter Range</u>	<u>Diameter Class</u>
1.00" – 1.49"	1"
1.50" – 2.49"	2"
2.50" – 3.49"	3"
3.50" – 4.49"	4"
etc.	etc.

- D. Merchantable Height (**MHT**).

Sawtimber: record the number of 16' logs (minimum ½ log) to the nearest ½ log to a minimum top diameter of 10 inches or to a point where the tree no longer meets **USFS grade 3** specifications due to forks, crook, excessive sweep, defect, etc. Record all ½ logs as a 5 (i.e. 1½ log tree = 15).

Pulpwood: record the number of 16' logs by estimating the number of 8 foot bolts contained in each merchantable stem to a minimum top diameter of 4" or to a point where the tree becomes un-merchantable due to forks, defect, etc. Individual trees must contain at least one 16' log (10).

***Minimum Standards for Diameter and Height**: Sawtimber trees must be **11.5" dbh** or greater and contain at least 8 feet of grade 3 log (10" minimum top diameter) anywhere in the stem. Pulpwood trees must be at least **6.0" dbh** or greater and contain at least one 16' log (10).

NOTE: Non-commercial size poles (6.0" dbh and smaller) will be tallied either as pulpwood or cull, and be given a height of one log (10). These poles will not be included in any volume reports, but will be used in stems per acre reporting analysis. Stems will be considered pulp when they are deemed to be healthy and good growing stock.

Culls: any live stem not meeting the above requirements for sawtimber or pulpwood will be recorded as cull and given a merchantable height of one log (10).

- E. Biomass Height (**BHT**) will be recorded to the nearest foot. This measurement will be made at the top point of the main stem that is 4.0" DOB (Diameter Outside Bark). This will be taken for all sawtimber, pulpwood, and culls. Minimum height for all products is 15 feet.
- F. Total Height (**THT**) will be recorded to the nearest foot. This will be taken for all sawtimber, pulpwood, and cull stems.
- G. Defect (**DFC**) will be recorded as a percentage within the given tree by increments of 10%. For a tree with no defect (100% sound), no entry will be made. A tree with 10% defect is recorded as a 10, a tree with 30 % defect is recorded as a 30, and so on. Determinations for defect will be made using Table A provided below. Defects can be recorded for both sawtimber and pulpwood.

- 7.) Text Data Fields. Upon completing tree data collection for each sample point, comments or observations about the surrounding stand area including forest cover type, wildlife habitat, density and size classification will be made and recorded as per the criteria set forth within the Data Collection Summary for Pocket Dog on PDAs listed below.

NOTE: The last two items under Data Collection Summary for Pocket Dog on PDAs are for increment boring recording. Cruisers will collect increment borings on the first co-dominate sawtimber tree north of plot center for yellow poplar, red oak, white oak, sugar maple, red maple, or other miscellaneous hardwoods. This will be collected on every 5th point. Choosing the first co-dominant tree north of plot center should ensure an adequate sampling of these major species.

8.) Additional Data on Pocket Excel. The following data will be collected outside of Pocket Dog in a Pocket Excel file that each cruiser will create at the start of each day.

A. Snags: **On every plot**, any snag that is encountered within the 20 BAF prism will require the following data to be collected under the snags tab:

- Species (using codes listed under data processing)
- DBH (1 inch classes)
- Decay Class (1 = sound; 2 = rotten)
- Snapped (1 = tree is intact; 2 = top snapped off)
- Total Height (or height of highest point if top is snapped off)(minimum 15ft height)

Note: Snags not meeting 15 foot height requirement will not be tallied.

B. Down & Dead Woody Debris: **This data will be recorded at every 5th plot.** The procedure described in Appendix B will be used to determine which stems will be tallied. Stands harvested in the last ten years as determined and mapped prior to the inventory by The Nature Conservancy and Forecon Inc will use a 300ft³ factor with a 33 foot limiting factor and all other stands will use a 200ft³ factor with a 66 foot limiting distance.

For each piece record the following:

Plot #

Piece #

Species (using codes listed under data processing)

Diameter

Decay Class (1 = sound; 2 = rotten)

Note: Stem must be at least 8 feet long and 5 inches in diameter to be tallied.

Data Processing

All inventory data will be down-loaded, processed and compiled by FORECON, Inc. using the TWO DOG 2.0 program. Listed below are the form classes to be used for sawtimber volume computations in the TWO DOG 2.0 program:

Species	Species Code	Form Class
Red Oak	1	78
Black Oak	2	78
White Oak	3	78
Chestnut Oak	4	78
Scarlet Oak	5	78
Black Walnut	6	78
Yellow Poplar	7	80
Cucumber	8	80
Sugar Maple	9	79
Red Maple	10	79
Black Cherry	11	80
White Ash	12	80
Basswood	13	78
Sycamore	14	80
Elm	15	78
Hickory	16	78
Birch	17	78
Aspen	18	78
Beech	19	80
Black Locust	20	78
Blackgum	21	78
Buckeye	22	78
Butternut	23	78
Cottonwood	24	78
Sassafras	25	78
Sourwood	26	78
White Pine	27	80
Hemlock	28	78
Paulownia	29	78
Magnolia	30	78
Sweetgum	31	78
Red Spruce	32	80
Red Pine	33	80
Virginia Pine	34	80
Miscellaneous Hardwood	35	78
Miscellaneous Softwood	36	80

Reports & Deliverables

The following will be provided for each tract:

1. Timber Volume and Valuation Report - A report will be developed to provide current sawtimber, pulpwood, and growing stock volumes along with current market valuations per tract. These estimates will be an opinion of fair market value at the time of the inventory. Stumpage prices will be assigned at the tract level; but will not account for individual tree or stand level quality. The prices used to estimate value will be subjectively based on any combination of published and unpublished data or FORECON, Inc. timber sales at or prior to the development of the report. Markets can and will change over time and any pricing cannot be guaranteed beyond market conditions at the time the report is written.
2. Field Data - Will be delivered as Two Dog job files for each tract.
3. Cruise Maps - Electronic formats (.pdf) will be created for each tract. These final maps will show plot locations and stand lines.
4. Shape files will be developed of the plots as well as the stands that are created during the timber inventory phase. A stand and plot shapefile will be provided with the following attributes;
 - a. Cruise Plot shapefile
 - i. Plot number
 - ii. Acceptable regeneration (4" to 48" height)
 - iii. Acceptable regeneration dominant species (4" – 48" height)
 - iv. Acceptable regeneration 48"+ height
 - v. Acceptable regeneration 48"+ height dominant species
 - vi. Invasive species
 - vii. Invasive species percent cover
 - viii. Forest pest species
 - ix. Forest pest intensity
 - x. Increment boring species
 - xi. Increment boring length
 - b. Stand shapefile
 - i. Stand number
 - ii. Acres
 - iii. CAR forest type
 - iv. Total stand sawtimber MBF volume
 - v. Total stand pulpwood volume
 - vi. Total stand sawtimber stems
 - vii. Total stand pulpwood stems
 - viii. Per acre stand sawtimber basal area
 - ix. Per acre stand pulpwood basal area
5. Ecological attributes (text data fields) that are taken will be linked to each individual plot. Maps will be provided as described below;
 - a. Map #1, Plot Level Acceptable Regeneration between 4" & 48" in height – Plots will be sized to show the count of desirable regeneration stems between 4" and 48" and color coded to show dominant species.
 - b. Map #2, Plot Level Acceptable Regeneration greater than 48" in height – Plots will be sized to show the count of desirable regeneration stems greater than 48" height and color coded to show dominant species.
 - c. Map #3, Plot Level Invasive Species – Plots will be sized to show percent of invasive species encroachment upon the plot and color coded to show invasive species.
 - d. Map #4, Plot Level Forest Pest – Plots will be sized to show the intensity of the pest occurrence and color coded to show the pest species.
 - e. Map #5, Plot Level Increment Cores – Plots will be sized to show the 10 year radial growth rate and color coded to show the species cored.

Audit

1. FORECON, Inc. will perform an internal audit of the field work. A minimum of 4% of the plots of each cruiser will be checked.
2. The internal check cruise will be performed by the designated field crew supervisor or approved representative. Internal audit results will be made available to the seller at regular intervals throughout the inventory upon request.
3. At each point the team will evaluate and tally errors in the cruiser's work as follows.
 - a. A sawtimber tree that is tally-able and on the plot but was not tallied is a missed tree. An out tree is a sawtimber tree that is not on the plot or not tally-able, but was tallied by the cruiser. Each missed in or out sawtimber tree on the plot shall count as one error. A +/- .5 foot tolerance in limiting distance will be allowed on borderline trees on level or gently sloping ground. A +/- 1.5 foot tolerance will be allowed on slopes of 20% or greater. (Limiting distances will be made to the pith of the tree in accordance with appropriate limiting distance tables.) Check cruisers must exercise due caution to ensure that the pin flag representing point center has not been moved from its original location before assessing errors in this category.
 - b. Each tree for which the cruiser tallies the incorrect species will be counted as one error.
 - c. Each sawtimber tree for which the cruiser tallies the incorrect DBH will be counted as one error.
 - d. Each sawtimber tree for which the cruiser tallies the incorrect merchantable height will be counted as one error. Cruisers will be allowed a variance of +/- .5 logs for merchantable heights. **
 - e. Each defect deduction recorded for a sawtimber tree must fall within 10% of defect deemed appropriate by the auditor, or auditing team. If the defect recorded exceeds this amount it will be recorded as an error.

**** Note:** Check cruisers must use good judgment when assessing errors in tree height and defect. It is the combination of these two parameters that contribute to an accurate accounting of volume in grade 3 or better sawlogs per tree. Errors may be recorded for severe or consistent deviations from acceptable measurements.

