

Garcia River Forest
Offset Project Data Report
California Air Resources Board

Forest Owner and Offset Project Operator:

The Conservation Fund

APPENDICES – January 2019

- Appendix A – Forest Inventory Cruise Specifications
- Appendix B – Modeling Plan
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Appendix A: Forest Inventory Cruise Specifications The Conservation Fund

Garcia River Forest – July 2015

Sampling Design and Overview

1.1. Plot Location

The Garcia River Forest is divided into three forested strata. Each strata captures areas within the projects with similar attributes, and all plots within a particular project's strata are analyzed together.

For Garcia River Forest, the strata designations reflect Water Lake Protection Zones (WLPZs), Working Forest, and Ecological Reserve. The strata are based on a geospatial analysis of existing GIS files. For example, the WLPZ stratum is based on the property wide stream network. The stream layer has been derived from TCF's GIS database, field information and LiDAR data. For the main stem of the Garcia River (digitized from high-resolution 2012 aerial imagery), there is a WLPZ buffer of 300 feet from the river's edge on both sides of the river. For other Class 1 streams, the buffer is 200 feet. Class 2 Large streams have a buffer of 100 feet; Class 2 standard streams have a buffer of 75 feet on either side of stream.

The Reserve is defined by the Ecological Reserve constraints prescribed and monitored through a Conservation Easement; the purpose of the Ecological Reserve easement is to manage for late seral conditions through a combination of reduced harvest levels and retention requirements.

Beyond the Reserve and the WLPZs is the Working Forest stratum which comprises the remaining portions of forested areas which are not subject to WLPZ management constraints or Reserve management objectives.

Strata Name	Strata	Gross Acres	Forest Acres (roads removed)	Description	Forest Carbon?
Reserve	RSRV	5,784.72	5,568.74	Forest Reserve – area designated in the Conservation Easement	yes
Working Forest	WF	14,333.01	13,800.37	Forest Area not along streams or in the Reserve	yes
Water Lake Protection Zone	WLPZ	3,219.67	3,086.25	300' - from Main Stem Garcia River Polygon 200' - from center line of Class 1 Streams 100' - from center line of Class 2 Large Streams 75' - from the center line of Class 2 streams	yes
Nontimber / Zero Carbon	NT	442.68	-	Nontimber management acres (<i>natural openings, but not buffered roads, in "Gross Acres" column.</i> <i>There a total of 1,325 acres of 'zero carbon' nontimber natural openings & buffered roads</i>)	no
	Total	23,780.08	22,455.36	Garcia River Forest Project Area	

A 5x20 plot grid was laid across the property from a random start point. The plots within each strata were assigned a random number used for plot selection. Once the plots had been assigned a random number the first 30% of the plots on the list were selected in consecutive order for sampling. If needed, additional plots will be selected from the list (following the randomly assigned numerical order) and measured until a sufficient number of plots have been measured to achieve the desired statistical accuracy. Cruisers then receive a list of the randomly chosen plots and their GPS locations.

1.2. Plot Design – Summary of Measurements

The plot design consists of a circular 1/10th acre plot (37.2 ft radius) for all conifer tree species, a circular 1/20th acre (26.3 ft radius) plot for all hardwood tree species, and a 1/100th acre circular fixed radius plot for regeneration (11.8 ft radius).

1.2.1. Circular 1/10th Acre (37.2 ft radius) Fixed-Area Plot Measurements (standing live and dead *conifer* trees ≥ 5.0 inches DBH)

- species
- diameter at breast height (DBH)
- height to the nearest foot (for trees ≥ 20.0 " DBH on GRF)
- height to crown base (for height trees)
- % defect, % missing height, % missing height, and timber defect code where needed
- height and decay class for all snags

1.2.2. Circular 1/20th Acre (26.3 ft radius) Fixed-Area Plot Measurements (standing live and dead *hardwood* trees ≥ 5 inches DBH)

- species
- diameter at breast height (DBH)
- when needed, % defect, % missing height, % missing volume and defect code
 - the only defect that is recorded for hardwoods is missing volume (e.g., missing height and large cavities)
- height and decay class for all snags

1.2.3. Circular 1/100 acre Regeneration Plot Measurements (11.8 ft radius): (standing live < 5.0 inches DBH)

- species
- count of trees at least 4.5 ft tall by 0-2.4 and 2.5-4.9 in DBH classes

- average tree height (within DBH classes by species)
- lesser vegetation – dominant lesser vegetation type (shrubs and grasses) and average height.

1.3. Plot Access and Road Point Procedures

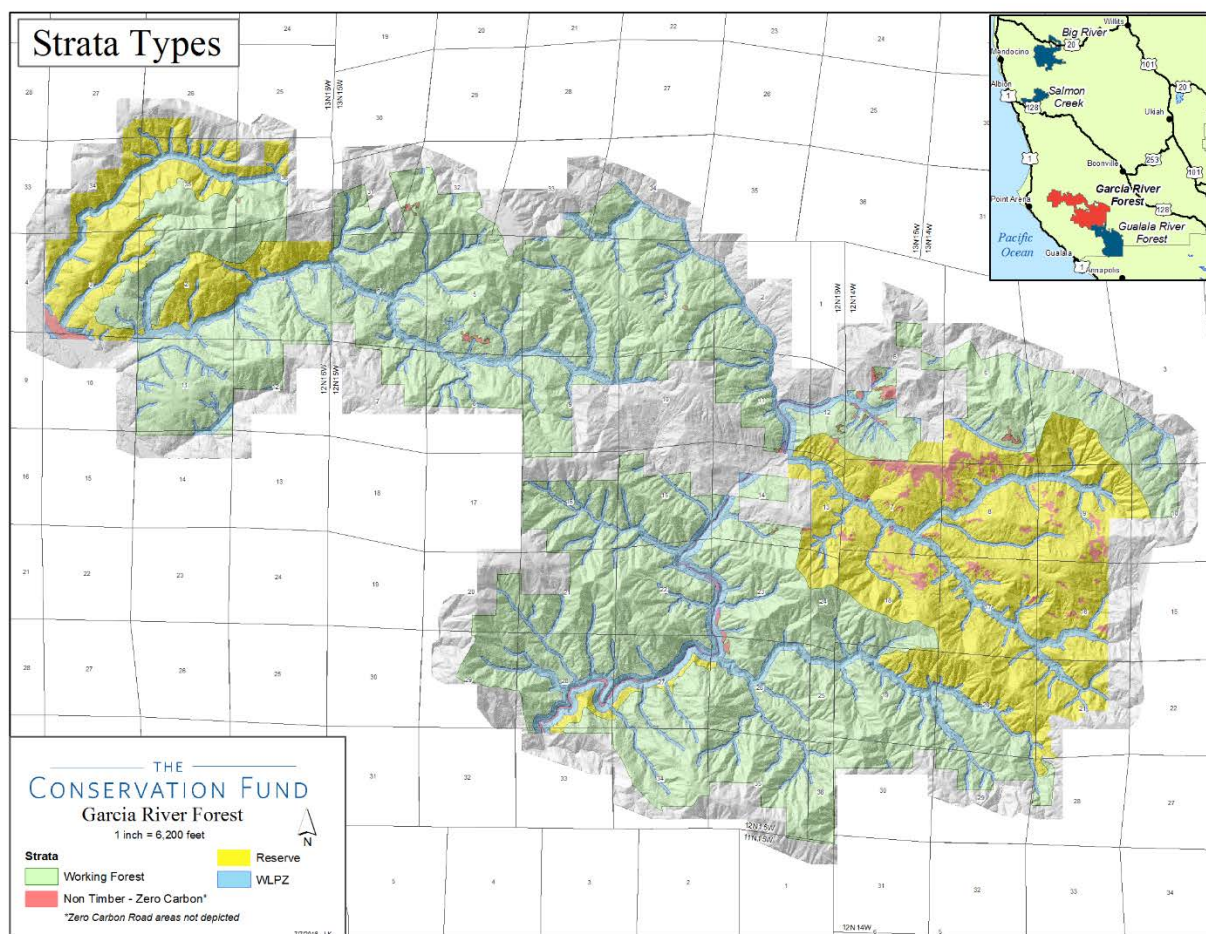
Each plot will be accessed from the nearest road entry point or the prior plot. The cruiser will navigate via GPS to the plot center. A map will be provided which shows where plots that have been placed and their corresponding GPS locations will be provided on a separate spreadsheet; shapefiles will also be provided to the cruisers.

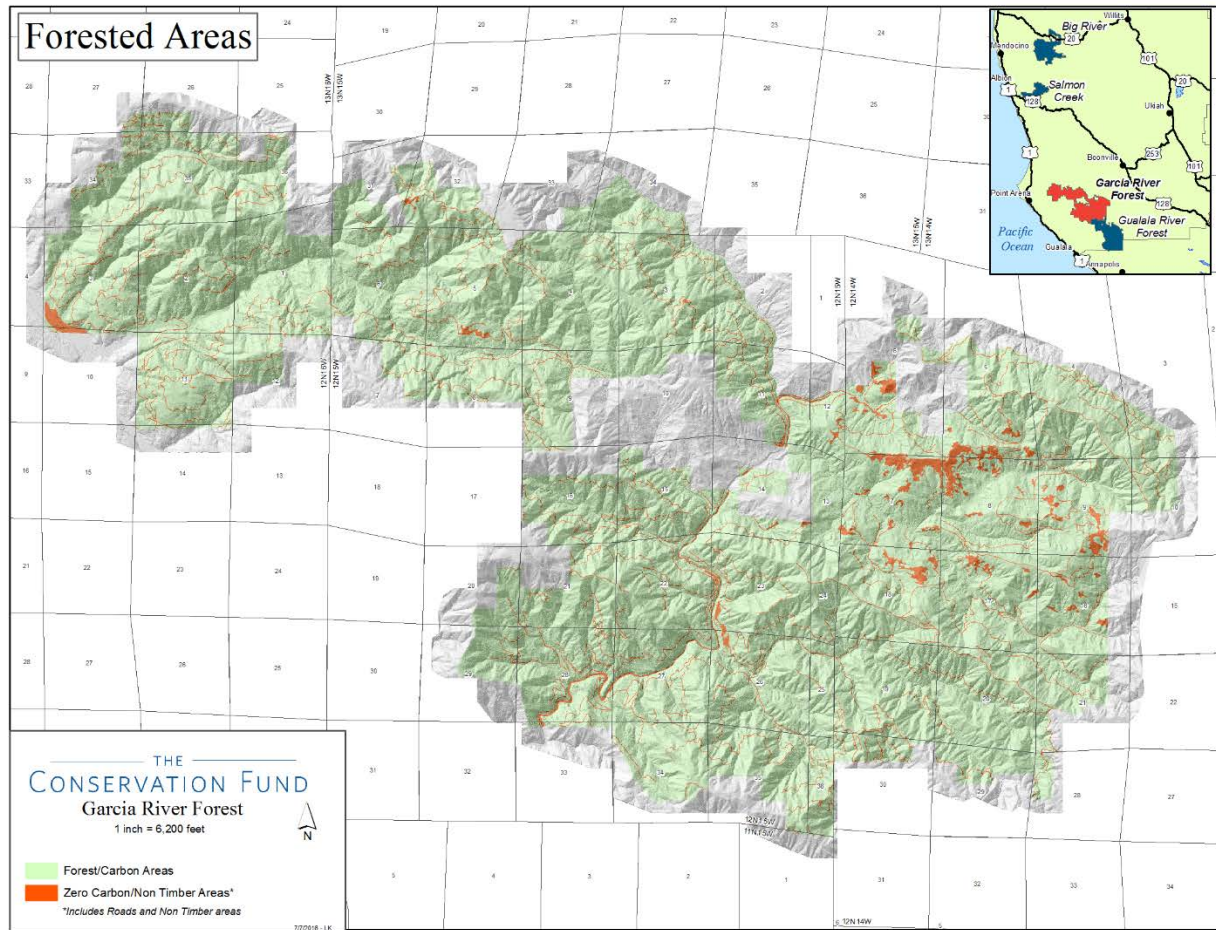
1.4. Plots on Truck Roads

Mapped forest roads – paved, permanent, and seasonal – are considered to be part of the zero carbon/nontimber stratum which is not sampled and is assumed to have 0 MgCO₂e/acre. Therefore, plots that fall on mapped forest roads must be offset.

Plots are located throughout the project area and may fall on a truck road or property edge. Plots that fall on unmapped roads are sampled. Plots that have *any portion* of the 37.2 ft radius land on mapped truck roads are offset 1 chain to the west, and if still on truck road the cruiser returns to the original point and offsets 1 chain north. The offset shall be in a cardinal direction moving clockwise on the compass until a bearing is found that will lead to a vegetated plot. Landings are treated as part of the truck road and not sampled. New plot centers will be mapped and the GPS coordinates will be provided to the data manager.

Garcia River Forest – ARB
Appendix A





1.5. Edge Plots

If a plot is near a property boundary according to GPS coordinates, but the cruiser *cannot* find a clear delineation of ownership change such as a boundary line or noticeable change in timber management then the plot is measured normally. However, if a portion of the plot, *but not the plot center*, is off property and the ownership boundary is very clear (e.g., fence, blaze line, obvious land management difference like a clearcut), the Walkthrough Method¹ is used. The Walkthrough Method (Figure 1) is a proven method to eliminate bias in boundary overlap situations. If a plot center is clearly beyond the property boundary, then the plot is thrown out and the cruiser navigates to the next plot.

¹ Ducey, M.J., J.H. Gove, and H.T. Valentine. 2004. A Walkthrough Solution to the Boundary Overlap Problem. Forest Science 50: 427-435.

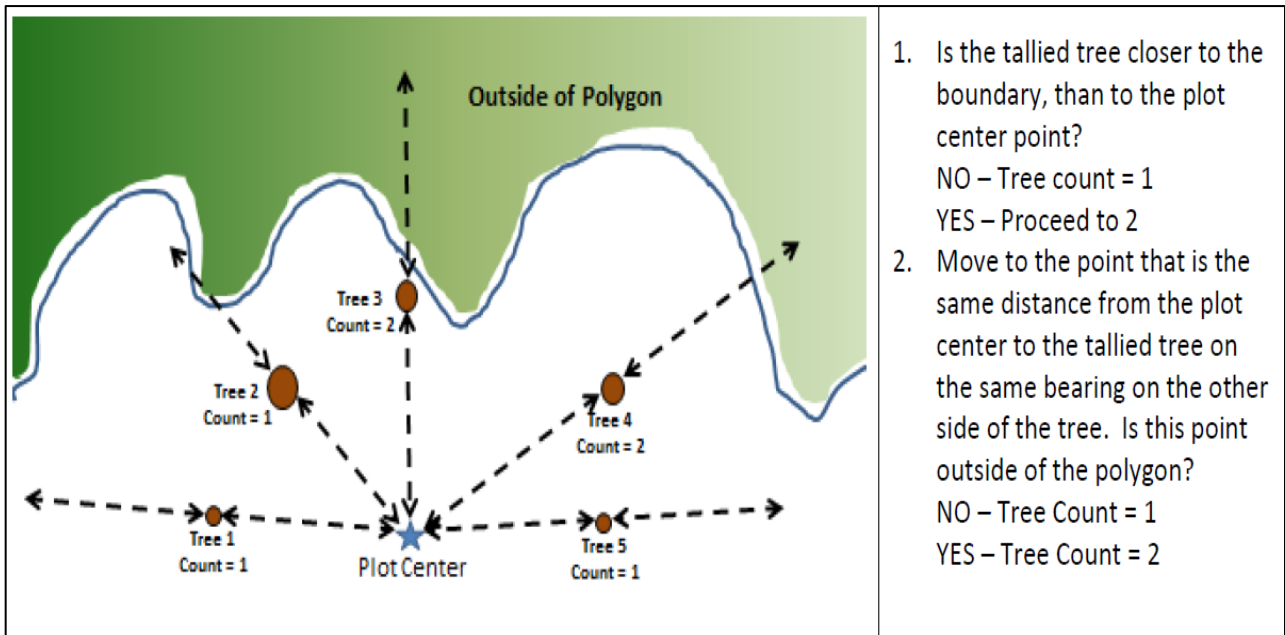


Figure 5. Decision Key and Diagram for Walkthrough Method. If a portion of a plot is beyond a clear boundary, the Walkthrough Method is used to collected data in a boundary overlap situation. Further explanation is available in Ducey et al (2004).

1.6. Plot Monumenting and Plot Navigation Procedures

The following monumenting should occur at all plots:

1. The plot center should be monumented with a plastic stake painted orange. The stake should extend at least 18" above the ground and be driven securely into the soil.
2. The plot number should be clearly written on an aluminum tag affixed to the plot center stake along with the date cruised and the cruiser's initials. Solid pink and solid white flagging is tied to the stake and also hung in the trees above the plot center.
3. GPS coordinates taken at plot centers and should be recorded on the plot sheet. **The GPS coordinates for plot center should be recorded 2 times for each plot:**
 - i. When the plot center is established
 - ii. When the plot is completed
4. All trees measured on the plot should have a line spray painted **at the location they were measured for DBH** on the uphill side of the tree and facing plot center where possible. The tree number should be spray painted **above** the DBH line. "Out Trees" – Trees whose center is just outside of the plot boundary should be spray painted with and "X" at DBH.
5. Trees in the 1/20th and 1/10th acre plots are numbered consecutively starting from the north and moving in a clockwise direction until the plots are completed.
6. Trees shall be numbered consecutively starting from "1" on each plot.

Sampling Procedure and Data Collection at Plots

2.1. 1/10th Acre (37.2 ft Radius) Plot for conifer trees and 1/20th Acre (26.3 ft Radius) plot for hardwood trees

2.1.1.Borderline Trees

Any tree (live or dead) near the plot border should be measured using a tape to check for in and out trees. A laser is not recommended to determine in and out trees. When checking borderline trees, the loggers tape should be affixed to the face of the tree at DBH and then pulled to plot center. Once at plot center, the measured slope distance should be corrected to horizontal distance. The radius of the tree should be added to the horizontal distance to plot center when calculating whether or not the tree is located within the plot. When checking in and out trees be mindful of the units, plot radius is measured in feet and 1/10 of feet whereas dbh is measured and recorded in inches to convert diameter in inches to the radius in 1/10 of feet divide the diameter by 24. For example a 12 in dbh tree has a radius of .5 feet (12/24). In the field a tree which is 37 feet horizontal distance from plot center to the face would be measured as 37.5 feet to the center of the tree or “out”.

2.1.2.Live Trees

All live conifer trees greater than or equal to 5 inches DBH are measured if the **CENTER** of the stem is within 37.2 feet of plot center. All live hardwood trees greater than or equal to 5 inches DBH are measured if the **CENTER** of the stem is within 26.3 feet of plot center. Distance to plot center should be measured at DBH. Trees will be tallied and measured in a clockwise direction beginning in the north. **All trees should be marked and numbered with a line painted at the location where DBH was measured and the tree number should also be painted on the tree.** The tree number should be recorded.

The following data should be collected for each tree measured:

- **Species** – The species and species codes of trees can be found in the table below.
- **Group** – Each tree in the plot has a group assigned to it. Trees can be live (..) or snags (SN). See Table 2 below for a complete description of the group codes. **All snags (SN) must** have a decay class from 1 to 5 assigned to them. The decay class descriptions for snags can be seen in table 4 below.
- **Diameter at Breast Height (DBH)** see figure below – Diameters are measured at a point 4.5 feet above the ground level or root collar on the uphill side of the tree. Measurement accuracy is to the **nearest one tenth-inch**. In the case of irregularities in DBH, such as swelling, bumps, depressions,

branches, etc., diameters are measured immediately above the irregularity at the place where it ceases to affect the normal stem form. For redwood stump sprouts the ground level should be considered to be the top of the parent stump.

- o **DBH for Forked trees** – Forked trees are measured as two separate trees if the fork originates below DBH. When the fork originates below DBH but has subsequently grown together the tree is cruised as two trees and the DBH for each is estimated by the cruiser. If the fork originates above DBH then the tree is measured and counted as a single tree. DBH should be measured above or below the fork at the most reasonable point without swell.
- o **DBH for Extreme Lean Trees** – Trees with extreme leans should be measured 4.5 feet from the point where they leave the ground. In some cases, this may be on the downhill side of the tree.

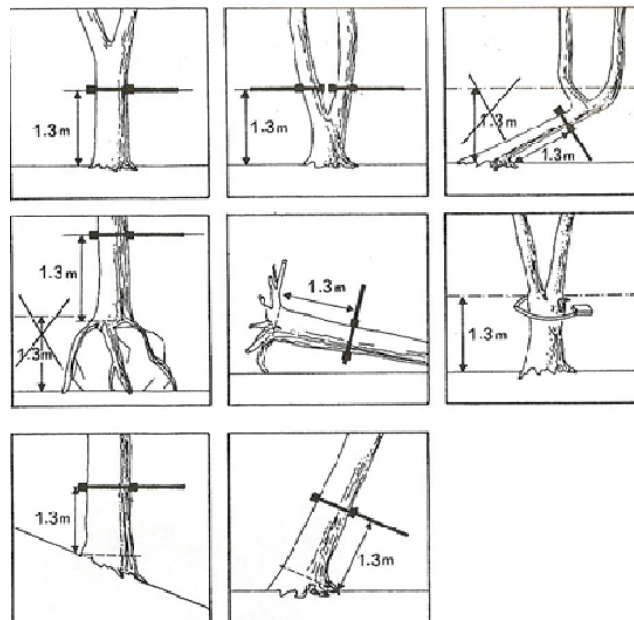


Figure 6. Point of measurement of diameter at breast height (from Pancel, 1993)² On slopes, the DBH is taken on the uphill side of the tree.

- **Height** – Total height is measured on large conifers on every plot. For the Garcia River Forest, **all conifers greater than or equal to 20.0 in DBH** should be measured for height.
 - **Leaning or Sweep/Crook Trees** – Trees with lean and/or crook or sweep are measured for total height from the ground to the tree top. If the lean, sweep, or crook is more than 45° (100% slope), the bole length should be estimated

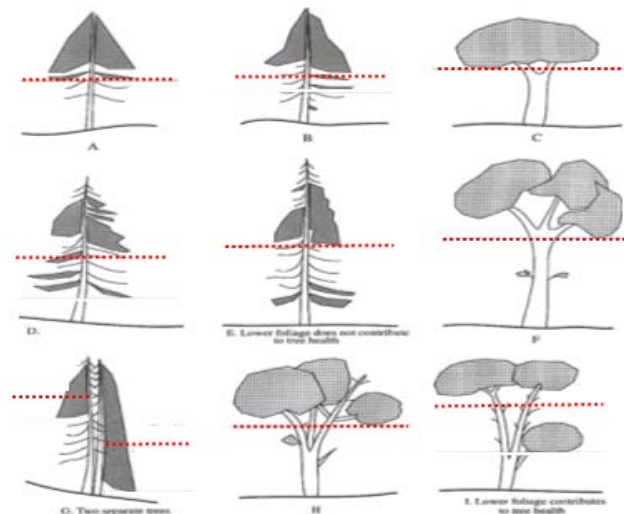
² Pancel, L., ed. 1993. Tropical forestry handbook. Berlin, Germany, Springer-Verlag. Volume 1, 738 pp

using correction factors based on the lean. These factors will be supplied to cruisers in 5 degree increments (bole length = tree height / [SIN (lean degrees)]).

- **Height to Crown Base (HTCB)** - This measurement provides an estimate of the total vertical crown area. The measurement is taken on every height measure tree. The measurement is taken from the base of the tree on the uphill slope to the visually balanced base of the crown, since tree crowns are often irregular. Figure 3 below provides examples of how the height to crown base measurement is acquired.
- **Damage/Defect** - A damage code is assigned to damaged trees. See codes in Table 4 below for descriptions of these codes. Damaged trees should have a defect % recorded in the Age/Defect % column of the plot card. Cruisers should use **10% defect classes** when estimating percentage defect. For example, trees with forks or crooks generally have 0-10% defect. Fire scars can be 10-20% defect. Butt rot is generally not more than 50% defect. Conk rot may be from 10 to 100% defect depending on the severity of the rot.

Percent missing height should be recorded on trees with broken tops and is an estimate of the percent of the tree missing from the estimated total height. Large hollows or other bole defects that impact the gross volume of the tree should be noted and a **% missing volume** estimated. Percent missing volume is an estimate of the volume of the void missing from the estimated total volume. Both of these deductions are based on ocular estimates in the field. Defect deductions are only taken for trees ≥ 8 inches in DBH.

Figure 7. Height to Crown Base Measurement Examples (use the dotted line)



2.1.3. Snags (Standing Dead Trees³) > 15ft Tall

All snags within the plot and over 5in DBH and 15ft tall should be measured for **DBH** and **height** and should have their species noted. All snags must have their **decay class** noted in the defect column (see Table 3). All snags should have a line painted where they were measured for DBH and their tree number painted above the line and numbered in sequence with the live trees.

³ Standing dead trees and snags are synonyms, and are used interchangeably in this document.

Table 14: List of Tree Species and their Species Codes

AS	<i>Fraxinus sp.</i>	Ash species
BM	<i>Acer macrophyllum</i>	Big Leaf Maple
BO	<i>Quercus kelloggii</i>	Black Oak
BP	<i>Pinus muricata</i>	Bishop Pine
CB	<i>Umbellularia californica</i>	California Bay
CO	<i>Quercus chrysolepis</i>	Canyon Live Oak
CU	<i>Aesculus californica</i>	California Buckeye
DF	<i>Pseudotsuga menziesii</i>	Douglas-fir
EF	<i>Ficus carica</i>	Edible Fig
GC	<i>Chrysolepis chrysophylla</i>	Giant Chinquapin
GF	<i>Abies grandis</i>	Grand Fir
LO	<i>Quercus wislizenii</i>	Interior Live Oak
MD	<i>Cornus nuttallii</i>	Mountain Dogwood
MP	<i>Pinus radiata</i>	Monterey Pine
NM	<i>Torreya californica</i>	California Nutmeg
OL	<i>Olea europaea</i>	Olive
PM	<i>Arbutus menziesii</i>	Madrone
PP	<i>Pinus ponderosa</i>	Ponderosa Pine
PY	<i>Taxus brevifolia</i>	Pacific Yew
RA	<i>Alnus rubra</i>	Red Alder
RW	<i>Sequoia sempervirens</i>	Redwood
SO	<i>Quercus parvula var. shrevei</i>	Shreve's Oak
SP	<i>Pinus lambertiana</i>	Sugar Pine
TO	<i>Lithocarpus densiflorus</i>	Tanoak
TY	<i>Heteromeles arbutifolia</i>	Toyon
UK	N/A	Unknown
WA	<i>Alnus rhombifolia</i>	White Alder
WH	<i>Tsuga heterophylla</i>	Western hemlock
WI	<i>Salix sp.</i>	Willow species
WM	<i>Myrica californica</i>	Wax Myrtle
WO	<i>Quercus garryana</i>	Oregon White Oak

Table 15: Status Code Descriptions

Status Code	Code Definition	Description	Data Source
..	Live	Default code for trees with normal form. <i>All regeneration also should have this code.</i>	1/10th acre plot (conifers)
SN	Snag	Standing trees that are dead. Snags have no branches or leaves and are greater than 15 ft tall.	1/20th acre plot (hardwoods)
LV	Lesser Vegetation	Lesser vegetation is noted in the 1/100 th acre regen plot.	1/100th acre plot

Table 16: ⁴. Snag Decay Class Descriptions

Decay class	Limbs and branches	Top	% Bark Remaining	Sapwood presence and condition *	Heartwood condition *
1	All present	Pointed	100	Intact; sound, incipient decay, hard, original color	Sound, hard, original color
2	Few limbs, no fine branches	May be broken	Variable	Sloughing; advanced decay, fibrous, firm to soft, light brown	Sound at base, incipient decay in outer edge of upper bole, hard, light to reddish brown
3	Limb stubs only	Broken	Variable	Sloughing; fibrous, soft, light to reddish brown	Incipient decay at base, advanced decay throughout upper bole, fibrous, hard to firm, reddish brown
4	Few or no stubs	Broken	Variable	Sloughing; cubical, soft, reddish to dark brown	Advanced decay at base, sloughing from upper bole, fibrous to cubical, soft, dark reddish brown
5	None	Broken	Less than 20	Gone	Sloughing, cubical, soft, dark brown, OR fibrous, very soft, dark reddish brown, encased in hardened shell

*Characteristics are for Douglas-fir. Dead trees of other species may vary somewhat. Use this only as a guide.

⁴ Forest Service. 2012. Forest Inventory and Analysis National Core Field Data Collection Procedures for Phase 2 Plots. Version 6.0. Page 427. National Core Field Guide, U.S. Department of Agriculture, Forest Service

Table 17: Damage Codes

First Digit	Second Digit	Third Digit
0 - No Damage	N/A	N/A
1 - Unspecified	0 – (always code 0)	0 - Unspecified
		1 - Light Damage
		2 - Moderate Damage
		3 - Severe Damage
		4 - Fatal Damage
2 - Mechanical	1 - Fire	0 - Unspecified
	2 - Logging	1 - Light Damage
	3 - Crown	2 - Moderate Damage
	4 - Bole	3 - Severe Damage
	5 - Roots	4 - Fatal Damage
	6 - Tags, Nails, etc.	
3 - Chemical	1 - Foliar (broadcast)	0 - Unspecified
	2 - Stem (spot treatment)	1 - Light Damage
	3 - Soil (root treatment)	2 - Moderate Damage
		3 - Severe Damage
		4 - Fatal Damage
4 - Disease	0 - Unknown	0 - Unspecified
	1 - Mistletoe	1 - Light Damage
	2 - Needle Rusts	2 - Moderate Damage
	3 - Stem Decay	3 - Severe Damage
	4 - Stem Rusts	4 - Fatal Damage
	5 - Stem Cankers	
	6 - Root Disease	
	7 - Armillaria mellea	
5 - Insects	1 - Defoliators	0 - Unspecified
	2 - Bark Beetles	1 - Light Damage
	3 - Sucking Insects	2 - Moderate Damage
	4 - Pitch Moths	3 - Severe Damage
		4 - Fatal Damage
6 - Animal	1 - Deer & Elk	0 - Unspecified
	2 - Bear	1 - Light Damage
	3 - Livestock	2 - Moderate Damage
	4 - Porcupine	3 - Severe Damage
	5 - Mt. Beaver	4 - Fatal Damage
	6 - Small Mammals	
	7 - Birds	

First Digit	Second Digit	Third Digit		
7 - Weather	1 - Windthrown	0 - Unspecified		
	2 - Snow, Ice, Freezing	1 - Light Damage		
	3 - Drought (Summer)	2 - Moderate Damage		
	4 - Desiccation (Winter)	3 - Severe Damage		
	5 - Sunscald	4 - Fatal Damage		
	6 - Lightning			
	7 - Flooding			
8 - Suppression	0 - (always code 0)	0 - Unspecified		
		1 - Light Damage		
		2 - Moderate Damage		
		3 - Severe Damage		
		4 - Fatal Damage		
9 - Physical	1 - Broken top	Fork codes	Lean Codes	Codes For Others
	2 - Dead Top	1 - Below 1.3m	0 - Unspecified	0 - Unspecified
	3 - Multiple Tops	2 - Above 1.3m	1 - <25 degrees	1 - Light
	4 - Forked Tree	3 - Above 5m	2 - 26 to 45 degrees	2 - Moderate
	5 - Leaning Tree		3 - >45 degrees	3 - Severe
	6 - Crook or Sweep		4 - Tree Down	4 - Fatal
	7 - Bole Cracks			
	8 - Epicormic Branching			

2.2. Hundredth Acre (11.8 ft radius) Plot

2.2.1. Regeneration – Trees < 5in DBH

All trees less than 5 inches DBH are measured on every plot. The sample area measured for regeneration is a fixed 1/100th acre plot (11.8 ft radius). All species that could potentially have a tree form are measured, see table 1 for species that should be measured as trees, if the individual is at least 4.5 ft tall

- **Species** – Record species for all trees
- **DBH** – Count the trees by species within 2.4 inch DBH classes (0 to 2.4 and 2.5 to 4.9), if the base of the tree is within the 1/100th acre plot.
- **Height** – record the average height by species and DBH class for each tree record.

2.2.2. Lesser Vegetation

Record the dominant lesser vegetation type and height in the regeneration plot and density of the ground cover in 20% classes (**Open**: 0-20%, **Low**: 20-40%, **Medium**: 40-60%, **Dense**: 60-80%, **Extremely Dense**: 80-100% cover). Lesser vegetation should be given the LV status code.

Table 18: Lesser Vegetation Type Codes

Lesser Vegetation Type	Name	Description
WS	Woody Shrub	Woody plants
FE	Fern	Fern species
IN	Invasive Species	French Broom or Pampas
LV	Unknown	
GR	Grass species	Grass species

2.3. Additional Plot Information

Any further information concerning the stand being cruised can be extremely important.

- GPS coordinates should be recorded at each plot center when the plot is established, and again when the plot is completed.
- The cruiser should also record plot aspect, % slope, cruiser, and date
- Items that should be noted are the location of skid trails that occur within the plot, springs, watercourses and historical artifacts when they assist in relocating the plot.
- Wildlife species of concern observed should be noted including raptors and their nests pileated wood peckers, tree vole, red legged frog, mountain lions, bears, etc.
- The distance to the nearest Class I watercourse should also be noted if the plot is within 200 feet of a Class I watercourse.
- If a plot has no trees, please make a note of the plot conditions and record one species with species code XX, DBH equal to 12, and tree count equal to 0.

2.4. Site Class Sampling

A site tree should be selected at least once per day for each cruiser or cruising team from the population of dominant conifer trees encountered throughout the day. Site trees should be **redwood, Douglas-fir, grand fir, or sugar pine**.

To be considered eligible for site tree measurement, a tree must have the following qualities:

- be a conifer located within or near the plot (preferably within)
- be a robust, dominant tree at least 25 years in age demonstrate good

phenotype, and vigor, such as a straight bole and symmetrical crown and healthy top growth.

- Free of diseases, crooks, forks, beetles, mistletoe etc
- free of defect including forks, beetles, mistletoe, conk rot, butt rot and bole cankers, and disease (beetles, mistletoe, etc.)

Final selection should be made on the basis of determining which of the eligible trees is the most vigorous. Relative vigor should be assessed by evaluating the crown condition, foliage complement, and bole condition of the trees present on the plot. Trees with full, healthy crowns, and no apparent disease or damage should be considered more vigorous than trees lacking these qualities. In many stands it may be difficult to find trees meeting these criteria; thus, it is important to look for such trees at each plot (until the minimum number have been identified and measured within a given stand). **Trees selected for site tree measurement shall be marked with an “ST” on two sides of the tree with paint.**

If no site trees are found meeting the criteria mentioned above, the cruiser may find an appropriate site tree off of the plot. In this case, the cruise notes shall clearly indicate that the measurement occurred off plot. The tree shall be painted as described above.

Data Entry and Transfer

Data will be collected using iPad tablets that will be provided by the cruising contractor. The cruising contractor will also be responsible for purchasing the required licenses. Cruisers shall email completed data to TCF at the end of each work day. Cruisers should carry paper data sheets in the field so that data can be collected in the event that an iPad stops functioning.

If minor missteps/oversights come to light during the desk QA/QC process (described in the Modeling Plan, Appendix B), but there is deemed to be an appropriate and available substitutions which will not cause a plot to fail a check cruise, then occasionally these substitutions are used for logistical reasons. Examples of field data collection oversights with appropriate substitutions include: estimating aspect from geospatial records, estimating height using a regression for trees which were mistakenly not measured in the field, and other similar minor oversights. When the plot is re-measured during the next forest inventory effort, these missing data points will be collected.

Check Cruise Specifications

Total plot carbon and gross board foot volume must be within 5% of the check cruise results. Any cruiser who has more than 25% of their plots outside of this 5% range must have all of their plots re-cruised at their expense.

Post Disturbance Inventory Update Procedure

The inventory will be updated each year there is a measurable disturbance resulting from timber harvesting or natural disaster such as fire or wind storm. All plots that were sampled in the 2015 inventory which were in a disturbed area will be re-cruised and the new measurements will be applied to the plot from the date of re-cruise forward. The cruising methodology described in this document will be used for the disturbed plots.

Plot Selection Procedure

In re-cruise efforts (following disturbance events or in the Continuous Forest Inventory), all plots in the selected area that were originally cruised in 2015 will be cruised. If there are insufficient plots in a stratum, then additional plots are randomly selected from the 5 X 20 chain grid. In the case that there are insufficient plots in the 5 X 20 chain grid, then another grid 5 X 10 chains is overlaid on the original grid and plots are randomly selected. The grid can be further reduced to 2.5 X 2.5 chains to facilitate the re sample. Whenever possible always re cruise appropriate 2015 plots and use this procedure to generate the remaining, additional plots, if necessary.

Change of Inventory and Accuracy

At some point in the future, the landowner may wish to change the sample design or intensity to reflect a change in modeling or new science in that event the new inventory design will be submitted to ARB for approval. Further, it is anticipated that a change in inventory accuracy may be desired. A change in accuracy would be contemplated if the landowner chose to stop participating in the carbon market or the market suffered a serious downturn. In the event the landowner stops active trading the landowner shall maintain the option to reduce the sample intensity and confidence limits such that the landowner can verify previously accrued credits while reducing the inventory costs.

Example Paper Plot Card

See below for the data form that should be used in case the iPad does not work.

[illegible]

Slope Correction Table and Extreme Lean Trees

Slope correction table for finding horizontal distances on steep sites, and finding the bole length for extreme lean trees.