4. When a check cruise for a particular cruiser is complete (10 plots suggested minimum), the total number of errors will be calculated and divided by the total number of trees included in the check cruise plots. If the per tree error rate exceeds .10 or 1 per 10 trees the field work is deemed unacceptable. All unchecked work by the cruiser who performed the unacceptable work must be redone and the cruiser must be retrained by the supervisor as to field procedures.

DATA COLLECTION SUMMARY FOR POCKET DOG ON PDAS

Plot Level Data Collection

Tract ID: Tract Name

Date: Month/Day/Year (numerical)

Filename: Tract_Cruisers Initials_Date

Line/Point: Numerical designation from inventory map.

Comments: List any general notes or information pertinent to the plot or stand conditions including forest health, harvesting, unproductive/non-forest areas, site limitations, etc.

Text Data Fields: Items 1 through 8 will be taken at every plot. Items 9 and 10 will be taken at every 5th plot.

Individual Stem Data Collection

Species (SP): From the numerical code list for Pocket Dog.

Product Code (PROD):	Sawtimber	01
	Pulpwood	02
	Cull	05

DBH: Diameter Breast Height by one-inch diameter classes.

Merchantable Height (MHT): For all Sawtimber and Pulpwood trees record the number of 16-foot logs to the nearest ½ log. Record ½ logs as a 5 (i.e. 2½ log tree = 25). Minimum height for sawtimber is 5. Minimum height for pulpwood is 10.

Biomass Height (BHT): For all stems record the height to the point of the main stem that is 4.0" DOB (Diameter Outside Bark) to the nearest foot.

Total Height (THT): For all stems record the total height to the nearest foot.

Defect (DFC): Recorded as a percentage of the defect within the tree by increments of 10% (i.e. a tree with 30% defect is recorded as 30, and a tree with 40% defect is recorded as a 40).

Text Data Fields

Acceptable Regeneration (4" to 48" height): Using a 3.7 foot radius plot, record number of healthy seedlings of commercial tree species that are 4" - 48" tall.

Acceptable Regeneration Dominant Species (4"- 48" height): Using the species codes found in TABLE B, record the dominant regeneration species.

Acceptable Regeneration 48"+ height: Using a 3.7 foot radius plot, record number of healthy seedlings of commercial tree species that are 48"+ tall.

Acceptable Regeneration Dominant Species (48"+ height): Using the species codes found in TABLE B, record the dominant regeneration species.

Invasive Species: Using a 52.6 foot radius plot, record the most dominant invasive species from the following list:

- *Ailanthus altissima* Tree-of-heaven
- *Alliaria petiolata* Garlic mustard
- *Celastrus orbiculata* Oriental bittersweet
- *Elaeagnus umbellata* Autumn olive
- *Microstegium vimineum* Japanese stilt grass
- *Rosa multiflora* Multiflora rose

Note: Cruiser should record all other instances, besides the dominant species, in their Comments.

Invasive Species Percent Cover: Using a 52.6 foot radius plot, record the percent cover that the most dominant invasive species occupies.

Forest Pests: Using a 52.6 foot radius plot, record the most prevalent forest pest that is found from the following list:

- Butternut canker
- Hemlock woolly adelgid
- European gypsy moth

Note: Cruiser should record all other instances, besides the most prevalent pest, in their Comments.

Forest Pests Intensity: Using a 52.6 foot radius plot, record the intensity of the most prevalent infestation using the following list:

- Low: 2 or less occurrences
- Moderate: 2 to 4 occurrences
- Severe: 4 or more occurrences

Increment Boring Species: On all increment boring plots (every 5th plot) record the species that is cored from the following list:

- Yellow-poplar
- Northern Red Oak
- White Oak
- Sugar Maple
- Red Maple
- Miscellaneous Hardwood

Increment Boring Length: Measure and record the last ten years of growth (in tenths of inches).

TABLE A

VOLUME DEDUCTIONS (Percent)								Bolt No.	
60-64							2-100	8	
56-60							3-100		
52-56						3-100	4-90	7	
48-52						3-100	4-90		
44-48					5-100	4-90	4-90	6	
40-44					5-90	5-90	5-80		
36-40				7-100	6-90	6-80	6-80	5	
32-36				7-90	7-80	7-80	6-70		
28-32			9-100	8-90	7-80	7-70	6-70	4	
24-28			10-90	9-80	8-70	7-60	7-60		
20-24		13-100	11-80	9-70	9-60	8-90	8-50	3	
16-20		14-90	11-70	10-60	9-50	9-50	8-40		
12-16	21-100	15-70	12-60	11-50	9-40	9-40	8-40	2	
8-12	23-80	17-60	14-50	12-40	11-30	10-30	9-30		
4-8	39-100	26-60	19-40	16-30	13-30	12-20	11-20	10-20	1
0-4	61-60	30-30	22-20	17-20	14-10	12-10	11-10	10-10	

* Merchantable height must exceed this figure to qualify (exception 1 bolt height)

TABLE B:

Dominant Regeneration Species List
mixed oak
poor oak
yellow-poplar
hard maple
red maple
black cherry
other desirable
other undesirable

DATA MANAGEMENT & PROCESSING

- 1) Project Manager fills out Project Outline Report and provides direction to crew boss and crew members.
- 2) Crew boss provides copies of Project Outline Report to crew members.
- 3) Field collection of data by crew members.
- 4) Crew members close the PocketDog software to ensure that all trees/points have been safely recorded and backup the job file.
- 5) Crew members swap files with crew boss and other crew members.
- 6) Crew boss and crew members open swapped files and verify that plot/tree tallies are correct.
- 7) Crew boss and crew members back up files to SD chips.
- 8) Crew boss fills out, dates and initials Daily File Report
- 9) Crew members upload data to office computers, fill out Two Dog Log Book and error check their own job files releasing custody of data to crew boss. Or, crew boss uploads files and ensures that the field crew error check their own files at a later date. Crew boss does not release custody of job data to the Project Manager until each crew member has error checked his/her own file.
- 10) Crew boss releases custody of job data to Project Manager.
- 11) Project Manager takes custody of data and cross-references Daily File Reports against Client Manager report.
- 12) Project Manager directs office personnel to merge job files and print hardcopy of reports that will be stored in the job file.
- 13) Project Manager validates sale reports and sends data to clients

DEFENITIONS:

Culls: A live tree that has no commercial value as a result of poor shape or damage from injury, insects or disease.

Snags: A dead tree that is still standing.

Sawtimber: See Section 6D under Methodology.

Pulpwood: See Section 6D under Methodology.

FAST, PRACTICAL PERPENDICULAR DISTANCE SAMPLING

Mark J. Ducey

June 2007

Introduction

The newest field method for downed wood inventory is based on very elegant (some would say obscure!) mathematical theory. But it is easy to implement, and it has also proven to be the fastest and most effective in the field in a wide range of conditions.

In the proceedings for a 2001 workshop on downed wood inventory, I wrote: “There are two methods of CWM inventory that we know are quick and reasonably accurate: line intersect sampling (or LIS), and point relascope sampling (or PRS)”. In 2001, that was a perfectly true statement. About a year later, I heard from Mike Williams and Jeff Gove about a new method they had developed. From a mathematical standpoint, the method was beautiful. But my first reaction was that it would be wildly impractical in the field. “Nothing ventured, nothing gained,” I thought. It was the end of the summer and I had two students working for me who knew LIS backwards and forwards. I sketched out a protocol for PDS and had the students do a quick comparison study in a couple of nearby stands. I expected dismal failure.

Two weeks later, I analyzed the data the students brought in. PDS was unbiased in practice, and gave results of comparable quality to LIS (as judged by standard error) in about 20% of the time. To be sure, there were still a few details to work out; the basics of the method are documented in Williams and Gove (2003), but important practical issues are covered in Williams et al. (2005a, 2005b). Manuscripts covering the field trials are still making their way through the peer-review system, but the results have been consistent from New England, to the Colorado Rockies, to coastal British Columbia: PDS is consistently the most efficient method, often by a huge margin.

How Does It Work?

PDS is a probability proportional to size (PPS) method. Nearly all foresters have been trained in another PPS method: prism cruising. Recall that in prism cruising, each tree is surrounded by an “inclusion zone” – the area from which the tree can be tallied. In prism cruising, that inclusion zone is a circle with radius proportional to DBH. The area of the circle is proportional to tree basal area. That means trees are sampled with probability proportional to their basal area. If all we care about is basal area, we merely have to count trees and multiply by the basal area factor (BAF).

In PDS, we establish a sample point, and then sight on downed logs at their “perpendicular point”—the point on the log at which our line of sight is perpendicular to the log axis. In principle,

what we want to know is the cross-sectional area of the log at that perpendicular point, and the distance from the sample point to the perpendicular point. We include logs in the tally only if they are closer than a critical distance that is proportional to cross-sectional area (Figure 1). The volume per acre is just the number of logs tallied, times a volume factor that depends on the proportion between distance and area.

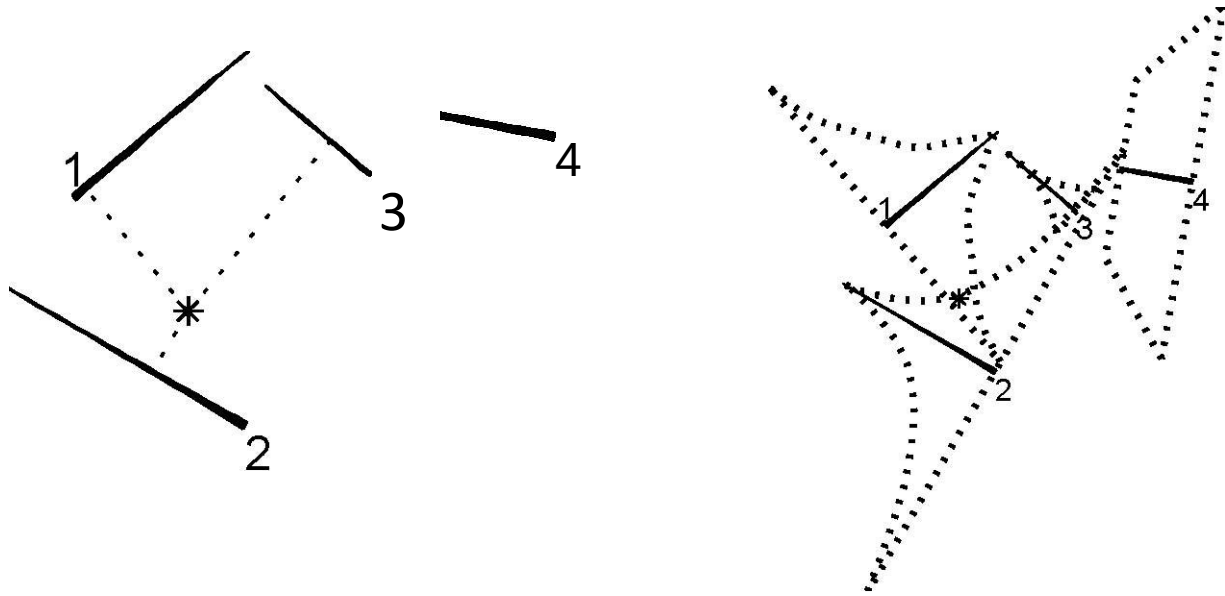


Figure 1. The left panel illustrates the geometry of PDS. From the sample point (*), we sight on the logs at their perpendicular point. We are past the end of log 4, so log 4 doesn't have a perpendicular point. For logs 1, 2, and 3, if they are large enough in relation to their distance, they can be tallied. The right panel shows the "inclusion zones" for the four logs. The inclusion zones taper as the logs taper. In this case, logs 1 and 2 are close enough to the sample point to be tallied, but log 3 is not.

That sounds complicated, but it really isn't. Here's why:

1. All we need to do is decide whether a log will be tallied, or not. For nearly all logs, a quick estimate of diameter and distance, aided by a simple table, will decide the question.
2. If we can't decide – if our visual estimate of distance and diameter makes a log "too close to call" – all we need is to measure one diameter and one distance, and use the same table to decide if the log was supposed to be tallied.
3. Deriving the volume factor is hard (then again, when is the last time you had to derive the BAF of a prism?). But if you already know the volume factor, the math for estimating downed wood volume is trivial.

At this point, the astute reader may already be wondering what we do for variables other than volume. There are several possible answers, and I'll give a particularly fast, easy one later. Save the question.

Practical Issues

All field methods eventually confront a series of practical challenges. In the case of downed logs, these including sloping logs, forked logs, and crooked logs. PDS also faces some challenges with very thick logs, because of the geometry of the inclusion zones. Let's solve that first challenge, then address the others.

Thick Logs (or portions of logs)

Look again at Figure 1. You'll see that the inclusion zones can flare out dramatically at the basal end of the logs. That's because the critical distance is proportional to cross-sectional area, which is proportional to the *square* of log diameter. Double the diameter of a log, and you quadruple the distance from which the log should be tallied. That's fine, until you realize that a very thick log should be tallied from a very long distance away... and you might not see it, or you might waste many minutes searching around a sample point just in case there's a large log out there somewhere. Either situation is bad.

A practical solution is to "cap" the critical distance at some reasonable value (usually related to the expected visibility from sample points to logs). For logs (or portions of logs) that are small enough, this solution has absolutely no effect. For logs (or portions of logs) that are thick enough, it means we don't have to look as far – but it means we *do* have to record the diameter at the perpendicular point, and we *do* have to know the diameter to know how much volume the log represents. But that's easy to put into a table...

To distinguish PDS with a capped critical distance from ordinary PDS, we call this approach "distance-limited PDS."

Crooked, Forked, and Sloping Logs

For nearly every other downed wood inventory technique, logs with crooks, forks, and slope present separate challenges that require separate correction techniques. In PDS, the correction technique is the same. It's also fairly easy (provided you understand some basic geometry, and are willing to do a little math back in the office).

Here's the important geometric setup. It has two parts:

1. The log axis in Figure 1 is *straight and horizontal*. Now, suppose we have a log that has isn't straight, isn't horizontal, or both. Where is its log axis? It's easy to find one end: the pith (or where the pith would be, if it hadn't already rotted away) at the basal end. The other end is over, under, or at the other end of the log. If the log is forked, pick the tip that is farthest from the first end. Connect the two ends with a line – and, if necessary, level the line – and that is the log axis. If the log has a lot of sweep, the log axis may not follow the log, but that's OK. The perpendicular point and the critical distance are always judged from the sample point to the log axis.
2. The cross-sectional area that determines whether or not a log is counted is *in the plane perpendicular to (or "normal to") the log axis*. The cross-sectional area that matters is really the area in a vertical slice perpendicular to the log axis, not necessarily perpendicular to the log itself. If the log is sloped, the area may well be slightly elliptical. Likewise, if the log is crooked (or even very rotten!), the area may be slightly elliptical. You can be fancy (calculate the area of an ellipse) or simple and approximate

(average two diameter measurements) depending on your need for precision.

What about forked logs? If the plane slices through the log on more than one branch, what we need to do is accumulate the *area* (not the diameter!) from those branches. Remember that the first task is to decide whether the log *might* be tallied, so visualize taking bolts from those branches and bundling them up. If the accumulated cross-sectional area doesn't reach the cross-sectional area for a single stem of the diameter that would be tallied, then you don't have to worry about the forked log any more! If it does, then record the diameters of those branches, and sum up the area back in the office, just to be sure.

What About Variables Other Than Volume?

Think back to prism cruising. We know how much basal area per acre every tree represents (the BAF). To find out how many trees per acre a tree represents, we measure its DBH, use that to calculate the basal area of the tree, and then divide that into the BAF. Simple. Why don't we do that for PDS?

Well, we could, but it would be a lot of work to get an accurate volume for a log (especially for heavily decayed or forked logs!). There are a couple of other solutions we could use in PDS, but they still involve work, and would slow the method down a lot. The question is, what variables do you really care about?

In operational forestry in New England, the following variables *don't* seem terribly important:

- ☐ Total number of logs per acre. Most of the "logs" are fairly small bits of wood. There are a lot of them. Knowing just how many "a lot" is doesn't impact any management decisions.
- ☐ Surface area coverage. This might be important in other regions.
- ☐ Aggregate measures of size such as total length of logs per acre, or sum of squared lengths.

What does seem useful is number of very large logs per acre, especially if those logs are hollow. By "large" we mean large at the basal end; a mammal doesn't care too much what's at the tip if the base will make a good den site. The fastest and easiest way to get the number of large logs, is to count only the large logs on a smallish ($1/10^{\text{th}}$ acre or so) fixed radius plot. There's no reason (practical or theoretical) why we can't augment PDS in this way.

For a research-grade survey, where any and every downed wood variable might eventually be of interest, consider one of the alternative methods. The papers describing those methods are still in the peer-review process, so contact Mark Ducey for the latest version.

Worked Example

Let's suppose, for the moment, that we are doing PDS in the woods with a volume factor (VF) of 200 ft^3/acre . (That factor seems to work well in a variety of stand conditions.) We tally 4 logs using PDS. Then our estimate of volume per acre is $4 \times 200 = 800 \text{ ft}^3/\text{acre}$. Do that a whole bunch more times, and take the average, and you are done. Seems simple, right? It is.

Well, not quite that simple, if we've used a distance limit. Now suppose that to avoid having to search far and wide, we've set a distance limit of one chain (66 feet). A portion of a "cheat sheet" for this setup is shown below:

<u>D, inches</u>	<u>A, ft²</u>	<u>PD, ft</u>	<u>Counts as (ft³/ac)</u>
3	0.049	5.3	200
4	0.087	9.5	200
5	0.136	14.8	200
6	0.196	21.4	200
7	0.267	29.1	200
8	0.349	38.0	200
9	0.442	48.1	200
10	0.545	59.4	200
11	0.660	66.0	218
12	0.785	66.0	259
13	0.922	66.0	304
14	1.069	66.0	353
15	1.227	66.0	405
16	1.396	66.0	461
17	1.576	66.0	520
18	1.767	66.0	583

You can see how the critical distance (labeled here as PD) goes up, then levels off when it hits 66 feet. Also, you can see that the logs 10" and smaller at the perpendicular point all count as VF; the others count for more.

So, suppose that we tallied 4 logs from our sample point. 3 of them were 10" or smaller at the perpendicular point, and we probably didn't even write down the diameter. It doesn't matter; those logs each count as 200. The fourth log was 16" at the perpendicular point. It counts as 461 ft³/acre. So our total for this point is 3x200+461=1,061 ft³/acre. Again, you wouldn't cruise the timber in a stand with just one prism point; you will want to put in quite a few points in a stand (or other area of interest), and take the average.

For More Details

The papers by Williams and Gove (2003) and Williams *et al.* (2005a, 2005b) are fairly technical, but document PDS in considerable detail. There is a spreadsheet included on the CD for this workshop that includes a "cheat sheet" for PDS; you can change the volume factor and the distance limit to suit your survey needs. If you would like to explore PDS further, including variants for estimating things other than volume, contact Mark Ducey for further advice.

References

Williams, M.S. and J.H. Gove. 2003. Perpendicular distance sampling: an alternative method for sampling coarse woody debris. *Canadian Journal of Forest Research* 33: 1564-1579.