Slope Correction Table									
			26.3	37.2	33.0	50.0	66.0	100.0	ratio
% slope :	degrees	SIN(degrees)	(1/20th)	(1/10th)	ft	ft	ft	ft	
10.0	5.71	0.10	26.4	37.4	33.2	50.2	66.3	100.5	0.9950
15.0	8.53	0.15	26.6	37.6	33.4	50.6	66.7	101.1	0.9889
20.0	11.31	0.20	26.8	37.9	33.7	51.0	67.3	102.0	0.9806
25.0	14.04	0.24	27.1	38.3	34.0	51.5	68.0	103.1	0.9701
30.0	16.70	0.29	27.5	38.8	34.5	52.2	68.9	104.4	0.9578
35.0	19.29	0.33	27.9	39.4	35.0	53.0	69.9	105.9	0.9439
40.0	21.80	0.37	28.3	40.1	35.5	53.9	71.1	107.7	0.9285
45.0	24.23	0.41	28.8	40.8	36.2	54.8	72.4	109.7	0.9119
50.0	26.57	0.45	29.4	41.6	36.9	55.9	73.8	111.8	0.8944
55.0	28.81	0.48	30.0	42.5	37.7	57.1	75.3	114.1	0.8762
60.0	30.96	0.51	30.7	43.4	38.5	58.3	77.0	116.6	0.8575
65.0	33.02	0.54	31.4	44.4	39.4	59.6	78.7	119.3	0.8384
70.0	34.99	0.57	32.1	45.4	40.3	61.0	80.6	122.1	0.8192
75.0	36.87	0.60	32.9	46.5	41.3	62.5	82.5	125.0	0.8000
80.0	38.66	0.62	33.7	47.6	42.3	64.0	84.5	128.1	0.7809
85.0	40.36	0.65	34.5	48.8	43.3	65.6	86.6	131.2	0.7619
90.0	41.99	0.67	35.4	50.0	44.4	67.3	88.8	134.5	0.7433
95.0	43.53	0.69	36.3	51.3	45.5	69.0	91.0	137.9	0.7250
100.0	45.00	0.71	37.2	52.6	46.7	70.7	93.3	141.4	0.7071
% slope :				HD = COS(ARCTAN(</100)0*SD					
slope in degrees :				HD = COS(<)* SD					
ratio method :				HD =ratio*SD ex					
leaning trees :				bole length = tree height/[SIN(lean degrees)]					

Appendix B: Garcia River Forest Modeling Plan

I. Introduction

This modeling plan for the Garcia River Forest – ARB Project (“GRF” or “Project”) describes the details of the forest modeling and other analytical aspects of the Project. It is intended to detail specific methods used in the GRF and is a technical supplement to the Initial OPDR. Information required by Appendix B of the Protocol is included in this document. Topics include methods used in data collection, methods for estimating heights, modeling, harvested wood product calculations, as well as the results of those analyses.

The modeling plan is a living document which will be revised and clarified as necessary; the change log at the end of the modeling plan records changes to methods or calculations.

II. Project

The Project is located in Mendocino County in the coastal mountain range. Maps of the project area are included in the Initial OPDR. The Project is primarily a mixed conifer forest of redwood and Douglas-fir with occasional small openings and oak woodlands. For the Project, the property was stratified into three categories based on geographically specific long-term management objectives. The forest has been described as being ‘heterogenously homogenous’ and forest management is expected to play an important role in shaping the future condition of the forest. Each stratum is intended to capture forest dynamics, including disturbance, succession, and growth. The three strata are: watercourse and lake protection zones (WLPZ), Working Forest, and the Reserve. These strata, and the geospatial methods used to calculate them, are described in detail in the Initial OPDR (Section VIIA). Roads and natural openings greater than one acre are assumed to have 0 MtCO₂e/acre. During reporting periods with full site visits, the geospatial road network will be carefully reviewed and any changes to the permanent road network on the Project will be incorporated into the project. Road infrastructure which has been added (e.g., spur road built for timber harvesting) to the forest since the last site visit will be added to the Project’s road database. The acres associated with the new roads be subtracted from forested acres following the procedures described in the Initial OPDR. Roads which have been actively decommissioned will be tracked as decommissioned, but will *not* be added back in to the ‘forested acres’ (e.g., will continue to be counted as 0 MtCO₂e/acre) until the area has recovered and is forested.

Site class

Over the years, the productivity of the Garcia Forest has been assessed several times. Results show that the forest is primarily Dunning’s timber site class 3. Site class estimates were based on the measured site index and the site class ranges defined by Shih (2002).⁵ The first assessment was a property-wide inventory in 2010 which collected tree age information, height, DBH and species on dominant conifer trees across the forest. The 2010 data were used to calculate site indices for individual trees following

⁵ Shih, T.-T. 2002. Timberland Site Class on Private Lands Zoned for Timber Production. Page 10. Technical Working Paper, California Department of Forestry and Fire Protection, Fire and Resource Assessment Program.

recommended equations (Krumland and Eng 2005)⁶. A geospatial cross walk of the results was used to refine the SSURGO soils layer for the forest. For many of the soil polygons defined by SSURGO, redwood site class was either missing or did not align with field measurements (generally underestimating productivity). The 2010 site indices were used to fill in missing information and update site classes. The refined site class layer from the 2010 inventory is used to select the appropriate species specific height regression (further described below). The 2010 classification efforts are only applicable to this Project as a means to identify the appropriate Project specific height regression model.

In 2015, another property-wide inventory was conducted; information from 181 dominant sugar pine, redwood, and Douglas-fir was collected. Again, site indices were calculated for individual trees following recommended equations (Krumland and Eng 2005). The averaged forest-wide site index for sugar pine, redwood, and Douglas-fir provides a robust input to the growth and yield model, FORSEE. FORSEE expands the input site index estimate to other species for modeling.

It is important to note that the Protocol requires the use of the of Forest Inventory and Analysis (FIA) productivity classes for the differentiation of “high” and “low” sites for common practice baseline assessment (Protocol, Appendix F). Because there is not adequate information regarding FIA productivity classification available from the SSURGO soil layer or the US Forest Service, the Project was conservatively assumed to have a “high” site productivity for the Assessment Area common practice analysis.

III. Forest Inventory.

Collection

As mentioned in the Initial OPDR, a simple random/systematic stratified sampling (SRSS) design of field measurements is used to estimate carbon stocks. Field measurements are collected in nested, fixed-area permanently installed plots. The plots are re-measured on a rolling basis, ensuring that at any point in time all forest inventory data is 12 years old or less. Field methodology for on-the-ground data collection is laid out in Appendix A: Forest Inventory Cruise Specifications. There are a few additional steps for the forest inventory – QA/QC, data transfer, height estimation – which are related to the field measurements, but are secondary processing steps; these steps are discussed here.

The 2015 field inventory ran from late July until early November. The date of September 2, 2015 was selected as the date to peg the forest inventory for growth and yield modeling because it is roughly in the middle of the cruising period and aligns with the project commencement date of February 2, 2004.

QA/QC

Data are carefully checked for quality and consistency in several steps. Forest inventory data are check-cruised for accuracy. Check cruising identifies and corrects errors found in field measurements. Plots are

⁶ Krumland, B., and H. Eng. 2005. Site Index Systems for Major Young-Growth Forest and Woodland Species in Northern California. Page 220. State of California, The Resources Agency, Department of Forestry and Fire Protection, California.

check cruised on a cruiser-by-cruiser basis. A cruiser is considered to have passed the check cruise if their total merchantable BF/acre and MtCO₂e/acre are within 10% of the check cruiser's estimate and if these estimates are not statistically different using a paired t-test at the 90% confidence level.

After data collection, values are transferred into a Microsoft Access database. Cruisers may collect data electronically or on paper plot cards. If using a data logger, collection options are customized for the GRF cruise design (e.g., species codes, required fields). Plot values are double-checked after entry. The raw data logger outputs or the paper plot cards, whichever is applicable, are retained. Next, the data are imported into the Access database through an import macro procedure. Once in the database, a suite of QA/QC tests are run to identify any irregularities or problems. The QA/QC tests alerts the inventory manager of individual trees that fail the following tests:

- values outside the defined range of max and min DBH data
- values outside the defined range of max and min HT data
- unknown species code
- incorrect or missing defect codes or defect percentages
- missing heights on large conifer trees
- measured heights < measured HTCB

If questions arise during this stage of data review, the inventory database manager reviews the data or plot cards and contacts the field technicians to clarify entries, or to collect new data if necessary. If minor missteps/oversights come to light during the desk QA/QC process, but there is deemed to be an appropriate and available substitutions which will not cause a plot to fail a check cruise, then occasionally these substitutions are used for logistical reasons. Examples of field data collection oversights with appropriate substitutions include: estimating aspect from geospatial records, estimating height using a regression, or maintaining only 1 unique GPS point for a plot location. When the plot is re-measured during the next forest inventory effort, these missing data points will be collected.

Data Management System and Processes

Microsoft Access databases for inventory and modeling are created and maintained for each reporting period. Following the QA/QC procedures, the data for the reporting period are ready for analysis. Unique datasets are maintained for each reporting period, and datasets from each reporting period are archived when applicable verification and reporting activities are completed.

As plots are re-measured following disturbance events or inventory updates, the measurements are incorporated into a new copy of the databases; old plot data is removed using replicable queries. The old data are archived and retained. Activities on each plot, such as re-measurement or disturbance events, will be tracked in a separate database which will serve as a plot level activity log.

All biological data are stored on personal computers and at least one other external backup device. Data backups are accomplished using the SyncBack file synchronization software. Data and worksheets used for project reporting are archived and saved following each submission. Any future work on these data sources is done on copies and the originals are saved for future reference. Additionally, all

databases, worksheets, forms, and reports provided to the third-party verifiers are uploaded to the Conservation Fund’s cloud-based ShareFile account for file transfer and record retention.

Data management and calculations rely heavily on Access database based tools to translate field measurements into volume and biomass estimates. A suite of in-house computer code written in several languages⁷ aid in the processing and analysis of the data stored within Microsoft Access inventory databases. The relevant computer code is stored in both the inventory databases and also on a server using the Mercurial version control software.

Estimating Tree Height.

Tree height is an important variable in volume and biomass equations; however, tree height measurements are time consuming and often difficult to collect. Tree heights are measured to the nearest foot following the procedures outlined in Appendix A: Forest Inventory Cruise Specifications for approximately a third of the plots. To improve data collection efficiency, tree heights estimates are used for the remaining subset of plots. For plots where tree heights collected were not collected, species-species regressions equations developed for GRF, or created in FORSEE, are used to estimate height.

When total tree height is estimated using a height regression, the height to crown base (HTCB) measurement is assumed to be half of the height.

GRF Height Regression

Height regression models were developed by species for GRF using data collected on the property. The height-diameter models were based on equation forms developed from research on managed coastal redwood/Douglas-fir forests in Mendocino County⁸ (Eng 2012). Eng identified equation forms which adequately predicted height from DBH by species.

A 2010 forest inventory of GRF provided an expansive dataset from the Project for fitting the models. There were adequate sample sizes for species-specific models for common species – redwood, Douglas-fir, grand fir, sugar pine, tanoak, and pacific madrone. True oaks – black oak, canyon live oak, interior live oak, and Oregon white oak – have very similar growth forms and lineages and were grouped together for a more robust dataset; the species grouping is referred to as ‘QX’ for the *Quercus* grouping.

To select the best model for the Project, three models per species were built and compared. The first model used the coefficient values published by Eng, the second used property-wide species datasets, and the third used subsets of species datasets differentiated by site class. Model fitting was completed

⁷ The proprietary code was originally written by Jordan Golinkoff, PhD, a former TCF employee; it is maintained and updated by current TCF staff

⁸ Eng, H. 2012. Tree Height Estimation in Redwood/Douglas-fir Stands in Mendocino County. Pages 649–654. General Technical Report - Proceedings of coast redwood forests in a changing California: A symposium for scientists and managers, Pacific southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

in R⁹ (R Core Team) using the hash¹⁰ and ggplot2¹¹ packages; fitting also used in-house R code and functions. The models were reviewed and compared. A 2004 dataset from GRF was used for the model validation; model fit was also assessed with the 2015 inventory. Models with the best root-mean-square error (RMSE) were selected to be used for height estimation in the Project.

FORSEE Height Regression

A number of species present on the Project did not occur in sufficient numbers in the 2010 Project inventory to have species-specific models built. These species – ash, big leaf maple, California bay, California buckeye, California nutmeg, edible fig, giant chinquapin, pacific yew, red alder, white alder, Shreve’s oak, toyon, willow and wax myrtle – are estimated using the FORSEE internal height estimation process. FORSEE estimates values for missing heights during data input processing from measured sub-samples.

IV. Carbon Calculations

Methods for calculating the required carbon pools are described in the Initial OPDR, including equations and coefficients by species (Section VII B; Table 4 & Table 6). As discussed earlier, Access-based functions are used to execute equations used in estimating the whole tree biomass. Several species of trees occur in the Project, but do not have specific equations in the FIA volume of biomass equation documents required by the Protocol. In these situations, guidance from ARB¹² states that Live Oak equations and values are an appropriate substitution for Shreve’s Oak, and the “unknown hardwood” values are appropriate for other hardwoods – wax myrtle, toyon, edible fig – without specified equations. If new species are identified in GRF during future inventories, the appropriate equations will be identified from the FIA (2014) equation set, with guidance from ARB if necessary, and the species will be added to the Initial OPDR, modeling code, and forest inventory methodology.

Carbon stocks are calculated at the end of each reporting period. Because the forest inventory is collected over a period of time, it is necessary to adjust the height and diameter of trees to represent GRF’s carbon stocks at the end of the reporting period. The adjustment process is described in below. Once the trees have been adjusted, the carbon stocks are calculated following the procedures described in this modeling plan and in the Initial OPDR.

There is not an appropriate method for modeling standing dead tree measurements over time. Therefore, measurements of standing dead trees are not adjusted and are held constant until the next field visit.

Statistics

⁹ R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.

¹⁰ C. Brown. 2013. hash: Full feature implementation of hash/associated arrays/dictionaries. R package version 2.2.6. <http://CRAN.R-project.org/package=hash>

¹¹ H. Wickham. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, 2009.

¹² Personal Communication from Alex Yiu, ARB, March 16, 2016

According to the Protocol, the accuracy of forest inventories must be calculated to ensure that offset calculations are conservative. If the project accuracy exceeds a certain standard, then a project must deduct a portion of the claimed reductions to mitigate the uncertainties associated with the inventory. The acceptable level of variability before a confidence deduction is required is a 5% sampling error at the 90% confidence level. For temporal consistency, reporting period end adjusted values are used to calculate sampling errors.

The GRF project uses a simple random/ systematic stratified sampling design (SRSS) to estimate the forest carbon stocks. After all carbon pools are calculated on a plot level, stratified random sampling formulae are used to calculate the sampling error of the Project. The means of strata are multiplied by their area weights and summed. The variances are multiplied by the square of the area weights and summed. The standard error is the square root of the summed weighted variances. The overall 90% sampling error is calculated by multiplying 1.645, the z-statistic, by the overall standard error and then dividing by the overall mean. The accuracy is the resulting percentage.

The overall mean and standard error equations are the end result of the SRSS sampling. Intermediate results describe within strata means and standard errors. The equations and terms defined below detail how the overall mean and overall SE from a SRSS sample are calculated. Because the Project samples without replacement from a finite population of fixed plots, the finite-population correction factor (FPC) is included in the variance calculation (Avery and Burkhardt 2002)¹³. In some conventions, the FPC is ignored because it results in a very small change in variance; however, given the importance of the variance calculation in the Protocol, the long timeframe of the project, and the possibility that the project could have more plots added in the future, it is included.

$$\text{Equation 1: SRSS Overall Mean } \bar{y}_O = \frac{1}{N} \sum_{h=1}^L N_h \bar{y}_h$$

$$\text{Equation 2: SRSS Overall Standard Error } SE_O = \sqrt{S_{y_o}^2} = \sqrt{\sum_{h=1}^L \left(\frac{N_h}{N} \right)^2 \left(\frac{N_h - n_h}{N_h} \right) \left(\frac{S_h^2}{n_h} \right)}$$

The table below for definitions of the variables in equations 1 and 2.

Note, for fixed area plots, if 20 ($n_h = 20$) 1/10th acre fixed area plots are installed in a strata that is 100 acres in size, then the total potential number of plots in strata is: $N_h = 100 \text{ acres} * 10 \text{ plots/acre} = 1,000$ plots. The fixed area plots are nested. Overlap between fixed area plots is not permitted, therefore the largest plot size (1/10th acre) is representative of the sampling unit and the total potential number of sampling units that within a stratum or the population. Plots are not allowed to overlap with each other, but partial plots may be cruised if a plot crosses an obvious property boundary. (These plots are

¹³ Avery, TE and HE Burkhardt. 2002. Forest Measurements, 5th ed. Waveland Press, Inc. Long Grove, IL.

inventoried with the Walk Through Method, see Appendix A). Therefore, the variable N can be a decimal value.

SRSS variable definitions & equations adopted from Shiver and Borders (1996)¹⁴ and Thompson (2012)¹⁵.

Variables	Definition
L	Number of strata
N_h	Total potential sampling units in stratum <i>h</i>
N	Total potential sampling units in the entire population
n	Actual number of sampling units in all strata
n_h	Actual number of sampling units in stratum <i>h</i>
$\bar{y}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} y_{hi}$	The sample mean for stratum <i>h</i> where each plot value is <i>y_{hi}</i> . The stratum mean is found by summing all of the plot values and dividing by the number of plots.
$S_h^2 = \frac{1}{n_h - 1} \sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2$	The sample variance is calculated as any variance would be calculated; using the sum of the squared differences of each plot value from the mean value and adjusting by the degrees of freedom.
<i>y_{h,i}</i>	Observed value for variable <i>y</i> on sampling unit <i>i</i> in stratum <i>h</i>

If the sampling error is above 5.0%, then the Protocol requires that a confidence deduction is taken. The confidence deduction is the sampling error minus 5.0%, rounded to the nearest 1/10th of a percent (see Protocol, Appendix A.4). If the sampling error is 20.0% or above, the confidence deduction is 100%.

V. Growth & Yield Modeling: FORSEE

Growth and yield models are used to simulate the growth of forest and the impact of management activities overtime. GRF uses an approved model, FORSEE, for modeling forest management and updating forest inventories. FORSEE¹⁶ is developed and maintained by the California Growth and Yield Modeling Cooperative (CAGYM). FORSEE is a scalable and flexible modeling environment with a

¹⁴ Shiver, B.D. and Borders, B.E. 1996. Sampling Techniques for Forest Resource Inventory. John Wiley & Sons, Inc. New York, NY.

¹⁵ Thompson, SK. 2012. Sampling, Third Edition. John Wiley & Sons, Inc. Hoboken, NJ.

¹⁶ CAGYM. May 2008. FORSEE User's Guide: Beta Evaluation Release Version 1.7.

graphical user interface and a database interface. It has a batch processing mode that allows multiple stands to be processed at once. The batch processing mode uses user-defined logic written in visual basic scripts. FORSEE's growth libraries are based on the previously developed CRYPTOS model for the California Redwood Region. FORSEE outputs grown trees DBH and height, among other metrics. Currently, tree biomass and carbon values are calculated outside of the FORSEE environment using TCF-created code, as previously described; however, if future builds of FORSEE include appropriate and accurate ways to calculate biomass and carbon of trees and stands, the Project will consider using the FORSEE calculation capabilities.

Site Trees

The growth model, CRYPTOS, used by FORSEE requires a 50-year breast high age based site index for each stand. To get this, the site index is calculated with a 50-year base age for all site trees collected in the forest inventory. Then, the site index values are averaged across the Project and applied to each plot. Each plot is modeled as a stand in FORSEE (e.g., individual plots are modeled and for growth and management), and using the averaged site index values provide a robust metric for the forest and limits microsite influence.

Tree Ingrowth/Regeneration

Tree regeneration occurs during modeled forest growth and management. Seedlings which are 1" in DBH and 7' tall are added 5 years after a harvest occurs. The species composition of the seedlings is determined by the stratum; the number of seedlings is determined by the harvest type. Species composition of the new trees is based on a stratum level analysis of the forest inventory. The basal area of trees were calculated from the commencement date inventory to identify the relative species composition in a stratum at the project start. FORSEE recommends limiting regeneration record lists to minimize processing time and therefore, ingrowth lists were limited to species which compose a majority of a stratum's basal area (> 97.5%). After removing species which compose a minor component of the forest, the relative weight was recalculated and entered into the FORSEE regeneration setup.

The number of trees per acre that grow into a stand is based on the silvicultural prescription. The Project RPF determined the appropriate values based on experience and regional norms. The RPF considered the type of harvest and the tree type in formulating the values in the table below. For example, Variable Retention and Rehabilitation harvests are generally planted with conifers at a TPA of 270. In regeneration harvests, hardwoods are modeled as chemically treated and there is assumed to be 90-95% mortality therefore natural hardwood regeneration is from natural seed dispersal or stump sprouts from the remaining 5-10% live hardwoods and the number of hardwood seedlings is very low, estimated by the RPF to be 10 TPA. Thus, a conifer TPA of 270 and hardwood TPA of 10 is used for tree ingrowth for Variable Retention and Rehabilitation prescriptions. In selection harvests which rely on natural regeneration of conifers, ingrowth is from seed and sprouting. The amount of ingrowth corresponds to the silviculture prescription and seedlings are added at a rate thought to be equal to the number of trees that would live to maturity. For example, in a WLPZ single tree selection harvest, the harvest is light-touch (~15 trees per acre harvested) and which leads to low levels of stump-sprouting and seedling

recruitment. Selection harvests outside of the WLPZ have more trees removed (~25 tree per acre harvested) and thus also higher levels of stump-sprouting and seedling recruitment. Transition harvests are more aggressive uneven-aged management with more forest openings and corresponding more natural conifer regeneration. Commercial thinning and conifer release treatments also open the forest up and allow for natural regeneration, but are intermediate treatments and only allow for a moderate level of recruitment.

Silviculture	Description	Conifer Regen TPA	HW Regen TPA
WLPZ Silviculture	Natural regeneration	15	5
Selection	Natural regeneration	25	10
Transition	Natural regeneration	50	10
Variable retention	Natural regeneration (HW) and planted (Conifer) seedlings	270	10
Commercial Thin	Natural regeneration	30	10
Rehabilitation	Natural regeneration (HW) and planted (Conifer) seedlings	270	10
Conifer Release (HW Treatment)	Natural regeneration	20	5

Small tree TPA adjustments.

The tree per acre (TPA) values for species with greater than 1000 TPA in the 2.5" to 5" DBH size class is adjusted to account for small tree mortality in plots with high numbers of small trees. Plots with TPAs greater than 1000 for small trees are reduced to 1000 TPA. This adjustment is necessary because previous modeling exercises showed that small trees mortality in FORSEE is not realistic for dense seedling areas. Over time, unchecked high numbers of small trees lead to unrealistic, crowded stands. The TPA adjustment occurs as part of the data processing prior to input into the FORSEE modeling environment.

FORSEE Broken Top Trees

For trees with broken tops, the growth and yield model, FORSEE, allows two height values to be tracked: Height to Unbroken Top (Total Height) and Physical Top (Top Height). In the forest inventory, broken top trees are denoted by a defect code (91X). When a broken top tree is in a plot where all tree heights are measured, the Top Height of the tree is the measured value and the Total Height value is estimated using a regression. In uncommon situations such as a very productive microsite, the measured Top Height of a tree may be taller than the estimated, regressed height. In this case, the measured height is used for both the Total Height and the Top Height values. When a broken top tree is in a plot which does *not* have measured heights, then the cruiser indicates the defect by a defect code and also estimates the percent total height missing. In this situation, the Total Height is estimated using the regression

equations and the Top Height is calculated by subtracted the percent missing height recorded by the cruiser from the Total Height.

The biomass calculations for broken top trees is explained in the Initial OPDR (Section VII B); the biomass calculation uses Top Height, the height to the physical top.

VI. Adjusting the Forest Inventory

One key use of the growth and yield model, FORSEE, is adjusting the forest inventory to the year and date of interest. For the life of the project, the most common adjustment is updating the inventory to the reporting period end date (February 14) of the year of interest. This step is necessary because only a portion of the forest plots are re-measured annually, and the inventory may take place months before the end of the reporting period. The adjustments in FORSEE only applies to standing live trees; there is not an appropriate method to model standing dead trees and the field measurements are held constant until the plot is revisited.

Adjusting the Forest Inventory to the Reporting Period 1 Start Date: 1/1/2015

Given that the 2015 inventory is pegged at a date of September 2, 2015, it is necessary to backward adjust the inventory to determine the forest carbon stocks at the beginning of the reporting period (January 1, 2015). The height and diameter of each tree was decreased by the portion (~ 0.668) of annual growth between the inventory date and the beginning of the reporting period, January 1, 2015. The annual height and diameter growth increment for each tree was determined by growing the forest forward by one 5-year period in FORSEE and then dividing by 5.

Adjusting the Forest Inventory to the Reporting Period 1 End Date: 2/14/2016

It was also necessary to adjust the forest inventory to reflect the end of reporting period, February 14, 2016. The height and diameter of each tree was adjusted forward by adding a portion (~0.452) of annual growth increment to each tree.

Future Forest Inventory Updates

The forest inventory will be updated yearly to reflect tree growth. Plots within a harvested area or other disturbed areas will be re-measured within a year of the disturbance. Additionally, a portion of plots will be re-measured each year on a rolling basis as a continuous forest inventory (CFI). Plot data from the previous field visit will be removed, archived, and replaced by the fresh measurements. At any point in time, plot data in the forest inventory will range from 1 to 12 years old. After new data are incorporated into the forest inventory, all plots will be updated using FORSEE to model the forest at the end of the reporting period. The inventory updates will use the same method of adjusting the forest inventory as described above (e.g., determine the annual DBH and Height increment for each tree in FORSEE, then adjust the tree by the applicable portion of annual growth to reporting period end). Originally, the OPO intended to use the “Inventory Update” feature within FORSEE; however, the Inventory Update feature in FORSEE appears to grows the forest to a common *year* not to a common *date*.

Adjusting the Forest Inventory to Project Commencement: 2/2/2004

The Project originally commenced as an early action project under the Climate Action Reserve's 2.1 Protocol. To transition the Project to the Protocol, a representative commencement date inventory had to be developed. Transition Guidance¹⁷ outlines a process to backcast a current inventory to the project's commencement date. It is a five step process: grow the current inventory forward using an approved growth-and-yield model for one 5-year period, determine the DBH and height growth per period, determine the annual growth increment, subtract the annual increment for the number years between the current inventory and commencement date, and finally, add a tree list that represents harvests. The first four steps will be covered together, and then the final step – adding a tree list that represents harvests – will be discussed.

To backcast the current forest inventory to the date of project commencement, February 2, 2004, the current inventory was brought into FORSEE. Then, all of the plots were grown for one 5-year period; this is shortest period available in FORSEE. Next, current inventory values were subtracted from the FORSEE forward grown output. The difference is the growth for the 5-year period. The annual height and DBH growth increment was calculated for each tree by dividing by 5. Once these annual values were identified, the number of years (~11.584) was calculated between the current inventory date and the date of project commencement. Then, the annual height and diameter growth increments were multiplied by the years since commencement. The height and diameter increments for the time since commencement were subtracted from the current inventory's height and diameter measurements for each tree. All trees that were backcast to be less than 2.5" DBH and 7' tall at project commencement were removed from the inventory; these trees are too small to be included in the forest inventory or accurately modeled by FORSEE. If following the backcast process, all trees on a plot are below the threshold DBH and height values, the plot is treated as a 'no-tally' plot.

The forest inventory also had to be backcast to the end of the first reporting period, December 31, 2004. The carbon stocks of the end of the reporting period is necessary to calculate the number of credits that the project would have received, if it had been listed under the Protocol. The number of years between the current inventory and the end of the first reporting period was calculated (~10.668). Then, following the same procedure as described above, the annual diameter and height growth increments of trees were multiplied by the number of years and subtracted from the trees in the current inventory. Trees which did not meet the minimum size requirements were removed. For the years between project commencement and transition, an analogous calculation was performed resulting in a back adjusted year-end tree list for each year that GRF was a voluntary project (2004-2014).

Although trees which were harvested were "replanted", there were no additions to the backcast forest to represent other sources of mortality in GRF. The Transition Guidance does not discuss adjusting for natural or incidental logging operation mortality, and there are not adequate records or silvicultural reasons to necessitate it. Besides harvesting, mortality in the backcast is assumed to be negligible. This is

¹⁷ Guidance for Transitioning Early Action Projects to the California Air Resources Board's Compliance Offset Protocol U.S. Forest Projects. California Air Resources Board, March 2015. Available: http://www.arb.ca.gov/cc/capandtrade/protocols/usforest/usforestprojects_2014.htm

an appropriate assumption for several reasons. First, there is little natural mortality¹⁸ (Initial OPDR Section VII A 6) in the redwood region and the GRF in particular, which is a young forest. The dominant tree species in the redwood/Douglas-fir forest are long-lived. Redwoods, Douglas-firs, and even tanoaks can live to be hundreds of years old¹⁹. And finally, management of GRF has primarily been selection silviculture. Selection silviculture usually captures natural tree mortality and results in relatively little incidental tree mortality. Thus, it is reasonable to assume that inventory adjustments are unnecessary given the timescale, health, and management of the forest.

Since Project commencement in February 2004, there have been several commercial timber harvests on GRF. To account for these removals, the backcast tree list was adjusted to include the harvested trees. The multistep process relied on harvest volumes from the mills, marking tallies from foresters, and geospatial records of the timber harvest plans (THP). The first step was to identify the years and locations of harvests. The Project was first harvested under TCF ownership in 2007; there were also harvests annually since 2010. The geospatial boundaries of the THPs were identified by year harvested, and a geospatial intersect identified the plots in the current inventory which were harvested since project commencement. Next, marking tallies and volume worksheets were used to identify the volume and make-up of harvests. All harvests were prepared and supervised by registered professional foresters (RPF); however, each RPF compiled and retained their marking tallies slightly differently and in a few cases, substitutions were required due to insufficient data due to poor or lost records. Substitutions for marking tallies between harvests were recommended by the GRF RPF based on forest conditions and similar sales. In one case it was necessary to substitute a marking tally for White Woods for a pine harvest to capture relative tree size distribution information; this was also recommended and approved by the project RPF. If marking tallies recorded trees in four inch diameter classes instead of two inch classes, the total tally was divided in two and equal numbers of trees were assigned to each class. If the number of trees in a four inch category was odd, then the larger number of trees was assigned to the smaller two-inch category.

Marking tallies are used by foresters to track the number, size, and species of trees they select for harvest during sale layout. The tallies are representative of the harvest, but tend to underestimate the final harvested volume. To ensure that all harvested volume was accounted for, the board foot (BF) volumes of trees were calculated as identified in the marking tallies. Then, the classes were weighted by species as a percent of the total (marking tally) volume. The relative weights were multiplied by the scaled final harvest volume recorded at the mill; the result is a distribution of species and size classes of trees which add up to the final harvested volume. The volume of species by classes was then translated back into the number of trees removed during a harvest. Dividing the numbers of trees per class by the THP acreage identified the TPA of each tree class, and a final division identified the number of trees to replant in each 1/10th plot. This is a representative slice of each harvest added to each plot within a THP. The penultimate step, prior to adding the harvest backcast to the inventory backcast tree list, is to

¹⁸ Lindquist, J. L. 2004. Growth and Yield Report for the Whiskey Springs Redwood Commercial Thinning Study: A Twenty-Nine Year Status Report (1971-1999). California Forestry Report No 3, February 2004.

¹⁹ Plant Guide: Tanoak *Lithocarpus densiflorus*. USDA NRCS National Plant Data Center, May 2003. Available: https://plants.usda.gov/plantguide/pdf/cs_lide3.pdf

identify a total height of each tree. Using the DBH, species, and plot site class, heights were estimated using the regression models developed for GRF. Then, finally, the harvest backcast tree list was added to the inventory backcast tree list the year prior to their harvest (e.g., harvested in 2010, trees were added to the tree list in 2009).

In a few cases, tanoak trees were marked for cutting for stand improvement. In marking tallies, the total number of tanoaks cut was recorded (not the DBH size classes) and there are no scaling records for these noncommercial trees. To replant the tanoaks, the number of harvested tanoaks per acre was calculated from the total number of tanoaks in the tally. Based on RPF experience it was assumed that the tanoaks were 10-14" DBH. Therefore, a portion of a 13" tanoak was replanted per plot for harvests with a tanoak cutting component. A 13" tanoak in DBH was selected because it is a conservative estimate. The heights of the tanoaks were calculated using the GRF specific regression. Once added to the harvest tree list, the tanoaks were degrown consistent with the methods described above.

Once harvested trees had been added to the inventory tree list, the trees were adjusted backwards through incremental annual adjustment of height and DBH following the previously described methods to degrow trees. To ensure the trees have free-to-grow forest conditions when determining the annual growth increments, the harvested trees were grown forward in FORSEE in small stands with mixed species and size classes.

A combined backcast (backward adjusted) tree list was created for the date of project commencement, which is basis for the baseline modeling, and also for each reporting period end between project commencement and transition. The carbon stocks at project commencement and the yearend tree lists are calculated and used to calculate the number of credits that would have been available under the Protocol.

VII. Baseline Modeling

Approach

Improved forest management projects are required to use an approved growth and yield model, such as FORSEE, to estimate baseline business-as-usual carbon stocks. The Project began February 2, 2004; the baseline includes the time that the Project was under the CAR 2.1 protocol and the 100-years following transition, a total of 111 years (2004-2115). Project modeling begins with the representative commencement date inventory of standing live trees, and is shaped by the legal constraints affecting the Project at the time of project commencement, especially the California Forest Practice Rules (FPR)²⁰. The baseline modeling aims for maximum sustained production (MSP) of high-quality timber products through a growth and harvesting regime which conforms to the FPR Option C requirements.

According to the Protocol, the baseline must model standing live carbon stocks over time by creating a regime of growth and harvesting scenarios which comply with legal and financial constraints. Then, the results of the model are averaged over time (in this case, 111 years). The result is a single, average

²⁰ California Forest Practice Rules. 2004.

annual values for aboveground live stocks per acre. The belowground live stocks are calculated using the aboveground live stocks as an input as described in the Initial OPDR (Section VII B). There is not an appropriate method to model standing dead trees and the 2015 inventory results are consistently applied throughout the baseline modeling.

The baseline GRF forest model considers four distinct management regimes (described below). The process separately models each regime: Just Grow, Class 1 Streams, Class 2 Streams, and Unconstrained forest areas in FORSEE. Each plot within a stratum is modeled for the fractional area of the applicable management regimes. Each plot is modeled for the applicable management regime and then adjusted by the fraction prescribed during the last step of the baseline modeling.

Harvesting limitations on GRF can be broken up into two categories: locational constraints and forest condition constraints. Both types of constraints have been informed by the legal framework.

Legal Constraints

There are legal constraints which apply to the Project and are incorporated into modeling. Applicable details of the laws are discussed in later sections. (Laws are listed and briefly explained in Initial OPDR, Attachment K.) These are the only applicable constraints on the Project. Although there is a conservation easement on GRF, it is not a legally binding mandate that must be incorporated into the baseline modeling because the sale of the easement occurred on the date of Project commencement. There were no approved THPs on GRF at project commencement.

Silviculture

A variety of silvicultural prescriptions are allowed under the FPR base on the stand conditions. Choosing a prescription involves consideration of the basal area and species composition. The following is a brief description of common redwood region prescriptions.

Prescription	Description
Selection	The goal of this prescription is to create and maintain multistoried, uneven-aged stands with varied diameter classes. Trees are harvested individually or in small groups up to 1/4 acre in size. For Group Selection, trees are harvested individually or in groups up to 2.5 acres in size.
Transition	The goal of this prescription is to develop uneven-aged stands from stands that have an even-aged or irregular stand structure. Trees are harvested individually or in small groups up to 2.5 acres in size.
Variable Retention	Variable retention is a harvesting approach based on the retention of structural elements or biological legacies (trees, snags, logs, etc.) from the pre-harvest stand for integration into the post-harvest stand to achieve various ecological, social and geomorphic objectives. Retained

	trees may be intended to become part of future stands managed by the Selection method. Retained trees are often designated as decadent tree or snag recruitment and therefore not ever intended for harvest. ²¹ Variable retention only occurs if the average age of the dominate trees is at least 60 years old
Commercial Thinning	Commercial thinning is the removal of trees in a young-growth stand to maintain or increase average stand diameter of the residual crop trees, promote tree and timber stand growth, and/or improve forest health. The residual stand shall consist primarily of healthy and vigorous dominant and co-dominant trees from the pre-harvest stand. ¹⁴
Rehabilitation	The goal of this prescription is to regenerate stands that are primarily experiencing excessive hardwood competition and or low conifer occupancy. Successive harvests utilize uneven-aged silviculture.
Conifer Release	The goal of this prescription is to improve growth in stands that are primarily experiencing excessive hardwood competition, and that are well stocked with conifer seedlings. Successive harvests will utilize uneven-aged silviculture. Conifer release only occurs if there are at least 125 conifer seedlings between 0 and 6in DBH.

Location-Based Silviculture

Under the FPR, there are limitations on timber management near sensitive resources, such as streams or wildlife species. Based on location, forested acres may be subject to WLPZ Class 1 watercourse harvest constraints, WLPZ Class 2 watercourse harvest restraints, or harvesting may be completely restricted. To model these constraints, a geospatial analysis was conducted to identify the acres subject to each harvesting restrictions across the forest and per strata. This analysis was conducted on forested acres within the project (Initial OPDR, Figure 4; Section VII A).

Non-harvestable areas are modeled under the Just Grow management regime. These are designated protection zones by the FPR for certain sensitive species. The primary species of concern that has mandated protection zones in the coastal northern California region is Northern Spotted Owl (NSO). The forest non-harvestable area is calculated by removing non-harvestable NSO areas and other non-harvestable sensitive species areas from forested acres within the project.

GRF has 11 NSO activity centers. The FPR requires a 500 ft radius no-cut buffer around all NSO activity centers. In addition, the FPR requires that some NSO habitat extend 1000 ft from the activity center.

²¹ Description taken from the FPR.

The FPR states, “Within 500-1000 ft. of the active nest site or pair activity center, retain sufficient functional characteristics to support roosting and provide protection from predation and storms” (CA FPR 2007, 919.9, 939.9, p.87). To account for this requirement, an additional 250 ft of no-cut buffer was added to the 500 ft radius creating a 750 ft radius no-cut buffer around all NSO activity centers. There are additional requirements within .7 and 1.3 miles of the NSO nest sites for which modeling is not attempted because these requirements are met by the primary use of uneven-age management in the Project.

The GRF also has several tree voles and a sensitive vegetation species (American mannagrass) which are modeled as no harvest areas. The FPR requires that management activities take measures to protect instances of sensitive species. In the GRF, a 25 ft radius no harvest buffer was placed around tree vole points and a 25 ft buffer was used around sensitive vegetation species (Initial OPDR, Attachment N).

Areas within the project which are within 150 feet from a class 1 stream are managed following the WLPZ Class 1 Stream management scenario. Forested areas within the 75 feet of a class 2 stream are managed following the WLPZ Class 2 Stream management scenario. The stratum designation associated with streams is larger than the management buffers required in the FPR. Thus, although most of the WLPZ stratum is managed following the Class 1 Stream or Class 2 Stream management scenario, a portion of the stratum is managed under the Unconstrained management regime (described below) or the Just Grow management regime. The Class 1 Stream and Class 2 Stream acres are determined by calculating the forested acres in streamside buffers after the No Harvest acres have been identified.