Williams, M.S., M.J. Ducey and J.H. Gove. 2005. Assessing surface area of coarse woody debris with line intersect and perpendicular distance sampling. Canadian Journal of Forest Research 35(4): 949-960.

Williams, M.S., J.H. Gove, H.T. Valentine, and M.J. Ducey. 2005. Additional results for perpendicular distance sampling. Canadian Journal of Forest Research 35(4): 961-966.

The following table will be used to determine which stems will be tallied:

VOLUME
FACTOR: 200 ft³/acre
DISTANCE LIMIT: 66 ft
K 108.9

D, inches	A, ft ²	PD, ft	Counts as (ft ³ /ac)	D, inches	A, ft ²	PD, ft	Counts as (ft ³ /ac)
3	0.049	5.3	200	25	3.409	66.0	1125
4	0.087	9.5	200	26	3.687	66.0	1217
5	0.136	14.8	200	27	3.976	66.0	1312
6	0.196	21.4	200	28	4.276	66.0	1411
7	0.267	29.1	200	29	4.587	66.0	1514
8	0.349	38.0	200	30	4.909	66.0	1620
9	0.442	48.1	200	31	5.241	66.0	1730
10	0.545	59.4	200	32	5.585	66.0	1843
11	0.660	66.0	218	33	5.940	66.0	1960
12	0.785	66.0	259	34	6.305	66.0	2081
13	0.922	66.0	304	35	6.681	66.0	2205
14	1.069	66.0	353	36	7.069	66.0	2333
15	1.227	66.0	405	37	7.467	66.0	2464
16	1.396	66.0	461	38	7.876	66.0	2599
17	1.576	66.0	520	39	8.296	66.0	2738
18	1.767	66.0	583	40	8.727	66.0	2880
19	1.969	66.0	650	41	9.168	66.0	3026
20	2.182	66.0	720	42	9.621	66.0	3175
21	2.405	66.0	794	43	10.085	66.0	3328
22	2.640	66.0	871	44	10.559	66.0	3485
23	2.885	66.0	952	45	11.045	66.0	3645
24	3.142	66.0	1037	46	11.541	66.0	3809

Appendix C: Modeling Plan for the Rich Mountain Carbon Project

Timothy A. Robards, PhD, CF

Spatial Informatics Group, LLC

The PDD and associated excel files for the Rich Mountain Carbon Project contain all the material included here, however, this plan puts in one place the requirements of Appendix B.3 (Modeling Requirements) of the protocol.

1. Silvicultural Methods Modeled. The following elements are to be included:
 - a. Description of trees retained at harvest.
 - b. Harvest frequency.
 - c. Regeneration assumptions.

Table C.1. Silvicultural prescriptions modeled for the project activity. Clearcut in years 5 and 75 and single tree selection with 50 sq. ft. per acre basal area retention every decade with no species retention preference were also modeled for the baseline.

Strata	Rx ID	Rx Description	Activity Trigger(s)	Residual Stocking	Species Retention Preferences	Frequency to Check Trigger	Minimum Post-Harvest Time
Oak-Hickory	OHREG	Regeneration	18" Average DBH	15	Red Oak, White Oak	10 yrs	70 yrs
	OHTHIN	Harvest w/Reserves	>120 BA	80	Red Oak, White Oak	10 yrs	20 yrs
		Thinning from below	<16" Average DBH				
Cove Hdws	CHREG	Regeneration	18" Average DBH	15	Yellow Poplar, Red Oak, Sugar Maple	10 yrs	70 yrs
	CHTHIN	Harvest w/Reserves	>130 BA	80	Yellow Poplar, Red Oak, Sugar Maple	10 yrs	20 yrs
		Thinning from below	<16" Average DBH				
Northern Hdws	NHREG	Regeneration	18" Average DBH	15	Sugar Maple, Black Cherry, NRO	10 yrs	70 yrs
	NHTHIN	Harvest w/Reserves	>130 BA	80	Sugar Maple, Black Cherry, NRO	10 yrs	20 yrs
		Thinning from below	<16" Average DBH				
Mixed Hdws	MHREG	Regeneration	18" Average DBH	15	Red Oak, White Oak, Red Maple	10 yrs	70 yrs
All	GRSEL	Harvest w/Reserves	16" Average DBH	0		20 yrs	70 yrs
		Group Selection	Avg 1-acre size				20 yrs

Natural regeneration was modeled utilizing the sprouting feature of FVS, since these were primarily sprouting hardwoods. The non-forested stands were populated with a single cohort of early successional species in the first decade. The following table shows the per acre values by species. These were selected to emulate the pioneer species established from adjacent stands at a density post initial stem exclusion.

Table C.2. Regeneration for non-forested rangeland.

Species	Trees Per Acre
Black locust	100
Ash	100
Yellow popular	100
Red oak	5
Red maple	5
Elm	100
Total	410

2. A list of all legal constraints.

This may be found in sections 2.d and 5.c.i of the PDD. The only legal restriction modeled was to ensure that sufficient acres were maintained in riparian buffers to meet the State of Virginia requirement for retaining half of the volume in a 50 foot buffer on either side of watercourses. This was implemented by constraining the harvest in each strata to maintain either no harvest, thinning or single tree selection in those acres.

Table C.3. Restricted riparian acres by type.

CAR Assesment Type	Acreage
Oak - Hickory	25.7
Northern Hdwd	61.8
Mixed Hdwd	83
Cove Hdwd	109.6

3. A description of the site indices used by species.

Site index was estimated from the USDA NRCS soil series information available online from their website. The soils layer was overlaid with plot locations to estimate the soil type for each plot. Site index, by species, was associated with each soil type.

The data analysis and assignment of site indices to individual plots may be found in the inventory spreadsheet, in the *PlotSoilIntersection* sheet. There is a listing of the plot ID, site species code and 50-year site index value for 822 plots.

4. A description of the model used.

The Southern Variant of the Forest Vegetation Simulator (Keyser 2010) was used to model forest growth, mortality and harvest over time. Simulations were conducted in 5-year increments with harvests simulated mid-decade. No calibrations were done to the models. A minimum harvest level of 2,000 board feet per acre was required to ensure that modeled harvests were economical.

The project start date is June 20, 2002. In order to produce a baseline estimate and project the project activity for the first decade of the project, it was necessary to backdate the 2011 inventory to the start date. The inventory was backdated to the beginning of 2002. The backdate process used the following steps in MS Excel:

- 1) Decrement each tree diameter annually (Husch et al. 1993) using the average inside bark diameter increment, by species group, and the predicted bark ratio for the given tree size and species (Keyser 2010).
- 2) Annually decrement each tree total and merchantable height by calculating the difference in height from the height-diameter function and subtracting that from the respective height.

- 3) Add tree records to the plots in each year where harvest occurred. Harvest stand tables were estimated from the cut reports.

Modeling outputs must include two items, which are listed below with references to the outputs in the PDD.

1. Periodic harvest, inventory and growth estimates for the entire project area presented as total carbon tonnes and carbon tonnes per acre.

This may be found in tables 12 and 16 of the PDD for the baseline and project activity for the total carbon stocks estimates. This is shown below (Table C.4), with annual change or growth, along with the per acre estimates (Table C.5).

Table C.4. Total CO2e estimates of the baseline with growth shown as annual change in stocks.

Year	AG Live Tree	BG Live Tree	Standing Dead	Cut-All	Cut-Merch	Live Tree Growth	Dead Tree Growth
2002	288,584	55,763	14,970	343,731	184,024		
2012	78,324	15,088	14,970	617	332	(25,093.48)	-
2022	98,180	18,890	14,970	1,174	637	2,365.82	-
2032	147,097	28,505	14,970	1,477	800	5,853.24	-
2042	265,855	51,856	14,970	1,950	1,059	14,210.76	-
2052	422,005	82,285	14,970	2,631	1,431	18,657.95	-
2062	576,513	112,048	14,970	2,281	1,246	18,427.14	-
2072	713,362	138,166	14,970	711,998	368,270	16,296.58	-
2082	184,695	35,327	14,970	2,056	1,133	(63,150.55)	-
2092	190,894	36,483	14,970	2,149	1,177	735.47	-
2102	224,785	43,196	14,970	-	-	4,060.48	-

Table C.5. Per acre CO2e estimates of the baseline with growth shown as annual change in stocks.

Year	AG Live Tree	BG Live Tree	Standing Dead	Cut-All	Cut-Merch	Live Tree Growth	Dead Tree Growth
2002	50.2	9.7	2.6	59.8	32.0		
2012	13.6	2.6	2.6	0.1	0.1	(4.37)	-
2022	17.1	3.3	2.6	0.2	0.1	0.41	-
2032	25.6	5.0	2.6	0.3	0.1	1.02	-
2042	46.3	9.0	2.6	0.3	0.2	2.47	-
2052	73.4	14.3	2.6	0.5	0.2	3.25	-
2062	100.3	19.5	2.6	0.4	0.2	3.21	-
2072	124.1	24.0	2.6	123.9	64.1	2.84	-
2082	32.1	6.1	2.6	0.4	0.2	(10.99)	-
2092	33.2	6.3	2.6	0.4	0.2	0.13	-
2102	39.1	7.5	2.6	-	-	0.71	-

2. Harvest yield streams on modeled stands, averaged by silvicultural method and constraints, which must include the period over which the harvest occurred and the estimated volume of wood removed.

This may be found in the HarvestScheduleRichMtn excel spreadsheet, in the *DataBL* sheet for the baseline and in the *DataPA* sheet for the project activity.

Rounding:

Due to the large number of records and the differences in precision between Microsoft Excel and the F VS model some rounding error occurred. These rounding errors ranged from .01% – 2%. FVS rounds total heights, dbh, crown ratio, trees-per-acre; and other computer processing rounding error may be introduced, which results in different estimates of carbon stocks from the excel based calculations, namely the de-grow process and actual carbon stocking as of January 1, 2011. The carbon stocks on the project start date were considerably below Common Practice and the Minimum Base Line, thus no additional credits were gained or lost when using one number versus the other, as the Minimum Base Line had to be crossed before CRTs were issued. For forward projections, any modeling errors (to include rounding) will be trued up when the next inventory occurs in 2021.

References

Husch, B., C.I. Miller, and T.W. Beers. 1993. Forest Mensuration. Krieger Publishing Company, Malabar, Florida.

Keyser, C.E. 2010. Southern (SN) Variant Overview – Forest Vegetation Simulator. Internal Rep. U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 69.

Appendix D: Biomass Equations and Calculation Methods

Calculating biomass for a Reserve project requires several steps. For projects located outside of California, Oregon, Washington, Alaska, and Hawaii, an adjusted Component Ratio Method (CRM) for determining biomass for trees is required by the Reserve. The CRM approach was developed by the U.S.F.S. to provide for a consistent approach to determining biomass in all of the above and below ground components of live trees. The steps to convert individual trees to metric tons of CO₂e are listed below:

1. Calculate the biomass of the bole portion of the stem for each tree using the equations and instructions provided by the Reserve in a document titled: "Cubic Foot Volume Equations for the United States outside of California, Washington, Oregon, Alaska, and Hawaii" which is dated September 23, 2010 and can be found at: http://www.climateactionreserve.org/wp-content/uploads/2010/02/Volume_Equations_for_the_United_States_outside_of_California_Oregon_Washington_Alaska_and_Hawaii.pdf

The equations relevant to this project are attached as Appendix D.

2. The proper equation to use in Step 1 is determined by which Supersection the project is located within. Additionally the equations are species dependent. The species references and equation coefficients are provided by the Reserve in an Excel file located at: http://www.climateactionreserve.org/wp-content/uploads/2010/02/Volume_Equation_References_and_Coefficients_by_Species_for_Supersections_outside_of_CA_WA_OR_AK_HI_092310.xlsx

Appendix E provides the species equation reference along with the equation coefficients that are used in the biomass calculations in the Rich Mountain Project. Note that several species are present in the inventory that are not referenced in the Assessment Area Equation reference listed above. The species substitutions are also listed in Appendix E.

3. Once the cubic volume of the stem has been calculated following Steps 1 & 2 above the CRM approach is used to calculate the biomass of the remaining parts of the tree. The estimates from the Jenkins CRM method are adjusted by a ratio which is calculated using the bole biomass of the volume equations relative to the Jenkins bole biomass. The method is described in detail in the *"Database Description and Users Manual for Phase 2, version 4.0, revision 2 Appendix J, dated December, 2009."* The complete methodology is attached as Appendix F. Also in Appendix F are the species specific coefficients required to complete the CRM methodology. These references can also be found on the Reserve website at: <http://www.climateactionreserve.org/how/protocols/forest/resources/#biomass-equations>
4. Standing dead was calculated in FVS as it was deemed to be more accurate and would predict how standing dead wood changed over time according to the anticipated management. The submodel of FVS that tracks standing dead wood from time of death to transition to down dead wood is the Fire and Fuels Extension (FFE) (Rebain 2010). A full description of the standing dead tree model and carbon accounting may be found in Rebain(2010). Section 2.3 contains a description of the standing dead wood "snag" model. Existing snags are entered into the simulator by putting them in the tree list with the live trees, only indicating that they are dead via the status code. Snags are created by the simulator from the mortality models in FVS. Both the background and density-sensitive mortality models were switched on during the simulations. Snag records

are maintained internally by species and size classes of given age cohorts. There are three specific models for snags:

- There is a model for snag height reduction (2.3.4) that is a function of age, height, species and softness.
- There is a model for decay (2.3.5) that is a function of age, dbh and species.
- There is a model for fall down (2.3.6) that is a function of species, size, fire killed and sometimes decay status.

Section 2.6 contains a description of the carbon accounting for snags, which is termed “standing dead” in this section. Standing dead includes dead trees, including stems and any branches and foliage still present, but not including roots. The standing dead can only be calculated by the model using the FFE biomass functions, which is segmented into models for snags below or above 3 inches dbh. The FFE biomass functions and the model parameters specific to the Southern variant of FVS may be found in section 4.16 of the FFE document. Bole volume is based on the default FVS volume equations, which for the Southern variant of FVS may be found in Keyser (2010). Bole biomass is then calculated by multiplying volume by the wood density (table 4.16.5 in FFE documentation).

There is no separate tracking of snag belowground carbon in the simulator, thus the live tree ratio to estimate snag belowground carbon outside the simulator. The model reports in metric tons of C per acre that is then converted to CO₂ by multiplying by 3.67.

Appendix E: Volume Equations for the United States outside of California, Washington, Oregon, Alaska, and Hawaii.

Instructions

The equations for calculating cubic foot volume by Supersection and species are provided below for all trees having a **dbh equal to or greater than 5 inches, excluding woodland species**.¹ Refer to the *Volume Equation References and Coefficients by Species for Supersections outside of California, Washington, Oregon, Alaska, and Hawaii* document table available on the website to determine which equations to use and to retrieve the appropriate coefficients by Supersection and species relevant to the project. If an equation is needed for a species that is not listed in your Supersection, contact the Reserve for guidance.

Adjust the resulting VOLCFGRS (gross cubic foot volume) to VOLCFSND (sound cubic foot volume) by subtracting rotten and missing cull volume in the central stem of each tree. Use VOLCFSND with Appendix J of the *FIA Database: Database Description and Users Manual* (FIADB Users Manual) which is titled *Biomass Estimation Using the Component Ratio Method* found on the Forest Project Protocol Resources webpage.

Trees with dbh less than 5 inches do not require cubic foot volume calculations to estimate biomass using the Component Ratio Method. Biomass for trees less than 5 inches in dbh is calculated using Appendix J of the FIA Database Users Manual with dbh only.

Equations

The following equations compute cubic foot volume excluding bark from a 1 foot stump to a 4 inch top (VOLCFGRS).

Hahn, Jerold T., 1984.

Hahn, Jerold T. Tree volume and biomass equations for the Lake States. Res. Pap. NC-250. St. Paul,

MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1984. 10 p.

VOLCFGRS = Cubic foot volume for use with FIADB Users Manual, Appendix J, Tables 4 and 5

DBH = Diameter at breast height (inches)

SI = Site index

A1-A4 = Coefficients by species

SPN = Species number

$$\text{VOLCFGRS} = A1(\text{SPN}) \times \text{SIA}2(\text{SPN}) \times (1 - \text{EXP}(A3(\text{SPN}) \times \text{DBH}A4(\text{SPN})))$$

McClure, J. and Cost, N., 2010.

McClure, J. and Cost, N. Unpublished equations developed by Joe McClure and Noel Cost.

“REF_VOLCFGRS_VW” data base. Acquired from: Glenn Christensen, Resource Monitoring and Assessment/Forest Inventory and Analysis, USDA Forest Service, PNW Research Station, Portland Forest Sciences Laboratory. April 2010.

VOLCFGRS = Cubic foot volume or VOLCFGRS (for use with FIADB Users Manual, Appendix J, Tables 4 and 5)

DBH = Diameter at breast height (inches)

HT = Height (feet)

A1-D2 = Coefficients by species

SPN = Species number

Poles:

Conifer (SPN<300), DBH>=5.0 and < 9.0

Hardwood (SPN>=300), DBH>=5.0 and < 11.0

$$\text{VOLCFGRS} = C1(\text{SPN}) + C2(\text{SPN}) \times \text{DBH}^2 \times \text{HT}$$

Saw timber:

Conifer (SPN<300), DBH>=9.0

Hardwood (SPN>300), DBH>=11.0

$$\text{VOLCFGRS} = D1(\text{SPN}) + D2(\text{SPN}) \times \text{DBH}^2 \times \text{HT}$$

Scott, Charles T., 1981.

Scott, Charles T., Gross cubic foot volume from 1 foot stump to 4 inch top. Northeastern Forest Survey

Revised Cubic-Foot Volume Equations. Research Note NE-304, 1981.