	WLPZ Stratum Buffers	Stream Management Buffers
Garcia River (class 1)	300'	150'
Class 1 Streams	200'	150'
Large Class 2 Streams	100'	75'
Class 2 Streams	75'	75'

Modeling the No Harvest/Just Grow Management Scenario

The No Harvest acres in the Project were modeled by allowing FORSEE to grow the forest forward for the baseline; this is the Just Grow scenario. This is a species protection measure for NSO and other sensitive species.

All strata in GRF have a small portion of No Harvest areas, and so all plots are run for the Just Grow Management Scenario.

Modeling the Class 1 & Class 2 Stream Management Scenarios

Areas of GRF which were identified as being within the Class 1 Stream or Class 2 Stream management are modeled in FORSEE to be managed following the FPR. The prescription for streamside management is selection silviculture with a high rate of canopy retention. The percent canopy retention requirement

is the main difference between the two scenarios. If a stand has sufficient basal area and canopy cover to warrant a harvest, the watercourse specific harvesting regime is operated. If a stand does not meet the requirements, then a stand is grown forward one period (5 years) and then the harvesting parameters are re-evaluated. After a stand has been harvested, it is evaluated every two periods (10 years). If the stand meets the constraints, it is harvested; if it does not meet the constraints, it is grown forward. The FORSEE batch script allows for a stand-by-stand evaluation and management for the baseline timeline (111 years).

Light touch harvesting is allowed within stream buffers; the FPR requires that Class 1 watercourses have a 75 ft inner buffer with a retention of 85% canopy cover and a 75 ft outer buffer with a retention of 65% canopy cover. (All calculations assume an existing canopy cover of 90% in riparian areas based on riparian habitat classification by Department of Fish & Game in the summer of 2005.) To account for these different retention rates, a retention rate of 75% was used across the 150 foot Class 1 Stream management zone.

The FPR requires that Class 2 watercourses have a 50-75 foot buffer where at least 50% canopy cover must remain after harvest. To account for this requirement, Class 2 Streams were managed with a 75 foot wide buffer with a 50% canopy retention.

The canopy cover is calculated in the FORSEE batch script using a modified version of the Beer-Lambert law that scales the overlapping individual tree crown area to non-overlapping canopy cover. The individual tree crown area is calculated by FORSEE based on equations from the literature. The non-overlapping canopy is then calculated using the following formula²²:

$$\text{Equation: Non-Overlapping Canopy Cover} \\ CC_{\text{non}} = (1 - \text{Exp}(-CC_{\text{overlapping}}))$$

In this formula, $CC_{\text{overlapping}}$ is the overlapping canopy cover as a percentage of the ground area based on FORSEE's crown width models.

For Class 1 and Class 2 management, stands are entered if there is more than 125 ft² of basal area (BA) and more than the required amount of canopy cover. Stands are harvested to 75 ft² of BA at least or to the lowest BA possible given the canopy cover. Stands in the Class 1 and Class 2 Stream management are entered every 10 years at most but often less frequently.

Only the WLPZ stratum had portions of Class 1 and Class 2 management areas, so only plots in the WLPZ stratum are run for these management scenarios.

Forest Condition Silviculture

²² The Beer-Lambert law can be seen in Waring, R. H., and S. W. Running. 2007. Forest Ecosystems: Analysis at Multiple Scales. Elsevier Academic Press, San Francisco, CA. The conversion of this relationship to calculate non-overlapping canopy can be seen in Crookston, N. L., and A. R. Stage. 1999. Percent Canopy Cover and Stand Structure Statistics from the Forest Vegetation Simulator. Pages 16. General Technical Report, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Rocky Mountain Research Station.

After the geographically constrained forested acres – the No Harvest protection zones and the Class 1 and Class 2 Watercourse protection zones – are identified and removed, the remaining forested acres are the Unconstrained Acres. Silviculture on Unconstrained Acres is guided by parameters outlined in the FPR.

Modeling the Unconstrained Management Scenario

The FORSEE batch script for Unconstrained management evaluates each plot to determine if the stand meets particular conditions for harvesting. The script operates as a hierarchical waterfall. First, a stand is assessed for a selection prescription. If the stand can be harvested using selection silviculture then it is harvested, otherwise it is assessed for the conditions associated with the next prescription type, transition harvest. If the conditions for a transition harvest are met, the stand is harvested; if not, the next silvicultural prescription is assessed and implemented if suitable. There are six silvicultural options in the silvicultural waterfall, and each are assessed in turn in the FORSEE batch script. If a harvesting option is not found for a stand, then the stand is grown for one period (5 years) and then re-run through the waterfall of options.

The waterfall begins with selection and transition silviculture which are uneven-aged approaches. Variable retention, commercial thinning, conifer release, and rehabilitation are the next silvicultural regimes and are all considered even-aged approaches. When a stand is entered, hardwoods are reduced to 14 ft² BA. The 14 ft² of hardwood BA are retained for wildlife habitat. Uneven-aged harvesting only occurs if at least 25ft² of BA is available for harvest. The following tables outline the decision framework used to determine which silviculture to apply when entering a stand.

Pre-harvest stand conditions²³

Prescription	Miscellaneous	Conifer BA Lower Limit	Conifer BA Upper Limit
Selection	-	100	None
Transition	This harvest type only occurs twice per stand.	75	100
Variable retention	Greater than 50% of conifer basal area in trees larger than 18" DBH (this is a surrogate for tree age > 60 yrs)	30	75
Commercial Thin	50% of con BA < 14in DBH and at least 100 con TPA > 4in	15	75
Rehabilitation	Less than 300 point count conifer	0	50
Conifer Release (HW treatment)	At least 125 TPA of conifer stems <= 6in DBH.	0	75

The table below shows the post-harvest stand conditions as well as the constraints for re-entry and the type of management during the next silvicultural treatment.

Post-harvest stand targets

²³ Rule language can be found in the FPR sections 913.2; 913.4; 916.9. A more detailed silviculture decision chart on the baseline silviculture regimes is found below.

Prescription	Conifer BA Retention (ft²/acre)	HW BA Retention (ft²/acre)	Time to Next Treatment
Selection	75	14	Selection when BA > 125 and at least 10 years
Transition	50	14	Transition when BA >= 50 (at least 10 years) followed by Selection
Variable retention	7.5	14	Transition after at least 30 years
Commercial Thin	8.72	14	Transition after at least 30 years
Rehabilitation	0	14	Selection when BA > 125
Conifer Release (HW treatment)	-	14	Transition after at least 30 years

All strata in GRF have Unconstrained acres, so all plots are run for the Unconstrained Management Scenario.

Baseline Outputs

Records of harvests are output by FORSEE as the batch script is run. Then, the carbon of the output tree records are calculated. The final step is combining the applicable fractional values of each plot by management regime. This results in a carbon stock value per management scenario over the baseline, which is ultimately combined into a forest-wide value.

VIII. Harvested Wood Products

Baseline Harvested Wood Products

The harvested wood product (HWP) carbon is calculated following the guidance in Appendix C of the Protocol. The total amount of carbon in trees harvested, whole trees including belowground values, is calculated; this is the prior to mill delivery carbon stocks. Because there is not a regional market for tanoaks or other hardwoods, only merchantable conifers are included the HWP calculations. The amount of carbon in harvested wood delivered to mills, is the amount of carbon in the bole of trees to a six inch top. For the GRF assessment area, a mill efficiency of 0.675 is applied to the bole portion of harvested conifers. The total is then broken into product classes and 100-year carbon pools by applying the specified coefficients in the table below. These coefficients were applied to the wood delivered to the mill (only bole carbon) and the resulting 100-year product and landfill storage was then averaged to calculate the annual HWP carbon. Eighty percent of this total is the final HWP carbon pool. The secondary effects were calculated as 20% of the prior to mill delivery carbon stocks to estimate market leakage. The initial reporting period is 13.5 months (~1.12 years), and the annual baseline HWP is adjusted accordingly for the initial reporting period.

	Product	Product Breakdown	100 year Product Coeffs	100 year Landfill Coeffs
Product Breakdown from Assessment Area File Factors from Tables C.2 and C.3 in the Protocol	SW Lumber	97%	0.463	0.298
	HW lumber	0%	0.25	0.414
	SW Plywood	2%	0.484	0.287
	Oriented Strandboard	0%	0.582	0.233
	NonStruc Panels	0%	0.38	0.344
	Misc Prods	0%	0.176	0.454
	Paper	1%	0.058	0.178

Note: Coefficient values are rounded for display; calculations are completed with the ARB assessment file.

Actual Harvested Wood Products

Each year there is a harvest in the Project, scaled volumes harvest volumes from the mill are used to calculate the actual harvested wood products. The same coefficients, factors and process used in the Baseline HWP are used in the Actual HWP calculation.

IX. Financial Feasibility Analysis

The financial constraints of the baseline are considered in an analysis of the baseline modeling scenario. The analysis covers the lengths of the baseline analysis (111 years) and is conducted to determine if the business-as-usual scenario is financially viable. The harvested volumes of wood from the baseline modeling scenario are used a revenue generating input; the estimated costs of management, harvesting, and operations are based on management costs for GRF. The analysis uses a discount rate of 7%, a California regional norm. Prices of sawtimber have fluctuated historically, but are generally flat. For the baseline, flat sawtimber prices are assumed to continue.

RESULTS

X. Forest Inventory

The forest inventory had a total of 699 plots across the three strata. There were 172 plots in the Reserve (RSRV) stratum, 432 plots in the Working Forest (WF) stratum, and 95 plots in the Watercourse and Lake Protection Zone (WLPZ) stratum. The geospatial analysis and resulting acreages are described in the Initial OPDR (Section VIIA).

Site Class

In the 2015 Project inventory, site tree information was collected on 181 dominant, free-to-grow conifer trees. Mirroring earlier inventory efforts, GRF was found to be primarily site class 3.

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Species	50yr Site Index	100yr Site Index	Site Class
Douglas-fir	100.3	150.9	III
Redwood	91.4	139.3	III
Sugar Pine	100.0	153.5	NA

Estimating Tree Height: GRF Height Regression

The height-diameter height regressions developed for the Project were based on the following equation forms published for coastal redwood/Douglas-fir forests (Eng 2012):

Equation form 1: $\text{Height} = 4.5 + \exp(a + b \cdot \text{DBH}^c)$

Equation form 2: $\text{Height} = 4.5 + a \cdot (1 - \exp(b \cdot \text{DBH}^c))$

Three models were fit for each species/species grouping: coefficient values published by Eng (Eng), property-wide species data sets (All GRF), and by site class subsets of species data (RWSC). The model with the best root-mean-square error (RMSE) was selected to estimate heights for the Project. There were limited records of individuals in “other conifer” and “western hemlock” groups. Project and site specific models were not fit, instead the recommended values by Eng were used.

Species	Equation Form	Model	Site Class	Coefficients			RMSE
				a	b	c	
Douglas-fir	1	RWSC	2	6.0408	-5.0779	-0.41756	18.652
Douglas-fir	1	RWSC	3	5.3715	-4.4920	-0.5464	16.258
Douglas-fir	1	RWSC	5	5.1714	-6.5182	-0.7218	17.482
Grand Fir	1	All GRF	All	6.7166	-5.6958	-0.3118	10.606
Other Conifer	1	Eng	All	5.9429	-6.2041	-0.5531	NA
Pacific Madrone	2	All GRF	2	74.0637	-0.1607	0.6319	11.624
Pacific Madrone	2	RWSC	3	56.5570	-0.1538	0.8506	10.943
Pacific Madrone	2	All GRF	5	74.0637	-0.1607	0.6319	11.624
Oak Grouping	2	All GRF	2	67.3358	-0.1119	0.7605	11.952
Oak Grouping	2	RWSC	3	96.8665	-0.0939	0.6395	12.596
Oak Grouping	2	RWSC	5	73.6668	-0.1594	0.56902	10.988
Redwood	1	RWSC	2	9.0244	-7.4551	-0.1535	18.081
Redwood	1	RWSC	3	6.0474	-5.5023	-0.4047	17.838
Redwood	1	RWSC	5	5.0529	-19.974	-1.1128	12.94
Sugar Pine	1	All GRF	2	6.0956	-5.2794	-0.3908	10.482
Sugar Pine	1	RWSC	3	6.08095	-5.4166	-0.4009	10.402
Sugar Pine	1	All GRF	5	6.0956	-5.2794	-0.3908	10.482
Tanoak	1	RWSC	2	5.7840	-4.203	-0.30601	11.616
Tanoak	1	RWSC	3	4.9836	-3.8411	-0.5079	12.781
Tanoak	1	RWSC	5	4.4368	-3.9949	-0.7282	10.19
Western Hemlock	2	Eng	All	162.7225	-0.05723	0.9763	NA

Note: Coefficient values have been rounded for ease of display.

Estimating Tree Height: FORSEE Height Regression

The FORSEE growth and yield model estimates heights using provided subsamples of measured heights. The regressions are fit and calculated within FORSEE; the equations are not provided.

XI. Carbon Calculations

The summary of carbon stocks are included in the Initial OPDR (Section VII.C). Tables of standing live carbon stocks and standing dead carbon stocks (Table 7 and 9) display the values by property and by stratum. Live carbon stocks are adjusted using the growth and yield model; however, standing dead stocks are calculated based on field measurements and are held constant until new field measurements are available.

Statistics

The overall project mean and standard error are reported in the Initial OPDR (Section VII.D, Table 8). No confidence deduction is required because the Project has less than 5% sampling error at the 90% confidence interval, according to the Table A4 in the Protocol (reproduced below).

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

XII. Growth and Yield Modeling: FORSEE

Tree Ingrowth/Regeneration

The number of trees which grow into a stand after harvest was calculated by identifying the basal area of common species per stratum. The following weights of species regeneration were entered into FORSEE's regeneration setup. The applicable regeneration list is brought into the FORSEE growth modeling via the batch script when a harvest occurs.

Species	Species Code	Strata		
		RSRV	WF	WLPZ
Douglas-fir	DF	26.6%	26.4%	21.4%
Live Oak	LO	2.9%	0%	0%
Pacific Madrone	PM	5.9%	5.1%	0%
Redwood	RW	24.4%	16.8%	56.7%
Shreve's Oak	SO	5.1%	0%	0%
Sugar Pine	SP	0%	4.5%	0%
Tanoak	TO	35.1%	47.3%	21.9%
Total		100%	100%	100%
Forested Acres		5,569	13,800	3,086

XIII. Adjusting the Forest Inventory

Due to the complexity of the backcast, the forest inventory was adjusted to several different points in time corresponding to the Initial Starting Stocks and the many reporting period end dates (2005-2015). The carbon stocks from the adjusted inventories are reported in Appendix C: Calculation of GHG Reductions and GHG Removals.

XIV. Baseline Modeling

The baseline modeling was conducted in FORSEE. The modeling divides the forested acres of the Project into four distinct management regime based on location (location-based silviculture), which are then

harvested and grown forward according to forest condition, as applicable. The details of the scenarios are described in the baseline modeling approach section. The Just Grow/No Harvest scenario is 435.59 acres; Unconstrained scenario is 19,581.66 acres; Class 1 stream scenario is 1,167.99 acres; and the Class 2 stream management scenario is 1,270.12 acres. The management scenarios are intersected with the strata. The percent of each stratum modeled per management scenario is shown in the table below.

Strata	Unconstrained Mgnt	No Harvest	Class 1 Stream Mgnt (WLPZ1)	Class 2 Stream Mgnt (WLPZ2)
RSRV	97.3%	2.7%	0%	0%
WF	98.8%	1.2%	0%	0%
WLPZ	17.1%	3.9%	37.8%	41.2%

For modeling, each plot within a stratum is considered to represent a certain total number of forested acres. The total forested acreage is composed of smaller acreages modeled following the corresponding management scenarios. For example, each plot in the RSRV represents 31.52 acres of the Unconstrained management regime and 0.86 acres of the Just Grow/No Harvest management regime. Each plot in the RSRV stratum was modeled in the FORSEE batch modeling script for the Unconstrained management regime and the Just Grow/No Harvest regime for the length of the baseline and then scaled by the acre following the table below.

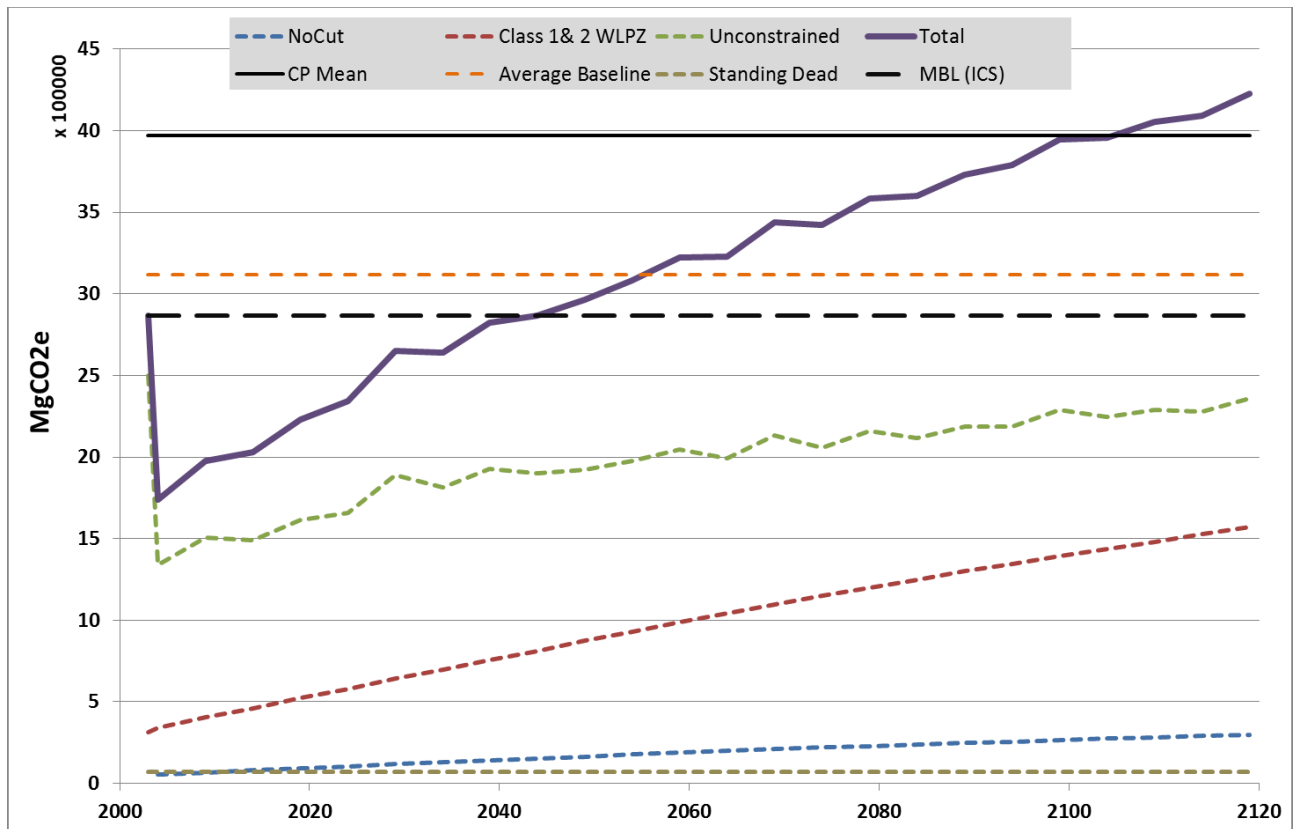
Strata	Total Forested Acres Per Plot	Unconstrained Acres Per Plot	No Harvest Acres Per Plot	WLPZ1 Acres per Plot	WLPZ2 Acres Per Plot
RSRV	32.38	31.52	0.86	-	-
WF	31.95	31.56	0.38	-	-
WLPZ	32.49	5.54	1.28	12.29	13.37

Note: Acre per plot values have been slightly rounded for ease of display.

Baseline Management Regime by Management Type

The modeled business-as-usual baseline of the Project over the next century has an average baseline value (orange dashed line) above the MBL (black dashed line). The total carbon stocks are modeled to steadily increase over the timeline of the baseline, after an initial pulse of aggressive harvesting. As shown in the graph below, all management regimes contribute to the modeled trend of increasing carbon stocks on the Project.

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The business-as-usual baseline modeling has moderate levels of harvesting for the length of the planning horizon. The table below shows the MtCO₂e/acre and total project MtCO₂e for the planning horizon. Only the aboveground carbon stocks are shown below.

	MtCO ₂ e/acre AG Live Trees			MtCO ₂ e AG Live Carbon		
Year	AG Live (MtCO ₂ e/Acre)	Annual Growth (All acres)	Annual Harvest (Harv acres)	AG Live (MtCO ₂ e)	Annual Growth (All acres)	Annual Harvest (Harv acres)
2003	127.7	start		2,867,171	start	
2004	77.4	-10.1	6.3	1,738,184	-225,797	141,071
2009	88	12.2	0.5	1,975,302	273,221	11,367
2014	90.3	2.1	2.6	2,027,455	47,546	58,848
2019	99.3	5.4	1.3	2,230,124	120,779	28,656
2024	104.2	3	2.5	2,340,300	67,907	56,100
2029	118	5.7	0.8	2,648,749	127,934	18,172
2034	117.5	1	3.8	2,638,622	22,619	84,800
2039	125.7	5.7	2.1	2,823,213	127,923	46,425
2044	127.8	2.4	3.1	2,868,684	54,599	68,598
2049	131.9	4.1	2.3	2,961,996	91,210	51,516
2054	137.2	3.7	2.7	3,080,839	82,923	60,453
2059	143.5	3.6	1.8	3,221,549	80,985	40,755
2064	143.9	2.2	3.5	3,230,231	49,268	79,248
2069	153	5.1	1.6	3,436,566	115,396	35,698
2074	152.5	1.3	3.5	3,424,423	29,552	78,069
2079	159.7	4.8	1.9	3,585,635	108,744	43,446
2084	160.4	1.9	3.4	3,601,398	41,893	76,003
2089	166.2	4.2	1.9	3,731,603	94,407	41,700
2094	168.7	2.4	3	3,788,545	54,220	67,310
2099	175.7	4	1.9	3,944,812	89,204	42,270
2104	176.1	1.7	3.3	3,954,847	38,495	73,157
2109	180.5	3.8	2.4	4,053,995	85,774	53,607
2114	182.3	2.4	3	4,093,955	54,408	67,728

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Appendix B

The baseline modeling table below shows the percentage of the Unconstrained GRF acreage (19,852 acres) which were managed using each silvicultural regimes per period. For the planning horizon, the most common prescription is selection.

	Management Used (Unconstrained Acres)							
Year	Commercial Thin	Conifer Release	Rehab	Selection	Transition	Variable Retention	No Entry	Total Managed
2004	1.0%	0.0%	8.8%	26.8%	9.4%	10.2%	43.8%	56.2%
2009	0.0%	0.0%	3.5%	1.0%	4.3%	0.5%	90.8%	9.2%
2014	0.0%	0.0%	4.4%	25.8%	7.8%	0.3%	61.6%	38.4%
2019	0.0%	0.0%	1.9%	6.9%	8.4%	0.0%	82.7%	17.3%
2024	0.0%	0.0%	2.0%	27.6%	4.0%	0.0%	66.5%	33.5%
2029	0.0%	0.0%	1.0%	8.3%	2.1%	0.0%	88.6%	11.4%
2034	0.3%	0.0%	1.3%	30.2%	8.9%	0.0%	59.2%	40.8%
2039	0.0%	0.0%	0.7%	14.1%	6.0%	0.0%	79.2%	20.8%
2044	0.0%	0.0%	1.0%	27.0%	9.9%	0.0%	62.1%	37.9%
2049	0.0%	0.0%	1.1%	20.3%	6.5%	0.0%	72.1%	27.9%
2054	0.0%	0.0%	0.2%	29.3%	6.1%	0.0%	64.4%	35.6%
2059	0.0%	0.0%	0.8%	16.8%	5.7%	0.0%	76.7%	23.3%
2064	0.0%	0.0%	0.8%	37.9%	4.1%	0.0%	57.2%	42.8%
2069	0.0%	0.0%	0.0%	18.4%	2.3%	0.0%	79.3%	20.7%
2074	0.0%	0.0%	0.6%	39.1%	3.9%	0.0%	56.4%	43.6%
2079	0.0%	0.0%	0.0%	21.3%	2.4%	0.0%	76.3%	23.7%
2084	0.0%	0.0%	0.2%	42.4%	2.1%	0.0%	55.3%	44.7%
2089	0.0%	0.0%	0.3%	21.9%	1.8%	0.0%	75.9%	24.1%
2094	0.0%	0.0%	0.0%	40.3%	0.5%	0.0%	59.2%	40.8%
2099	0.0%	0.0%	0.0%	23.7%	1.0%	0.0%	75.3%	24.7%
2104	0.0%	0.0%	0.2%	41.8%	1.8%	0.0%	56.2%	43.8%
2109	0.0%	0.0%	0.0%	29.1%	0.8%	0.0%	70.1%	29.9%
2114	0.0%	0.0%	0.0%	40.7%	0.8%	0.0%	58.5%	41.5%

XV. Harvested Wood Products

The harvested wood products for the baseline are summarized in the Initial OPDR (Section VIII A 5). The annual actual harvested wood products per year are summarized below.

Gross Harvest Volume (MBF)				Harvest Total (MBF)	Actual Carbon in Trees Harvested for Wood Products (CO ₂ e) Prior to Delivery	Actual Carbon in HWP Delivered to Mill (CO ₂ e)	Avg Baseline Carbon in Wood Products (CO ₂ e)
Year	RW	WW	DF				
2004	-	-	-	-	-	-	14,716
2005	-	-	-	-	-	-	14,716
2006	-	-	-	-	-	-	14,716
2007	960.39	43.52	509.96	1513.87	9,744	4,870	14,716
2008	-	-	-	-	-	-	14,716
2009	-	-	-	-	-	-	14,716
2010	71.09	0.22	48.91	120.22	774	387	14,716
2011	125.64	44.73	151.71	322.08	2,073	1,036	14,716
2012	881.68	107.19	192.81	1181.68	7,606	3,801	14,716
2013	365.72	190.56	705.46	1261.74	8,121	4,059	14,716
2014	8.56	-	658.33	666.89	4,292	2,145	14,716
2015/ 2016	352.02	-	810.43	1162.45	7,482	3,739	14,716
2017	44.47	9.15	9.87	63.49	409	204	14,716

XVI. Financial Feasibility Analysis

The financial feasibility analysis (Initial OPDR Attachment L) is discussion in the Initial OPDR (Section VII B 7).

Forest Carbon Inventory Change Log

#	Year	Change
1	2015/2016	Updated standing dead wood calculations to use Harmon 2011 values; calculated standing dead belowground biomass using Cairns 1997
2	2015/2016	Updated biomass equations for trees without an FIA equation to follow the ARB approved substitutions for Shreve’s Oak, Wax Myrtle, Toyon, and Edible Fig.
3	2015/2016	Extended the baseline modeling to run from the time since project commencement (2004) to the transition date, plus one-hundred years. Baseline timeline is now 2004-2115.
4	2015/2016	Expanded the Modeling Plan to explicitly include details such as Project-specific regression coefficients and inventory adjustment methodologies
5	2015/2016	Revised Reporting Period 1 to be 1/1/2015-2/14/2016, instead of a calendar year
6	2017 (RP2)	[duplicate, also noted in change log in the annual OPDR] Language was revised in the Modeling Plan regarding the use of the growth and yield model, FORSEE, to reflect an updated understanding of the inventory update process. (Modeling Plan, Section VI, Future Forest Updates)
7		
8		
9		
10		
11		

Appendix C: Calculation of GHG Reductions and GHG Removals Enhancements

The reporting period between 2/15/2017-2/14/2018 is the second reporting period that the Garcia River Forest Project is under the Protocol, therefore only the pertinent calculations are reported here. There was a negative credit difference between the early action protocol and the Compliance Offset Protocol.

Calculation of GHGs for Reporting Period Ending 2/14/2018

	Reporting Period 3 (Ending 2/14/2018)
Calculating GHG Reductions/Removals for Onsite Carbon Stocks	
Standing Live Stocks	5,638,856
Standing Dead Stocks	71,425
Actual Onsite Carbon Stocks (tonnes CO2e)	5,710,281
Confidence Deduction	0.0%
Adjusted Actual Onsite Carbon Stocks (adjusted for confidence deduction) (tonnes CO2e)	5,710,281
Increment in Actual Onsite Carbon Stocks (tonnes CO2e)	196,380
Baseline Onsite Carbon Stocks (tonnes CO2e)	3,945,838
Quantified GHG Reductions / Removals for Onsite Carbon Stocks (tonnes CO2e)	196,380
Calculating Carbon Stored in Wood Products Including Market Effects and Leakage	
Actual Carbon in Trees Harvested for Wood Products in (tonnes CO2e)	1,581
Baseline Carbon in Trees Harvested for Wood Products (tonnes CO2e)	57,608
Actual Carbon in Harvested Wood Delivered to Mills (tonnes CO2e)	790
Baseline Carbon in Harvested Wood Delivered to Mills (tonnes CO2e)	28,791
Actual Carbon Stored Long-term in Wood Products (tonnes CO2e) - Excl Landfill	245
Actual Carbon Stored Long-term in Wood Products (tonnes CO2e) - Incl Landfill	404
Baseline Carbon Stored Long-term in Wood Products (tonnes CO2e) - Excl Landfill	9,602
Baseline Carbon Stored Long-term in Wood Products (tonnes CO2e) - Incl Landfill	14,716
Diff Between Actual and Baseline Carbon in Harvested Wood (tonnes CO2e) - Excl Landfill	-9,357
Difference Between Actual and Baseline Carbon in Harvested Wood (tonnes CO2e) - Incl Landfill	-14,312
Difference in Actual and Baseline Carbon Stored in Wood Products (tonnes CO2e) - Landfill Adj	-14,312
GHG Reductions / Removals for Carbon Stored in Wood Products (tonnes CO2e) w/ mkt response	-11,449
Calculating Other Secondary Effects - Improved Forest Management Projects	
Difference Between Actual and Baseline Carbon in Harvested Wood (tonnes CO2e)	-56,027
Other Secondary Effects Emissions (shifting activities/materials) IFM Projects (tonnes CO2e)	-11,205

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Quantified GHG Reductions and Removals	
Annual GHG Reductions/Removals Net of Discounts and Secondary Effects (tonnes CO2e)	173,726
ARBOCs Issued - Net of Negative Carryover, bef. Buffer or adjust for Reversals (tonnes CO2e) Qty	173,726
Calculation of Buffer Pool Contribution	
Project Specific Reversal Risk Rating	19.24%
Annual Buffer Pool Contributions (ARBOCs)	33,418
Accounting for Reversals	
Annual Reversals (tonnes CO2e)	-
Total "Intentional Reversals" to be compensated by the Offset Project Operator (tonnes CO2e)	-
Compensating for Avoidable Reversals	
"Intentional Reversals" compensated by Offset Credits from the OPO's Account (tonnes CO2e)	-
Carryover "Intentional Reversals" which need to be compensated by OPO (tonnes CO2e)	-
ARBOCs Issued to Account Holder	
<i>Annual ARBOCs Issued to Account Holder</i>	140,308

Early Action Credits as Compared to COP ARBOCs

		Credits issued under early action protocol (CRTs)	Credits that would have issued under Compliance Protocol	Credits eligible to be converted to ARBOCs	Credit difference to be issued after transition
Early Action Credits	2004	-	-	-	-
	2005	77,040	-	77,040	-
	2006	77,040	-	77,040	-
	2007	174,109	62,133	174,109	-
	2008	228,814	93,327	228,814	-
	2009	189,898	122,661	189,898	-
	2010	504,413	106,092	504,413	-
	2011	35,683	107,805	35,683	-
	2012	128,411	109,091	128,411	-
	2013	212,359	106,752	212,359	-
	2014	211,630	115,662	211,630	-
TOTAL		1,849,397	823,523	1,849,397	-

Appendix D: Demonstration of Sustainable Long Term Management

Intro

ARB's 2014 US Forest Project Compliance Offset Protocol (COP) requires that projects employ sustainable long-term harvesting practices (see section 3.8.1). There are three options to demonstrate sustainable long-term harvesting. TCF is using option 3 to meet the criteria for the 2015 reporting period which states:

3. The Forest Owner must employ uneven-aged silvicultural practices (if harvesting occurs) and must maintain canopy cover averaging at least 40 percent across the entire forestland owned by the Forest Owner in the same Assessment Areas covered by the Project Area, as measured on any 20 acres within the Forest Owner's landholdings found in any of these Assessment Areas, including land within and outside of the Project Area (areas impacted by Significant Disturbance may be excluded from this test). (COP, pg 18)

Naturally occurring openings and meadows as well as areas disturbed by wildfire are excluded from this test according to guidance from CAR/ARB (Nickerson pers email 9/17/2015).

The Conservation Fund owns a total of approximately 53,000 acres within the Coast Redwood/Douglas-fir Mixed Conifer Assessment Area. These are – Big River 11,707, acres; Salmon Creek, 4,204 acres; Garcia River Forest, 23,780 acres; Gualala River Forest, 13,540 acres; and the Hardell Tract, 185 acres. All properties are forested and have been managed for forest products since the early 1900's.

Analysis

In June of 2015, digital aerial image information called "Phodar" was collected for all North Coast Forest carbon projects by Quantum Spatial. Using the Phodar and existing ground elevation information derived from 2011 LiDAR imagery, Quantum Spatial developed a digital canopy height model for the properties which contains canopy height and width (surface area) values for the vegetation within the assessment area. The resulting data allows 3-dimensions analysis of the properties; the digital height model was used to evaluate the forests canopy cover.

Canopy at least 3 meters tall was considered to be established woody vegetation. A 20-acre "moving window" was used to calculate the average percent canopy within all potential 20-acre polygons across the property in ArcGIS 10.1; a 20-acre area centered on each pixel was evaluated for percent canopy. All nonforested acres were removed from the data set prior to the analysis. The nonforested acres are known areas that have natural openings such as grasslands and river gravel bars which are not forestland and are not part of carbon calculations.

Because the Hardell Tract is not a carbon project, Phodar imagery was not collected for the entire property. Of the 185 acres, 57 acres do not have Phodar imagery. These 57 acres were analyzed for percent canopy cover using USFWS's i-Tree Canopy tool (<https://www.itreetools.org/>). To do this, the shapefile was imported into the online tool and 50 points were added and reviewed.

The attached maps show that the entire TCF forestland ownership within the Coast Redwood/Douglas-fir Mixed Conifer Assessment Area has at least 40% canopy cover. There were no areas on any of the properties evaluated which did not pass the 40% canopy test for trees greater than 3 meters tall.

Average percent canopy by tract.

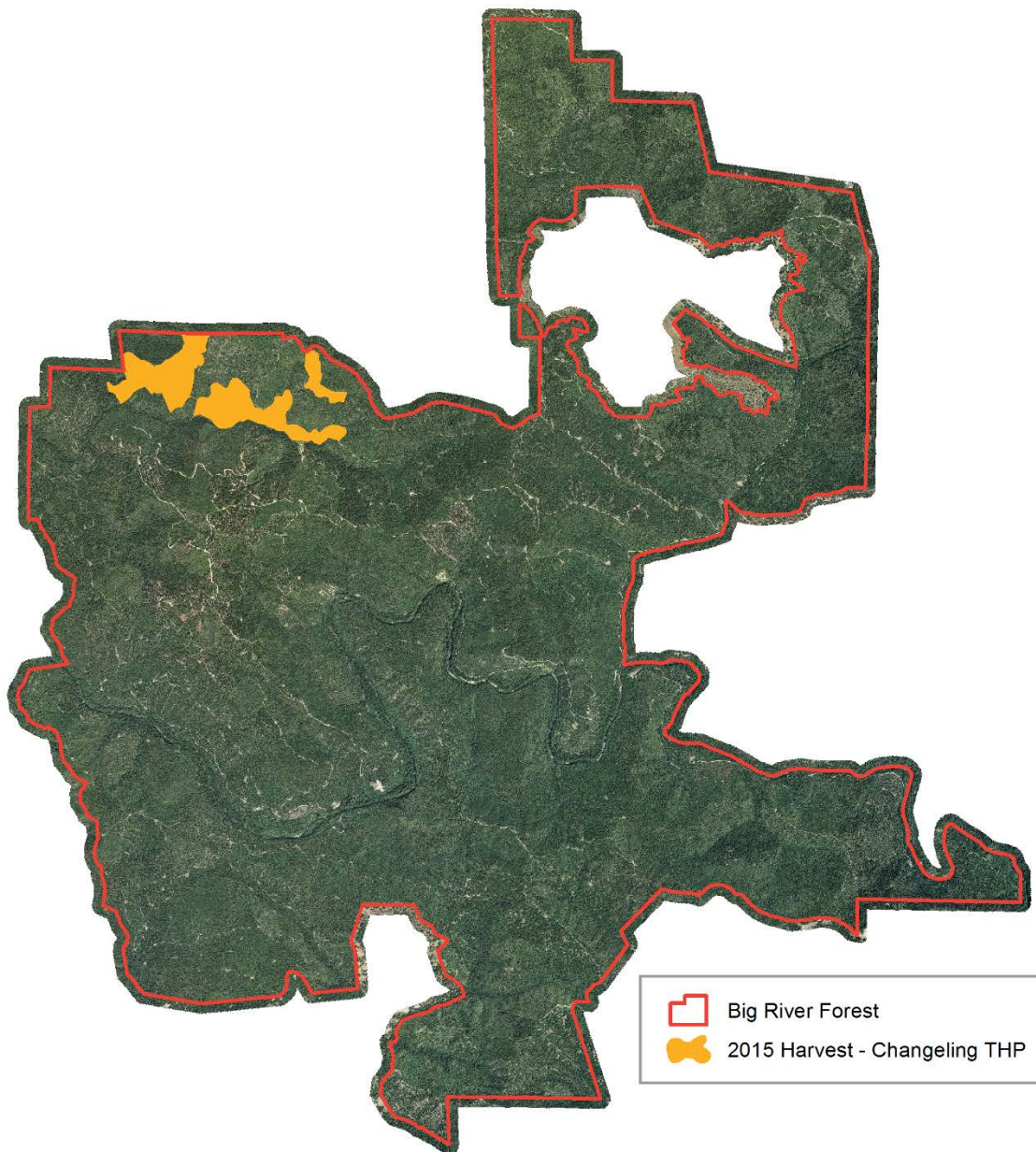
Forest Tract	Average Percent Canopy	Min Percent Canopy
Big River	91%	57%
Salmon Creek & Portion of Hardell Tract	91%	47%
Garcia River Forest	96%	57%
Gualala River Forest	95%	66%