VOLCFGRS = Cubic foot volume or VOLCFGRS (for use with FIADB Users Manual, Appendix J, Tables 4 and 5)

DBH = Diameter at breast height (inches)

BOLEHT = Height at a 4 inch top (feet)

A1-A6 = Coefficients by species

SPN = Species number

$$\text{VOLCFGRS} = A1(\text{SPN}) + A2(\text{SPN}) \times \text{DBH}^3(\text{SPN}) + A4(\text{SPN}) \times \text{DBH}^5(\text{SPN}) \times \text{BOLEHT}^6(\text{SPN})$$

Appendix F: Equation Reference and Equation Coefficients by Species used in the Rich Mountain Biomass Calculations and Species Substitutions

Table F. 1: Equation Reference and Equation Coefficients

Species ID	Common Name	Genus	Species	Equation Reference	A1	A2	A3	A4	A5	A6	B1	B2	C1	C2	D1	D2
531	American beech	Fagus	grandifolia	Scott, Charles T., 1981	-0.6	-0.00711	2.2693	0.01399	2.019	0.6518						
972	American elm	Ulmus	americana	Hahn, Jerold T., 1984	191.45	0.16087	-4.2E-05	2.7469								
540	ash spp.	Fraxinus	spp.	McClure, J. and Cost, N. 2010	0.064004	0.00241							-0.392822	0.001921	0.172701	0.001851
950	basswood spp.	Tilia	spp.	Scott, Charles T., 1981	-0.39	-0.00622	2.0066	0.0131	1.9939	0.6494						
762	black cherry	Prunus	serotina	Scott, Charles T., 1981	-0.04	-0.01783	1.8109	0.01358	1.9905	0.6553						
901	black locust	Robinia	pseudoacacia	McClure, J. and Cost, N. 2010	0.058647	0.002378							-0.206213	0.001592	0.603856	0.001483
837	black oak	Quercus	velutina	McClure, J. and Cost, N. 2010	0.042519	0.002613							-0.513128	0.001775	-0.515373	0.001775
602	black walnut	Juglans	nigra	McClure, J. and Cost, N. 2010	0.058647	0.002378							-0.033805	0.001656	0.42189	0.001596
832	chestnut oak	Quercus	prinus	Scott, Charles T., 1981	-0.26	0.00038	2	0.01068	1.998	0.6438						
261	eastern hemlock	Tsuga	canadensis	Scott, Charles T., 1981	0.24	-0.05895	2.0362	0.04947	2.0172	0.3366						
68	eastern redcedar	Juniperus	virginiana	McClure, J. and Cost, N. 2010	0.052928	0.002853							-0.315878	0.002207	-0.104252	0.002145
129	eastern white pine	Pinus	strobus	Scott, Charles T., 1981	0.11	-0.05977	2.0498	0.04965	2.0198	0.3468						
970	elm spp.	Ulmus	spp.	McClure, J. and Cost, N. 2010	0.032199	0.002589							-0.155066	0.001828	-0.316005	0.001851
544	green ash	Fraxinus	pennsylvanica	Scott, Charles T., 1981	0.06	-0.02437	1.5419	0.01299	1.9885	0.6453						
400	hickory spp.	Carya	spp.	Scott, Charles T., 1981	-0.27	-0.00466	2.1575	0.01174	2.0035	0.664						
833	northern red oak	Quercus	rubra	Scott, Charles T., 1981	-0.13	-0.00536	1.9172	0.01131	1.9975	0.6549						
316	red maple	Acer	rubrum	Hahn, Jerold T., 1984	431.19	0.019385	-4.7E-05	2.6776								
806	scarlet oak	Quercus	coccinea	McClure, J. and Cost, N. 2010	0.067831	0.00266							-0.225632	0.001917	0.003343	0.001887
110	shortleaf pine	Pinus	echinata	McClure, J. and Cost, N. 2010	0.066654	0.002168							-0.706167	0.002215	-0.68706	0.002211
318	sugar maple	Acer	saccharum	Scott, Charles T., 1981	-0.19	-0.01171	1.8949	0.0134	1.9928	0.6471						
653	sweetbay	Magnolia	virginiana	McClure, J. and Cost, N. 2010	0.057904	0.002603							-0.19841	0.001901	0.735415	0.001775
132	Virginia pine	Pinus	virginiana	McClure, J. and Cost, N. 2010	0.034943	0.002569							-0.284955	0.002264	0.333364	0.002118
802	white oak	Quercus	alba	McClure, J. and Cost, N. 2010	0.044339	0.002539							-0.37698	0.001948	0.148434	0.00188
920	willow spp.	Salix	spp.	McClure, J. and Cost, N. 2010	0.054564	0.002565							-0.451948	0.001921	0.518892	0.001802
621	yellow-poplar	Liriodendron	tulipifera	Scott, Charles T., 1981	-0.45	-0.00523	2.2323	0.01338	2.0093	0.6384						

Table F. 2: Species Substitutions

Species found in Inventory	FIA Code	Species used for Volume/Biomass Calculations	FIA Code
Cucumbertree	651	Magnolia	653
Sycamore	731	Elm	970
Blackgum	693	Sweetgum	611
Buckeye	330	Elm	970
Butternut	601	Elm	970
Sassafras	931	Willow	920
Sourwood	711	Willow	920
Paulownia	712	Elm	970
Misc. Hardwoods	998	Elm	970
Misc. Conifer	198	Virginia Pine	132
White Ash	541	Ash	540

Appendix G: Complete CRM Methodology and Species Specific Biomass Coefficients

The following Appendix is taken directly out of the FIA Database Description and Users Manual for Phase 2, version 4.0, revision 2, Appendix J , Dated December, 2009

Note that the Tables have been renamed to be consistent with this documents Appendix.

Biomass Estimation in the FIADB

In previous versions of the FIADB, a variety of regional methods were used to estimate tree biomass for live and dead trees in the TREE table. In FIADB 4.0, a new nationally consistent method of estimating tree biomass has been implemented. This new approach, called the component ratio method (CRM) (Heath and others 2009), involves calculating the dry weight of individual components before estimating the total aboveground or belowground biomass. The CRM approach is based on:

- converting the sound volume of wood (VOLCFSND) in the merchantable bole to biomass using a compiled set of wood specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of bark on the merchantable bole using a compiled set of percent bark estimates and bark specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of the entire tree (total aboveground biomass), merchantable bole outside bark, and belowground biomass using equations from Jenkins and others (2003)
- calculating the volume of the stump (wood and bark) based on equations in Raile (1982) and converting this to biomass using the same specific gravities used for the bole wood and bark
- calculating the top biomass (tree tip and all branches) by subtracting all other biomass components from the total aboveground estimate
- calculating an adjustment factor by developing a ratio between bole biomass from VOLCFSND to bole biomass from Jenkins and others (2003)
- applying the adjustment factor to all tree components derived from both Jenkins and Raile

The CRM approach is based on assumptions that the definition of merchantable bole in the volume prediction equations is equivalent to the bole (stem wood) in Jenkins and others (2003), and that the component ratios accurately apply.

The tables in this appendix describe the equations used in FIADB 4.0 to estimate components of tree biomass, including stem wood (bole), top and branches combined, bark, stump, and coarse roots. Most of these components are estimated through a series of ratio equations as described by Jenkins and others (2003). Stem wood biomass is calculated directly from the sound cubic-foot volume of the tree bole, percentage of bark on the bole, and specific gravities of both wood and bark.

Note that component equations are not available for woodland tree species or for saplings because saplings have no volume in FIADB. Because of this, only total aboveground biomass is estimated for saplings (trees from 1 to 4.9 inches in diameter) and woodland species [trees where diameter is measured at the root collar (DRC)]. The individual component biomass values for bole, top, and stump are not available in FIADB. Volume equations for woodland species include all wood and bark from ground to tip. When converted to biomass, the result is total aboveground biomass excluding foliage for these species. Belowground biomass is estimated for all trees greater than or equal to 1 inch.

Definitions of each biomass component and the equations used to estimate the oven-dry weight in pounds are shown in appendix tables F1 through F5.

- Appendix table F1 defines the columns that are stored in the TREE table, and clarifies the set of trees (species, dimensions, live or dead, etc) that are used in each calculation.
- Appendix table F2 defines the Jenkins component equations and explains how the equation results are used to estimate biomass. The 'Estimate name' in this table is the same name found in the coefficient definitions described in the biomass-related columns 38 to 49 of the REF_SPECIES table.
- Appendix table F3 contains the Jenkins equations used to estimate each biomass component. The equations use the exact coefficient column names found in the REF_SPECIES table (for example, JENKINS_TOTAL_B1 in appendix table J-3 is the column name in REF_SPECIES that holds the value of the coefficient needed in the total aboveground biomass equation). The Jenkins equations use the measured tree diameter to produce an estimate.
- Appendix table F4 contains the actual equations used in the FIADB to estimate the biomass components stored in the TREE table. These equations are a blend of Jenkins ratios, calculated bole biomass (based on calculated volume from the TREE table), and adjustment factors. The adjustment factor is an important step because it relates measurement-based bole biomass (DRYBIO_BOLE) to generalized equation-based bole biomass to improve or adjust the computed results of the Jenkins equations.
- Appendix table F5 contains equations that show the approach described by Heath and others (2009), where the proportion of the biomass component relative to stem volume is calculated first, and then is applied to DRYBIO_BOLE to develop the final estimate in pounds.

For more information please consult the publication by Heath and others (2009), titled *Investigation into calculating tree biomass and carbon in the FIADB using a biomass expansion factor approach*.

Table G. 1: Definition of Biomass Components stored in the TREE table

Component	Column name	Biomass Component Definition (all are oven-dry biomass, pounds)
Merchantable stem (bole)	DRYBIO_BOLE	Merchantable bole of the tree, includes stem wood and bark, from a 1-foot stump to a 4-inch top diameter outside bark (DOB). Based on VOLCFSND and specific gravity for the species. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees. (note that VOLCFGRS or VOLCFNET might be used after adjustment based on national
Top	DRYBIO_TOP	Top of the tree above 4 inches DOB and all branches; includes wood and bark and excludes foliage. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees.
Stump	DRYBIO_STUMP	Stump of the tree, the portion of a tree bole from ground to 1 foot high, includes wood and bark. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees.
Belowground	DRYBIO_BG	Coarse roots of trees and saplings with a DIA $\geq$ 1 inch DBH or DRC. Includes timber and woodland species, and live and dead trees.
Saplings	DRYBIO_SAPLING	Total aboveground portion of live trees, excluding foliage. For timber species with a DIA $\geq$ 1 inch and less than 5 inches DBH.
Woodland tree species	DRYBIO_WDLD_SPP	Total aboveground portion of tree, excluding foliage. For woodland species with a DIA $\geq$ 1 inch DRC. Includes live and dead trees. Woodland species can be identified by REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, or TREE.WDLDSTEM > 0

Table G. 2: Jenkins Biomass Component Equation DefinitionsTable

(Refer to the REF_SPECIES table for equation coefficients and adjustment factors)

Component	Estimate name	Definition
Total aboveground biomass	total_AG_biomass_Jenkins	Total biomass of the aboveground portion of a tree. Includes stem wood, stump, bark, top, branches, and foliage. (ovendry biomass, pounds)
Stem wood biomass ratio	stem_ratio	A ratio that estimates biomass of the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins. Includes wood only. This is the portion of the tree from a 1-foot stump to a 4-inch top DOB.
Stem bark biomass ratio	bark_ratio	A ratio that estimates biomass of the bark on the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Foliage biomass ratio	foliage_ratio	A ratio that estimates biomass of the foliage on the entire tree, by applying the ratio to total_AG_biomass_Jenkins.
Coarse root biomass ratio	root_ratio	A ratio that estimates biomass of the belowground portion of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Stump biomass	stump_biomass	An estimate of the stump biomass of a tree, from the ground to 1 foot high. Uses a series of equations that estimate first the diameter inside and outside bark, followed by volume inside and outside bark developed by Raile (1982). Wood
Sapling biomass adjustment	JENKINS_SAPLING_ADJUSTMENT	An adjustment factor that is used to estimate sapling biomass for the tree, by applying the factor to the total aboveground estimate excluding foliage. The adjustment factor was computed as a national average ratio of the DRYBIOT (total dry biomass) divided by the Jenkins total biomass for all 5.0-inch trees, which is the size at which biomass based on volume begins.