Additional Considerations

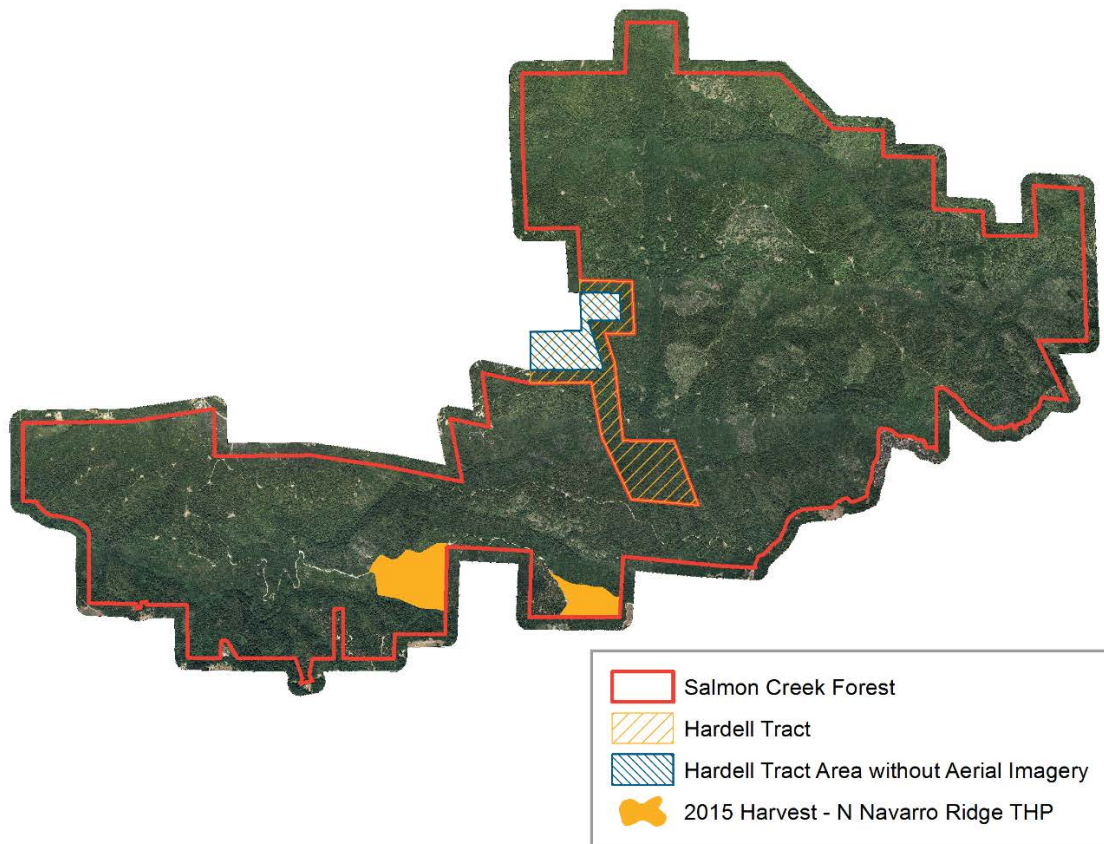
Since the Phodar imagery was collected, there have been three timber harvests in the project areas. The table below shows the approximate acres harvested after the Phodar acquisition. These harvests employed similar silviculture to other timber harvests on TCF property and are therefore presumed to meet the 40% canopy test. Most TCF harvests, including the three in the table below, have been selection harvests. Single tree and group selection harvests remove individual trees here and there from a large area; selection harvests leave significant canopy cover and forest structure. Given that the 2015 harvests employed silviculture consistent with previous timber harvests which retained at least 40% canopy, we can reasonably assume that the 2015 timber harvests also meet the test.

THPs with Harvest Operations since June 2015

Year	THP Name	THP Number	Forest Tract	Acres
2015	Olsen Gulch	1-14-036 MEN	Garcia River Forest	152
2015	Changeling	1-14-101 MEN	Big River	192
2015	North Navarro Ridge	1-10-005 MEN	Salmon Creek	82

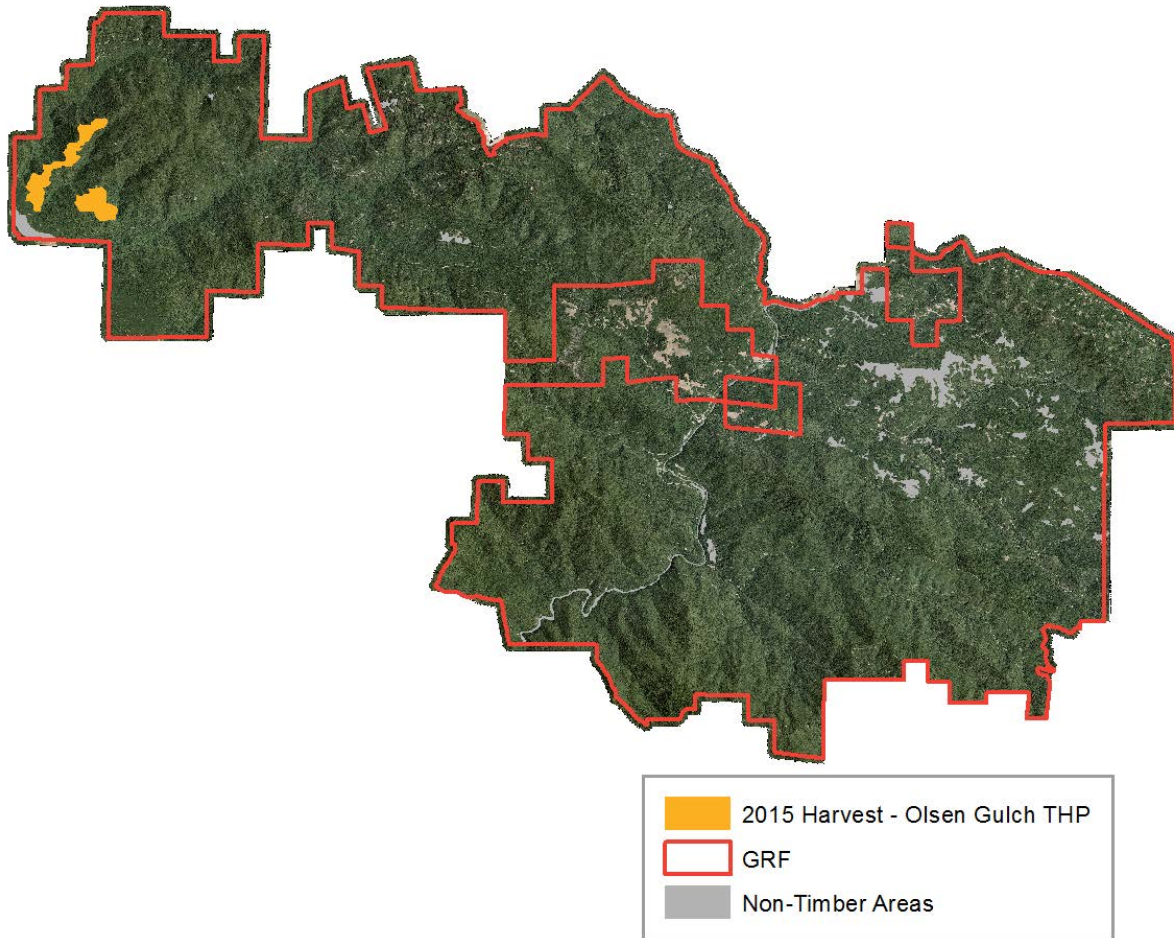


Big River Forest – the Big River tract had 40% canopy throughout. Areas that were operated on in 2015 with the Changeling THP are in yellow (192 acres). High-resolution aerial imagery was collected in June 2015 in conjunction with the Phodar data collection.



Salmon Creek Forest – The Salmon Creek Tract had 40% canopy throughout. The carbon project is outlined in red. The 2015 operations area in North Navarro Ridge THP is in yellow (82 acres). The Hardell Tract is in yellow cross-hatch; the blue cross-hatch in the center of the figure is the 57-acre portion of the Hardell Tract that did not have Phodar collection and was analyzed with iTree Canopy. The Hardell tract had 40% canopy throughout.

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Garcia River Forest – The Garcia River Forest had 40% canopy throughout. Areas that were operated on in 2015 with the Olsen Gulch THP are in yellow (152 acres). The areas in gray are natural openings including grasslands and the Garcia River gravel bar.



Gualala River Forest – The Garcia River Forest had 40% canopy throughout. The areas in gray are naturally occurring grasslands and are excluded from the analysis. There was no timber harvest in the forest in 2018

Lying Dead Wood Monitoring Plan

Garcia River Forest (CAFR 5141) & Big River/Salmon Creek Forests (CAFR 5106)

Background

The Conservation Fund (TCF) owns and manages nearly 74,000 acres in coastal northern California. Among the forestland owned by TCF are two early action carbon projects: Garcia River Forest (GRF) and Big River/Salmon Creek Forests (BRSC). These projects were originally developed and listed with the California Climate Action Registry (CCAR) using the 2.1 version of the Forest Project Protocol (FPP; CAR 2.1). They were successfully verified in 2007 and 2009 respectively and in every subsequent calendar year. GRF and BRSC projects were part of the Early Action Offset Program (EAOP) and were eligible to transition to the California Air Resources Board (ARB) Compliance Offset Protocol (COP). The projects began reporting and adhering to the COP in 2015. Additionally, some carbon credits issued under the early action program were transitioned to the compliance program and became COP compliance carbon credits (ARBOCs). Although the FPP and COP protocols differ in several ways – including calculation of biomass calculations, CO₂e conversion rates, verification methodologies, and reporting processes – during the transition, most differences were addressed and reconciled.

One major difference between the FPP and COP protocols is the treatment of the lying dead wood carbon pool. In the FPP, lying dead wood inclusion was required in project development and annual monitoring. In contrast, the COP excludes the lying dead wood carbon pool. Once the projects moved from the FPP to the COP, lying dead wood was not included in the forest's COP carbon calculation starting with the 2015 verified stocks.

Neither the Cap and Trade Regulation nor the COP requires transitioned projects to monitor or report on lying dead wood or other obsolete pools. The transition guidance (ARB 2015) is also silent on the matter. Section 95990(e)(3) does state that a party listing an early action project must “ensure that the GHG reductions ... credited in the applicable early action reporting period are permanent..., including reporting and verification to ensure permanence.” A 2013 ARB Frequently Asked Questions (FAQ) document states that Offset Project Operators (OPO) of transitioned FPP projects “will follow the requirements of CAR V2.1 for monitoring and reporting these carbon pool(sic). ARB will be developing further guidance to implement this requirement upon transition”. To date, no further guidance has been issued.

GRF and BRSC have converted early action credits from reporting periods that included lying dead wood. In the absence of further guidance, this monitoring plan is a proactive initiative by TCF to lay out a process to monitor and report on the lying dead wood carbon pool in GRF and BRSC and comply with 95990(e)(3) of the regulation in a repeatable, verifiable and efficient manner. This monitoring plan, and any derivative reports, is intended to be a companion to the forest inventory, analysis and reporting required under the COP for the live carbon pools on GRF and BRSC. This plan

involves installing a new set of lying dead wood monitoring plots and tracking them, and their average, through time.

Forests & Lying Dead Wood

Both forest projects are in Mendocino County, California. GRF is a 23,780 acre forest; it is primarily a redwood/Douglas-fir/tanoak forest with small areas of oak woodlands and grasslands. BRSC is composed of two separate tracts, Big River which is 11,707 acres and Salmon Creek which is 4,204 acres. BRSC is a total of 15,911 acres. The tracts are primarily redwood/Douglas-fir. Both GRF and BRSC have a long history of timber harvest and are a mix of 2nd growth and 3rd growth trees. TCF forest management continues to actively harvest trees using uneven-aged silviculture. Among the goals for the forests are promoting conifer stands with large trees while maintaining biodiversity. Lying dead wood is recruited and retained on site during forest management as part of TCF's management plan for wildlife habitat protection and carbon sequestration.

Lying dead wood is unevenly distributed throughout the forests; its distribution is extremely patchy and has been described as "irregular and heterogenous" (Evans and Ducey 2010). Some areas of the forest have no down dead biomass, while other places (e.g., with old growth redwood logs) may have substantial lying dead wood biomass. The processes which bring in lying dead wood are stochastic and difficult to predict. Natural events such as self-thinning and windstorms often recruit new pieces of lying dead wood. Additionally, active management, through timber harvesting, has also been observed to increase lying dead wood pieces (primarily tops and branches of harvested trees). Once on the forest floor, lying dead wood decomposes; the rate of biomass decomposition varies by species and is impacted by forest microclimates. Decomposition decreases the density of the wood over time and pieces eventually decay out of the measurable carbon pool. Given the policy and practice of protecting existing lying dead wood, the overriding assumption is that lying dead wood recruitment through natural events or harvesting will exceed the rate of decay and the pool will remain stable or increase over time since the forests are on a trajectory toward larger trees and increased overall stocking, as required by the COP and conservation restrictions.

Lying dead wood is an important carbon and habitat component of forest stands, but given the variability and stochasticity it is difficult to predict and model. Therefore, as used in 2.1 projects and verifications, repeated direct measurements of transects in the forest will be used to track lying dead wood biomass over time.

Monitoring Plan Objective

In natural resource management, monitoring is the "collection and analysis of repeated observations or measurements to evaluate changes in condition" (Elzinga et al 1998). The intent of this monitoring plan is not to calculate the total amount of lying dead wood biomass in the forest but to capture the trend of lying dead wood biomass over time (to ensure no reversals have occurred). Consistent with the methodologies used for past 2.1 Early Action and Transition verifications, the plan aims to gather data to assess the change over time in the amount of carbon in dead woody material at

least 6 inches in diameter and 6 feet long. If lying dead wood carbon stocks are stable within allowable confidence intervals or increasing over time, objectives will be considered met, and the pool will be considered permanent. This plan will install a new set of lying dead wood monitoring plots and will track them and their average over time.

A second objective is to make the LDW monitoring system consistent with the COP field verification methodologies to increase inventory and audit efficiency and consistency.

Previous Data Collection

Overview

For the years when GRF and BRSC were early action projects, lying dead wood measurements were collected in all forest inventories as required by the FPP. The previous data collection and verification procedures are outlined below for reference, and to demonstrate consistency.

Measurements

Lying dead wood was defined in the FPP as “Any piece(s) of dead woody material, e.g., dead boles, limbs, and large root masses, on the ground in forest stands” (CAR September 2007). Lying dead wood pieces were measured along a 100 foot line transect (slope distance). The 100 foot transect was composed of two 50 foot long arms that were 90° apart from one another. Both arms of the transect started at plot center and extended outward. One arm extended north from plot center; the other extended east from plot center (90° clockwise from the first 50 foot arm). The transect was measured with a tape (not a hip chain). The line transect had no width; down wood pieces were required to intersect the transect to be measured.

Down woody pieces must have met the following criteria to be measured:

- Average diameter of at least 6 inches, inside bark (determined by summing the large end diameter and the small end diameter and dividing by two)
- At least 6 feet in length
- Old growth stumps were not considered to be lying dead wood; however, old growth logs were included

If a piece of lying dead wood intersected the transect and met the above criteria, then the following data were collected:

- Decay classification using the USFS classification (see Table 1)
 - o As a rule of thumb “Down Hard” was classified as “no material giving way when kicked, sound when kicked is a thud”; hard logs generally have the top intact, the bark on, and the wood is sound
 - o As a rule of thumb “Down Soft” was classified as “material falls off when kicked, sound is muffled”; soft logs usually have sloughing bark, and the wood is decaying
- Average diameter (inches)

- o inside bark (determined by summing the large end diameter and the small end diameter and dividing by two)
- Length (feet)
 - o Where logs taper to a point less than six inches in diameter, the log length is measured from the place where the log is six inch diameter to other end of the log
 - o In some cases, there may be broken or decayed pieces where questions may arise about whether it represents one or two pieces of wood. Pieces are defined based on points of abrupt physical change based on breakage, branching, or advanced decay. Branches should be considered separate pieces where the branches meet the diameter and length requirements for individual pieces. Broken pieces which were obviously part of a single larger piece and are separated by less than six inches of space are counted at one piece. (see Figure 1)
- Species
 - o As wood decays, it may be difficult to determine the tree species of the lying dead wood piece. If the species cannot be determined, then the appropriate unknown species designation should be recorded (“unknown”, “conifer”, or “hardwood”)
 - o Species codes will follow the forest inventory methodology (Initial OPDR, Appendix A)
- If one log crosses both 50 foot arms of the transect, it is counted and measured twice

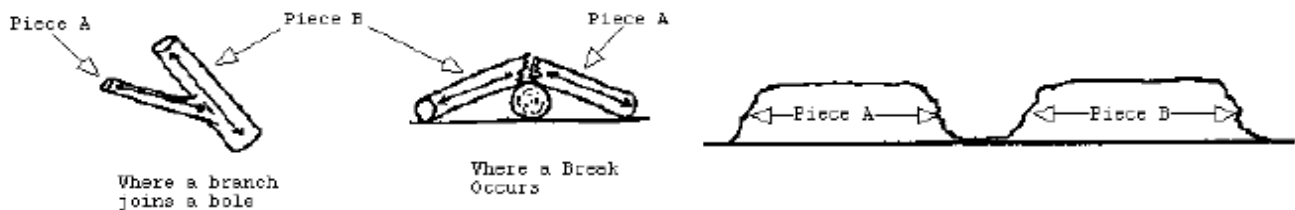


Figure 1: Down dead material diagram

Table 1: USFS Lying Dead Wood Decay Class Descriptions²⁴

<u>Decay Class</u>	<u>Structural Integrity</u>	<u>Texture of Rotten Portions</u>	<u>Color of Wood</u>	<u>Invading Roots</u>	<u>Branches and Twigs</u>
1	Sound, freshly fallen, intact logs	Intact, no rot; conks of stem decay absent	Original color	Absent	If branches are present, fine twigs are still attached and have tight bark
2	Sound	Mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	Original color	Absent	If branches are present, many fine twigs are gone and remaining fine twigs have peeling bark

²⁴ Forest Service. 2012. Forest Inventory and Analysis National Core Field Data Collection Procedures for Phase 2 Plots. Version 6.0. Page 427. National Core Field Guide, U.S. Department of Agriculture, Forest Service.

3	Heartwood sound; piece supports its own weight	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish- brown or original color	Sapwood only	Branch stubs will not pull out
4	Heartwood rotten; piece does not support its own weight, but maintains its shape	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Through- out	Branch stubs pull out
5	None, piece no longer maintains its shape, it spreads out on ground	Soft; powdery when dry	Red- brown to dark brown	Through- out	Branch stubs and pitch pockets have usually rotted down

Plots

In the past, under the FPP, lying dead wood transects were measured and recorded on every plot and added to the time and cost of inventory.

Data Management

In the past, lying dead wood measurements were collected and maintained in combination with the forest inventory. Following the FPP, field measurements were no more than 12 years old.

Previous Data Analysis

Calculating metric tonnes carbon equivalent per plot

The biomass and metric tonnes carbon equivalent in the lying dead wood from each transect were calculated by first converting the measurements of piece length, average diameter, and decay class to volume and biomass. This was done by calculating the volume of each piece assuming a cylindrical shape and then applying the species-specific density conversion to get the biomass of the piece (Table 2). Next, an expansion factor was calculated for each piece of wood to get the number of pieces per acre it represents. Finally, the expansion factor was multiplied by the biomass of each piece for a per acre value and all values for a transect were summed to get the per acre biomass value for the transect. Carbon was assumed to be 50% of biomass. In the last step, the per acre carbon values were converted to metric tonnes carbon dioxide equivalent (CO₂e) by multiplying by 3.666 (CAR 2.1).

Table 2: Down Dead Density Constants (kg/m³)²⁵

Species Code	Species Name	Hard Density ²⁶	Soft Density	Density Origin
DF	Douglas Fir	540.16	428.81	Measured
GF	Grand Fir	319.01	154.47	Measured
RW	Redwood	324.17	291.55	Measured
SP	Sugar Pine	319.01	154.47	Measured
WH	Western Hemlock	319.01	154.47	Measured
RA	Red Alder	511.44	363.78	Measured
TO	Tanoak	580.23	154.47	Measured
CB	California Buckeye	545.835	259.125	Mean of RA and TO
CL	California Laurel	545.835	259.125	Mean of RA and TO
CX	Conifer	364.272	236.754	Mean of DF, GF, RW, SP, & WH
GC	Grand Chinquapin	545.835	259.125	Mean of RA and TO
HX	Hardwood	545.835	259.125	Mean of RA and TO
XX	Unknown	416.147143	243.14571	Grand mean

Sample statistics

In the past, lying dead wood was combined with the other required pools (live tree biomass and standing dead tree biomass) and summarized on a plot level. From the plot level values, a forest-wide total carbon average per acre value, a total value, and a confidence interval (CAR 2.1) were calculated. The statistical summarization methods reflected forest stratification, stands, and sampling methods, which were refined and modified over the years.

Reporting

Previously, annual monitoring reports were submitted to the Reserve each year. These documents reported total annual carbon stocks, project compliance, disturbances, and leakage. The

²⁵ The dead wood density coefficients are result of field sampling dead wood in the same region as the project and were provided by John Nickerson.

²⁶ USFS decay class 1-3 represent “hard density” wood; decay classes 4 and 5 represent “soft density” wood

information within the annual monitoring reports was then reviewed by 3rd party verifiers during each verification.

Previous Verification

Following the FPP, projects were verified each year GHG emission reductions (e.g., carbon credits) were issued. The goal of the verification process was to demonstrate conformance to the FPP forest project criteria, review calculations for accuracy and completeness, and obtain reasonable assurance that the project had obtained the reported greenhouse gas emissions reduction and removals. TCF hired 3rd party verifiers each year since project commencement to verify the GRF and BRSC carbon projects. Third-party review included desk review of documents, a site visit, and a quantitative review of modeling process following the Forest Verification Protocol 2.0 (May 2007). The direct sampling of a selection of carbon inventory plots was required for each verification. The forest's calculations for the randomly chosen subset of plots was required to be within 15% of the verifiers calculations for a positive verification. The comparison was analyzed with a t-test of total plot carbon; lying dead wood was summarized and tested with all other carbon pools. During the annual site visits for GRF and BRSC, 2-3 plots were re-measured annually. This level of review, coupled with TCF's check-cruising policies, in the experience of the verifiers, provided a reasonable level of assurance that the project's reported greenhouse gas emission reductions and removals were materially correct.

Proposed Data Collection

Overview

To fulfill the monitoring process discussed by ARB in the 2013 FAQ, TCF intends to install lying dead wood transects on a random subset of currently maintained live tree inventory plots. The currently maintained live tree inventory plots, which have a revised design and stratification than the original FPP reporting plots, have been and will continue to be used in the transitioned projects and have been found by the verifiers to comply with the COP standards. A sample size analysis by TCF shows that the confidence of statistics for lying dead wood transects improves markedly up to around 75-100 samples and then reaches a point of diminishing returns. This monitoring plan proposes collecting and maintaining lying dead wood transects on at least 75 current COP plots per project.

Measurements

The proposed monitoring plan will use the measurement methodology outlined in the "Previous Data Collection: Measurements" section above.

Lying dead wood measurements will be part of an ongoing monitoring process. Transects may be measured on a rolling basis (a few plots each year) or on a periodic basis (all measurements completed in the same year), but all data will be twelve years old or less to be consistent with CAR V2.1.

Plots

The lying dead wood transects will be installed on a randomly selected portion of the fixed radius inventory plots currently in use for the transitioned carbon projects. At least 75 plots will be randomly selected for each project; if needed, additional plots will be randomly selected to reach the 90% confidence interval. There are 3 strata and 699 plots on GRF and 3 strata and 477 plots on BRSC in the current inventory; the forests use a stratified random sample design. Currently, data for live trees and standing dead trees are collected for each plot; the lying dead wood transects will be added to the randomly selected plots. The fixed radius plots (for standing trees) and the transects (for lying dead wood) will use the same plot center, monumenting procedure, and plot numbering system. Once the transects are established, the transects will be re-measured during the continuous forest inventory (CFI) visits.

If a fixed radius plot and lying dead wood transect is destroyed for some reason (such as harvesting, fire or landslide), the plot may be re-established in conjunction with the fixed radius plot following the procedures laid out in the project inventory documents.

Data Management

Data will be collected either with an electronic data collector (iPad application or electronic recorder) or on a paper datasheet. The plot number, cruiser name, and date will be collected for each plot in addition to the information for each piece of lying dead wood outlined above. If the transect does not have any lying dead wood on it, zeros will be recorded for the number of pieces of wood on the transect; the transect will be otherwise treated normally.

Proposed Data Analysis

Calculating metric tonnes carbon equivalent per plot

The proposed monitoring plan will use the carbon dioxide equivalent calculation methodology outlined in the “Previous Data Analysis: Calculating metric tonnes carbon equivalent per plot” section above.

Sample Statistics

The verified 2015 COP inventory for GRF and BRSC uses a simple random/systematic stratified sampling design to estimate forest stocks. Lying dead wood transects will be installed on a randomly selected subsample. Unlike in the FPP, lying dead wood will have separate sample statistics calculated.

To calculate the monitoring plot average for lying dead wood, first strata level means will be calculated from transect level data. Then, the strata level estimates will be combined for a mean of the monitoring plots (Equation 1)²⁷.

²⁷ The overall property level mean can be calculated in any statistics program/worksheet; however, for consistency with the variance calculation it is highly suggested that the calculations are done in R.

Equation 3: Overall Mean
$$\bar{y}_O = \frac{1}{N} \sum_{h=1}^L N_h \bar{y}_h$$

The distribution of lying dead wood data is not symmetric and bell-shaped (e.g., non-normal) and violates the assumptions behind z-statistics²⁸. Therefore, the variance in the population will be calculated and described by bootstrapping confidence intervals. Bootstrapping is a statistical method which makes very few assumptions about the distribution of the underlying dataset; the original dataset is randomly sampled with replacement many times in a computer program. During the bootstrap process, some values are allowed to appear more than once and other values are left out of a simulated dataset. The mean of the monitoring plots will be calculated on simulated datasets 10,000 times and the percentile method will be used to capture the 90% confidence interval²⁹. The boot package in R (Canty and Ripely 2015) will be used to run the analysis.

These calculations will result in a mean per acre lying dead wood value and a 90% confidence interval. The average and confidence intervals will be recalculated each year new field data are collected. No modeling will be used to adjust the lying dead wood in years between field measurements.

Table 3: SRSS variable definitions & equations adopted from Shiver and Borders (1996)³⁰ and Thompson (2012)³¹.

Variables	Definition
L	Number of strata
N_h	Total potential sampling units in stratum <i>h</i>
N	Total potential sampling units in the entire population
n	Actual number of sampling units in all strata
n_h	Actual number of sampling units in stratum <i>h</i>
$\bar{y}_h = \frac{1}{n_h} \sum_i^{n_h} y_{hi}$	The sample mean for stratum <i>h</i> where each plot value is <i>y_{hi}</i> . The stratum mean is found by summing all of the plot values and dividing by the number of plots.

²⁸ Outliers can skew the calculations even with a large number of sample sizes; therefore, the median and the interquartile range will also be calculated and reported.

²⁹In bootstrapping, there may be some slight variation in the outcomes because bootstrap resampling is random. However, the variation at such a high number of repeats is expected to be insignificant.

³⁰ Shiver, B.D. and Borders, B.E. 1996. Sampling Techniques for Forest Resource Inventory. John Wiley & Sons, Inc. New York, NY.

³¹ Thompson, SK. 2012. Sampling, Third Edition. John Wiley & Sons, Inc. Hoboken, NJ.

Reporting

Once this plan is approved, the lying dead wood monitoring requirements for both CAR (2.1) and ARB will be fulfilled by this monitoring plan and its associated reporting (CAR 2017). The per acre mean values and confidence intervals will be reported per project in an addendum to the Annual OPDR which will be submitted to ARB in association with reporting for the COP program.

Detecting Change Overtime

To determine if the lying dead wood pool has been increasing, decreasing, or remaining constant over time, two different years values will be compared. The first year the monitoring plan is implemented, the average value and a 90% confidence interval will be calculated. Each subsequent reporting year will also have an average per acre value and a 90% confidence interval. Consistent with CAR V2.1 verification requirements, the values from the first year of the monitoring plan and the current reporting year will be compared. If the two confidence intervals overlap, then the lying dead wood pool will be considered constant. If the confidence interval for the first year is lower than the reporting year and there is no overlap, then the lying dead wood pool will be reported as increasing. And if the confidence interval for the first year is higher than the reporting year and there is no overlap, then the lying dead wood pool will be reported as decreasing.

Proposed Verification

The lying dead wood monitoring and reporting will be verified following the FPP guidelines, at least once every six years. Typically, the review will align and occur simultaneous with the COP full verification and site visit. Consistent with CAR V2.1, verification teams will conduct a direct plot-by-plot comparison of measurements for lying dead wood. Calculation reviews and plot re-measurement will seek to provide verifiers with reasonable assurance to meet with materiality requirements of the CAR 2.1 FPP.

If a direct comparison of 2-3 plots shows the project's calculations to be within 15% of the verifier's plot level calculation (CAR May 2007), or are otherwise conservative (meaning the verifier's measurement has more lying dead wood carbon), then the project will have demonstrated that the lying dead wood carbon stock measurements are sound, and no further data collection will be required. If the results indicate that the project does not meet the 15% requirement, additional plots will be reviewed at the verification team's discretion.

Data QA/QC

Data quality assurance/quality control, storage, and management will align with the practices used with the FPP and COP inventory methodologies:

- data for each visit will be carefully reviewed by the data manager to ensure quality,
- the data for each visit will be retained,
- data will be archived when new measurements are collected,
- all new calculations will be conducted on database copies.

Implementation

Implementation schedule

Following review of the monitoring plan by ARB in March 2018, all transects for BRSC and GRF were installed and baseline data was collected Summer of 2018. Once the data from the new plots has been collected, lying dead wood calculations will be submitted as an addendum to COP reports and verified with the full site-visit COP verifications. Thereafter, the data will be collected periodically and will be no more than 12 years old at any point in time. On-the-ground site visits for lying dead wood will be concurrent with COP site visits beginning with the full verification following plan approval.

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Garcia River Forest – ARB
Appendix E

Lying Dead Wood: Field Procedures

Plot Location

Relocate plot center associated with the Continuous Forest Inventory (CFI) carbon inventory plot; only a subset of CFI plots was selected for LDW monitoring

- Lying Dead Wood (LDW) plots are aligned with the CFI carbon inventory plots
 - The same plot number and plot stake is used for the LDW and carbon inventory plots
 - If carbon plot has been disturbed or is missing, re-establish the plot center following the procedures outlined in the CFI carbon inventory procedures
 - See maps and plot lists for randomly selected LDW plots; the plots were pre-selected
- Attach a metal tag to the carbon plot stake at plot center
 - The metal tag will include “LDW”, date of installation, and direction of transects
- ***Not all plots will have pieces of LDW! Recording absence of LDW is just as important as recording presence!! Cruisers need to fill out a plot card (date, transect direction, etc) for each plot that is visited, including those without LDW***

Transects

- **Compass declination is 15 °east** for BRSC and Garcia
 - Double check the compass declination!!
- Two 50’ transects originate from plot center
 - Two 50’-transect “arms” equate to one hundred-foot transect
 - One arm 50’ runs north (0°); the other 50’ arm runs east (90)°
 - *Do not* slope correct – the transects are **slope distance** ³²
- If a transect arm runs into non-forested area or road (as defined in the CFI), then lay out a transect to the next cardinal direction in a clockwise order (try south, then west). If one or both transect arm continues to encounter a non-forested area or road, do not cruise, move to the next plot, and report to the inventory manager. An additional plot may be randomly selected for inclusion in the inventory, if the sample size is less than 75 plots or the confidence interval is outside desired limits
- Cruisers are encouraged to hang flagging near or at the end of each transect
- Logs on the border of the transect will be considered “in” if the pith/mid-point of the log is within the 50’ of the transect; if the transect just reaches the log at the end of transect, but the pith is not within 50’ then the log is not counted
- Do not count root wads or stumps

³² This will result in a measurement of the actual ground area of LDW on the projects; it will more conservative than a horizontal, slope corrected area. Both horizontal and ground area metrics are used in LDW methodologies (see Wagner 1982 “Practical Aspects of the Line Intersect Method”) and the latter is more reproducible.

Measurements

*For each piece of lying dead wood that is encountered along a transect that is at least six feet in length (measured from where the log is at least 6" in diameter to the bigger end) and **at least 6 inches in diameter where it crosses the transect**, take the following measurements.*

- Length (feet)
 - Measure from where the log is at least 6" in diameter to the end of the log
 - Do not excavate or otherwise unbury pieces of LDW from the soil – although in some cases removing duff may be necessary to establish a reasonable estimate of the end of the LDW pieces
 - Do not include splintered ends or heavily decayed/crumblly ends of logs, consistent bole density for the length of the log is desired
 - The boles are expected to have some variable decay/damage; if the bole is less than 6" in diameter for 6" or less, it considered a continuous piece
 - Indicating the log 'ends' with paint or flagging is encouraged
 - Length measurement is along (parallel) to the log
 - If field conditions prevent a clear measurement (e.g., if there are many logs intertwined in a slash pile), estimate the length as needed
 - *Units are in feet, record to the nearest 1/10th of a foot*
- Diameter (inches)
 - Pieces of LDW must at least 6" where they cross the transect
 - **Measure the diameter of the LDW at the midpoint between where the log is at least 6" and the large end**
 - **Mark the location of the diameter measurement**
 - If field conditions prevent a clear measurement (e.g., if there are many logs intertwined in a slash pile), estimate the midpoint and diameter as needed
 - Measure the log diameter perpendicular to the log and parallel to the ground
 - Measure log diameters as the log lays. Decaying wood may have irregularities, do not rotate logs or otherwise bias measurements
 - Use tree calipers or an instrument with a better or equal measuring precision
 - If a log is too large for calipers (over 36"), estimate using the calipers as a guide plus your tape and any other available measuring tools
 - *Units are in inches, record to the nearest 1/10th of an inch*
 - 5.95" rounds up to 6"; 5.94" rounds down to 5.9"
- Hardness (1-5 Decay Classifications)
 - Estimate the hardness of the LDW using the table below as a guide
 - It is encouraged to review several sections of the log and select the most applicable decay class
 - Note – the decay classes below are intended to be used as a guide
 - In the decay classes below 1-3 represent "hard density" wood; and decay class 4 represent "soft density" lying dead wood. Pieces which are decay class 5 are *not* intact lying dead wood pieces and are *not* included in the LDW inventory

- o When a previously inventoried LDW piece has progressed to decay class 5 (e.g., during a plot re-measurement a log decay classification is upgraded from class 4 to 5) and no longer has structural integrity, cruisers are encouraged, but not required, to note the change
- o The LDW pieces must be dead! If there are robust green leaves, sprouts, or similar, the piece is not dead and should not be included

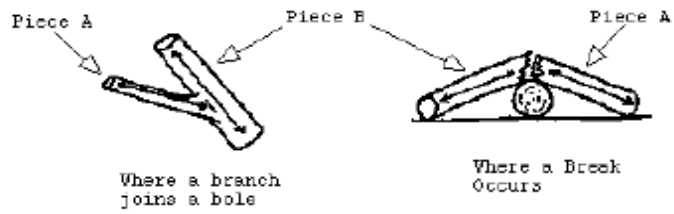
Decay Class	Structural Integrity	Texture of Rotten Portions	Color of Wood	Invading Roots	Branches and Twigs
1	Sound, freshly fallen, intact logs	Intact, no rot; conks of stem decay absent	Original color	Absent	If branches are present, fine twigs are still attached and have tight bark
2	Sound	Mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	Original color	Absent	If branches are present, many fine twigs are gone and remaining fine twigs have peeling bark
3	Heartwood sound; piece supports its own weight	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish-brown or original color	Sapwood only	Branch stubs will not pull out
4	Heartwood rotten; piece does not support its own weight, but maintains its shape	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Through-out	Branch stubs pull out
5	<i>None, piece no longer maintains its shape, it spreads out on ground</i> Log too decayed to be included in the LDW inventory	<i>Soft; powdery when dry</i>	<i>Red-brown to dark brown</i>	<i>Through-out</i>	<i>Branch stubs and pitch pockets have usually rotted down</i>

- Species
 - o Species of each LDW piece must be identified and recorded
 - It may be difficult to identify species beyond decay class 1 (when bark and needle/leaves begin to decay)
 - Use the 'unknown' hardwood or conifer category if species is unclear
 - If the species is known but not listed in the table below, record as 'unknown' hardwood or conifer and make a note on the plot card
 - o During plot remeasurement, unless there is a persuasive reason to change a species determination (e.g., a transcription error is suspected because a large redwood piece was identified as an unknown hardwood), retain the species call from the previous inventory

Species Code	Species Name	Notable characteristics...
DF	Douglas Fir	
GF	Grand Fir	
RW	Redwood	Reddish color
SP	Sugar Pine	
WH	Western Hemlock	
RA	Red Alder	
TO	Tanoak	
CB	California Buckeye	
CL	California Laurel	
CX	Conifer	Unknown conifer species
GC	Grand Chinquapin	
HX	Hardwood	Unknown hardwood species
XX	Unknown	

- If one log crosses both 50' arms of the transect, it is counted and measured twice
 - o Plot notes are encouraged!
- In some cases, there may be broken or decayed pieces where questions may arise about whether it represents one or two pieces of wood. Pieces are defined based on points of abrupt physical change based on breakage, branching, or advanced decay. Broken pieces which were obviously part of a single larger piece and are separated by less than six inches of space are counted at one piece. (see following Figure)
- Branches or forked pieces should be considered separate pieces where each branch or fork meet the diameter and length requirements for individual pieces.
 - o The bole of the tree (or the larger branch) should be measured first, then the smaller/adjoining branch. (Do not measure the any portion twice)
 - o Plot notes are encouraged!

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Appendix E



Sample Plot Card

Plot# _____		Cruiser _____				
Date _____						
LDW on Plot?		Yes No				
Transect 1 Degrees (<i>default 0°</i>)		_____				
Transect 2 Degrees (<i>default 90°</i>)		_____				
LDW ID	Transect	Species	Diameter (0.1")	Length (0.1')	Decay	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Garcia LDW Cruise - 2018						
Notes:						