Table G. 3: Jenkins Biomass Equations (Actual B1 and B2 coefficients and adjustment factors are stored in the REF_SPECIES table.) Note: these equations are used in appendix table J-4 to estimate the biomass components stored in the TREE table.

Component	Equation
total_AG_biomass_Jenkins (pounds) (total aboveground biomass, includes wood and bark for stump, bole, top, branches, and	$= \exp(\text{JENKINS_TOTAL_B1} + \text{JENKINS_TOTAL_B2} * \ln(\text{DIA} * 2.54)) * 2.2046$
stem_ratio	$= \exp(\text{JENKINS_STEM_WOOD_RATIO_B1} + \text{JENKINS_STEM_WOOD_RATIO_B2} / (\text{DIA} * 2.54))$
bark_ratio	$= \exp(\text{JENKINS_STEM_BARK_RATIO_B1} + \text{JENKINS_STEM_BARK_RATIO_B2} / (\text{DIA} * 2.54))$
foliage_ratio	$= \exp(\text{JENKINS_FOLIAGE_RATIO_B1} + \text{JENKINS_FOLIAGE_RATIO_B2} / (\text{DIA} * 2.54))$
root_ratio	$= \exp(\text{JENKINS_ROOT_RATIO_B1} + \text{JENKINS_ROOT_RATIO_B2} / (\text{DIA} * 2.54))$
stem_biomass_Jenkins (pounds)	$= \text{total_AG_biomass_Jenkins} * \text{stem_ratio}$
bark_biomass_Jenkins (pounds)	$= \text{total_AG_biomass_Jenkins} * \text{bark_ratio}$
bole_biomass_Jenkins (pounds)	$= \text{stem_biomass_Jenkins} + \text{bark_biomass_Jenkins}$
foliage_biomass_Jenkins (pounds)	$= \text{total_AG_biomass_Jenkins} * \text{foliage_ratio}$
root_biomass_Jenkins (pounds)	$= \text{total_AG_biomass_Jenkins} * \text{root_ratio}$
stump_biomass (pounds)	Volumes of wood and bark are based on diameter inside bark (DIB) and DOB equations from Raile, 1982. $\text{DIB} = (\text{DIA} * \text{RAILE_STUMP_DIB_B1}) + (\text{DIA} * \text{RAILE_STUMP_DIB_B2} * (4.5 - \text{HT}) / (\text{HT} + 1))$ $\text{DOB} = \text{DIA} + (\text{DIA} * \text{RAILE_STUMP_DOB_B1} * (4.5 - \text{HT}) / (\text{HT} + 1))$ Volume is estimated for 0.1ft (HT) slices from ground to 1 foot high (HT), and summed to compute stump volume. $\text{Bark_volume} = \text{Volume_outside_bark} - \text{Volume_inside_bark}$ Bark and wood volumes are multiplied by their respective specific gravities and added together to estimate biomass
top biomass_Jenkins (pounds)	$= \text{total_AG_biomass_Jenkins} - \text{stem_biomass} - \text{bark_biomass} - \text{foliage_biomass} - \text{stump_biomass}$

Table G. 4: Equations used to calculate Biomass Components stored in the TREE table

Column name	Equation (refer to Appendix J-3 for details on variables found in equations below)
	$\text{AdjFac} = \text{DRYBIO_BOLE} / \text{bole_biomass_Jenkins}$ $\text{AdjFac_woodland} = \text{DRYBIO_BOLE} / (\text{total_AG_biomass_Jenkins} - \text{foliage_biomass_Jenkins})$
DRYBIO_BOLE (wood and bark) (see note below)	$\text{VOLUME} = \text{VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound)}$ $= (\text{VOLUME} * (\text{BARK_VOL_PCT}/100.0) * (\text{BARK_SPGR_GREENVOL_DRYWT} * 62.4)) + (\text{VOLUME} * (\text{WOOD_SPGR_GREENVOL_DRYWT} * 62.4))$ Note: For woodland species, volume equations produce volume outside bark, from ground to tip including branches, therefore DRYBIO_BOLE is the biomass from ground to tip. Wood and bark volumes need to be estimated before converting to biomass as follows: $= (\text{VOLUME} * (\text{BARK_VOL_PCT}/100.0) * (\text{BARK_SPGR_GREENVOL_DRYWT} * 62.4)) + ((\text{VOLUME} - (\text{VOLUME} * (\text{BARK_VOL_PCT}/100.0))) * (\text{WOOD_SPGR_GREENVOL_DRYWT} * 62.4))$
DRYBIO_TOP	$= \text{top_biomass_Jenkins} * \text{AdjFac}$
DRYBIO_STUMP	$= \text{stump_biomass} * \text{AdjFac}$
DRYBIO_SAPLING	$= (\text{total_AG_biomass_Jenkins} - \text{foliage_biomass_Jenkins}) * \text{JENKINS_SAPLING_ADJUSTMENT}$
DRYBIO_WDLD_SPP	$= \text{DRYBIO_BOLE (trees} \geq 5 \text{ inches DIA)}$ $= \text{DRYBIO_SAPLING (trees} < 5 \text{ inches DIA)}$ For tree species where REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, and/or TREE.WDLDSTEM > 0 Note: volume equations produce volume from ground to tip, including branches; DRYBIO_BOLE is the biomass of all wood from ground to tip
DRYBIO_BG	$= \text{root_biomass_Jenkins} * \text{AdjFac (for timber spp } \geq 5 \text{ inches DIA)}$ $= \text{root_biomass_Jenkins} * \text{AdjFac_woodland (for woodland spp } \geq 5 \text{ inches DIA)}$ $= \text{root_biomass_Jenkins} * \text{JENKINS_SAPLING_ADJUSTMENT (for all trees} < 5 \text{ inches DIA)}$
Note: If DIA $\geq$ 5.0 and VOLCFSND > 0 then VOLUME = VOLCFSND If DIA $\geq$ 5.0 and VOLCFSND = (0 or null) and VOLCFGRS > 0 then VOLUME = VOLCFGRS * Percent Sound If DIA $\geq$ 5.0 and VOLCFSND and VOLCFGRS = (0 or null) then VOLUME = VOLCFNET * (Ratio of cubic foot sound to cubic foot net vol)	

Table G. 5: Alternative method to calculate Biomass Components, following Heath and others, 2009

Component	Equation
DRYBIO_BOLE (wood and bark)	$\text{VOLUME} = \text{VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound)}$ $= (\text{VOLUME} * (\text{BARK_VOL_PCT}/100.0) * (\text{BARK_SPGR_GREENVOL_DRYWT} * 62.4)) + (\text{VOLUME} * (\text{WOOD_SPGR_GREENVOL_DRYWT} * 62.4))$
TOP_proportion	$= \text{top_biomass_Jenkins} / \text{bole_biomass_Jenkins}$
DRYBIO_TOP	$= \text{TOP_proportion} * \text{DRYBIO_BOLE}$
STUMP_proportion	$= \text{stump_biomass} / \text{bole_biomass_Jenkins}$
DRYBIO_STUMP	$= \text{STUMP_proportion} * \text{DRYBIO_BOLE}$
BG_proportion	$= \text{root_biomass_Jenkins} / \text{bole_biomass_Jenkins}$
DRYBIO_BG	$= \text{BG_proportion} * \text{DRYBIO_BOLE}$
BARK_proportion	$= \text{bark_biomass_Jenkins} / \text{bole_biomass_Jenkins}$
DRYBIO_BARK	$= \text{BARK_proportion} * \text{DRYBIO_BOLE}$

Table G. 6: Species Dependent Biomass Coefficients for CRM Methodology

Species Code	COMMON NAME	GENUS	SPECIES	JENKINS_TOTAL_B1	JENKINS_TOTAL_B2	JENKINS_STEM_WOOD_RATIO_B1	JENKINS_STEM_WOOD_RATIO_B2	JENKINS_STEM_BARK_RATIO_B1	JENKINS_STEM_BARK_RATIO_B2	JENKINS_FOLIAGE_RATIO_B1	JENKINS_FOLIAGE_RATIO_B2	JENKINS_ROOT_RATIO_B1
68	eastern redcedar	Juniperus	virginiana	-2.0336	2.2592	-0.3737	-1.8055	-2.098	-1.1432	-2.9584	4.4766	-1.5619
110	shortleaf pine	Pinus	echinata	-2.5356	2.4349	-0.3737	-1.8055	-2.098	-1.1432	-2.9584	4.4766	-1.5619
129	eastern white pine	Pinus	strobus	-2.5356	2.4349	-0.3737	-1.8055	-2.098	-1.1432	-2.9584	4.4766	-1.5619
132	Virginia pine	Pinus	virginiana	-2.5356	2.4349	-0.3737	-1.8055	-2.098	-1.1432	-2.9584	4.4766	-1.5619
260	hemlock spp.	Tsuga	spp.	-2.5384	2.4814	-0.3737	-1.8055	-2.098	-1.1432	-2.9584	4.4766	-1.5619
316	red maple	Acer	rubrum	-1.9123	2.3651	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
318	sugar maple	Acer	saccharum	-2.0127	2.4342	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
400	hickory spp.	Carya	spp.	-2.0127	2.4342	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
531	American beech	Fagus	grandifolia	-2.0127	2.4342	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
540	ash spp.	Fraxinus	spp.	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
602	black walnut	Juglans	nigra	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
611	sweetgum	Liquidambar	styraciflua	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
621	yellow-poplar	Liriodendron	tulipifera	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
650	magnolia spp.	Magnolia	spp.	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
762	black cherry	Prunus	serotina	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
802	white oak	Quercus	alba	-2.0127	2.4342	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
832	chestnut oak	Quercus	prinus	-2.0127	2.4342	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
833	northern red oak	Quercus	rubra	-2.0127	2.4342	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
837	black oak	Quercus	velutina	-2.0127	2.4342	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
901	black locust	Robinia	pseudoacacia	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
920	willow spp.	Salix	spp.	-2.2094	2.3867	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
950	basswood spp.	Tilia	spp.	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
951	American basswood	Tilia	americana	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
970	elm spp.	Ulmus	spp.	-2.48	2.4835	-0.3065	-5.424	-2.0129	-1.6805	-4.0813	5.8816	-1.6911
Species Code	COMMON NAME	GENUS	SPECIES	JENKINS_ROOT_RATIO_B2	JENKINS_SAPLING_ADJUSTMENT	WOOD_SPGR_GREENVOL_DRYWT	WOOD_SPGR_GREENVOL_DRYWT_CIT	BARK_SPGR_GREENVOL_DRYWT	BARK_SPGR_GREENVOL_DRYWT_CIT	MC_PCT_GREEN_WOOD	MC_PCT_GREEN_WOOD_CIT	MC_PCT_GREEN_BARK
68	eastern redcedar	Juniperus	virginiana	0.6614	0.63086	0.44	1	0.4	8	34.75	16	60.25
110	shortleaf pine	Pinus	echinata	0.6614	0.76331	0.47	1	0.35	4	77.29787	4	60.25714
129	eastern white pine	Pinus	strobus	0.6614	0.72911	0.34	1	0.47	22	64.97059	22	70.48936
132	Virginia pine	Pinus	virginiana	0.6614	1.01056	0.45	1	0.54	4	78.06667	22	89.92593
260	hemlock spp.	Tsuga	spp.	0.6614	0.62759	0.41	23	0.46	23	78.33	23	97.67
316	red maple	Acer	rubrum	0.816	0.7443	0.49	1	0.6	5	63.53061	5	78.95
318	sugar maple	Acer	saccharum	0.816	0.84103	0.56	1	0.54	5	57.39286	5	89.92593
400	hickory spp.	Carya	spp.	0.816	0.74366	0.62	23	0.62	23	68.88	23	56.74
531	American beech	Fagus	grandifolia	0.816	0.63243	0.56	1	0.67	5	54.53571	5	88.95522
540	ash spp.	Fraxinus	spp.	0.816	0.93622	0.51	23	0.46	23	61	23	86
602	black walnut	Juglans	nigra	0.816	0.8722	0.51	1	0.33	3	79.11765	5	89.39394
611	sweetgum	Liquidambar	styraciflua	0.816	0.74856	0.46	1	0.42	5	74.19565	5	90.78571
621	yellow-poplar	Liriodendron	tulipifera	0.816	0.85175	0.4	1	0.38	5	95	1	123.52632
650	magnolia spp.	Magnolia	spp.	0.816	0.79248	0.43	23	0.44	23	91.75	23	92.75
762	black cherry	Prunus	serotina	0.816	0.79248	0.47	1	0.63	3	53.44681	16	90.7778
802	white oak	Quercus	alba	0.816	0.76989	0.6	1	0.56	5	68.26667	5	88.875
832	chestnut oak	Quercus	prinus	0.816	0.72243	0.57	1	0.54	3	77.12281	5	60.25926
833	northern red oak	Quercus	rubra	0.816	0.81068	0.56	1	0.68	5	83.14286	5	90.89706
837	black oak	Quercus	velutina	0.816	0.77993	0.56	1	0.6	3	83.14286	5	89.63333
901	black locust	Robinia	pseudoacacia	0.816	0.93185	0.66	1	0.29	3	40.83333	9	87.89655
920	willow spp.	Salix	spp.	0.816	0.84031	0.36	23	0.5	23	127	23	99
950	basswood spp.	Tilia	spp.	0.816	0.67171	0.32	23	0.48	23	105	23	90
951	American basswood	Tilia	americana	0.816	0.67171	0.32	1	0.48	3	105.34375	1	90.3125
970	elm spp.	Ulmus	spp.	0.816	0.79248	0.54	23	0.43	23	66	23	91.08
Species Code	COMMON NAME	GENUS	SPECIES	MC_PCT_GREEN_BARK_CIT	WOOD_SPGR_MC12VOL_DRYWT	WOOD_SPGR_MC12VOL_DRYWT_CIT	BARK_VOL_PCT	BARK_VOL_PCT_CIT	RAILE_STUMP_D08_B1	RAILE_STUMP_D18_B1	RAILE_STUMP_D18_B2	
68	eastern redcedar	Juniperus	virginiana	22	0.47	1	12	0.12667	0.914	0.11975		
110	shortleaf pine	Pinus	echinata	22	0.51	1	16	0.08091	0.90698	0.08469		
129	eastern white pine	Pinus	strobus	22	0.35	1	16	0.08091	0.90698	0.08469		
132	Virginia pine	Pinus	virginiana	22	0.48	1	13.4	0.08091	0.90698	0.08469		
260	hemlock spp.	Tsuga	spp.	23	0.43	23	16.18	0.12667	0.914	0.11975		
316	red maple	Acer	rubrum	11	0.54	1	8.6	0.11585	0.94181	0.1074		
318	sugar maple	Acer	saccharum	11	0.63	1	15.6	0.12798	0.92267	0.12506		
400	hickory spp.	Carya	spp.	13	0.68	23	16	0.12798	0.92267	0.12506		
531	American beech	Fagus	grandifolia	22	0.64	1	6	0.12798	0.92267	0.12506		
540	ash spp.	Fraxinus	spp.	23	0.55	23	16	0.12766	0.91979	0.12152		
602	black walnut	Juglans	nigra	22	0.55	1	15	0.12766	0.91979	0.12152		
611	sweetgum	Liquidambar	styraciflua	11	0.52	1	15	0.12766	0.91979	0.12152		
621	yellow-poplar	Liriodendron	tulipifera	13	0.42	1	18	0.12766	0.91979	0.12152		
650	magnolia spp.	Magnolia	spp.	23	0.47	23	15	0.12766	0.91979	0.12152		
762	black cherry	Prunus	serotina	22	0.5	1	9.2	0.12766	0.91979	0.12152		
802	white oak	Quercus	alba	17	0.68	1	16	0.12798	0.92267	0.12506		
832	chestnut oak	Quercus	prinus	14	0.66	1	23	0.12798	0.92267	0.12506		
833	northern red oak	Quercus	rubra	17	0.63	1	20	0.12798	0.92267	0.12506		
837	black oak	Quercus	velutina	17	0.61	1	18.5	0.12798	0.92267	0.12506		
901	black locust	Robinia	pseudoacacia	22	0.69	1	15	0.12766	0.91979	0.12152		
920	willow spp.	Salix	spp.	23	0.39	23	16	0.09658	0.91882	0.08593		
950	basswood spp.	Tilia	spp.	23	0.37	23	10.53	0.12766	0.91979	0.12152		
951	American basswood	Tilia	americana	22	0.37	1	10.5	0.12766	0.91979	0.12152		
970	elm spp.	Ulmus	spp.	14	0.59	23	14	0.12766	0.91979	0.12152		

References

- Adkins, Thomas D. 2007. Soil Survey for Russell County Virginia. U.S. Department of Agriculture, National Resources Conservation Service. 769 p.
- Hatch, Danny R.; Thomas, Jeffery R. 2006. Soil Survey of Washington County Area and the City of Bristol, Virginia. U.S. Department of Agriculture, National Resources Conservation Service. 629 p.
- Husch, B., C.I. Miller, and T.W. Beers. 1993. Forest Mensuration. Krieger Publishing Company, Malabar, Florida.
- Keyser, C.E. 2010. Southern (SN) Variant Overview – Forest Vegetation Simulator. Internal Rep. U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 69 p.
- Miller, John. 2011. Personal Communication. Fire Chief, The Virginia Department of Forestry, Charlottesville, VA 24210. john.miller@dof.virginia.gov
- Rebain, S.A. 2010. The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 361 p.
- Woudenberg, Sharon W; Conkling, Barbara L; O’Connell, Barbara M; LaPoint, Elizabeth B; Turner, Jeffery A; Waddell, Karen L. 2010. The Forest Inventory and Analysis Database: Database description and users manual version 4.0 for Phase 2. Gen. Tech. Rep. RMRS-GTR-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 336 p.