

ATTACHMENT K

Usal Redwood Forest IFM Modeling Plan

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Growth and Yield Modeling:

The growth and yield modeling described in this modeling plan is performed using the FORSEE model and the AllCA_ResLib resource library, and is based on the following:

Plot Data:

The modeling presented in this document is based on 7,496 cruise plots installed in 2010 or later across the Usal Redwood Forest. A new inventory is in the process of being installed. This inventory design is described in Section VII of the Listing Application and in the Inventory Specifications included as Attachment L to the Listing Application. This modeling plan will be updated once the new inventory has been completed.

Updating the Inventory:

As timber management activities take place on the Usal Redwood Forest IFM Project Area, or disturbances such as fire or mortality resulting from pathogens or other factors occur, plots installed in 2015 will be relocated and remeasured within areas that have been harvested, treated for hardwood reduction, or subject to disturbance. By 2027, all of the plots installed for the new inventory conducted in 2015 will have been remeasured regardless of whether or not the plot had been harvested, treated for hardwood reduction, or subject to other disturbance. On this basis, Usal Redwood Forest IFM will maintain a forest inventory system that will meet the inventory specifications and requirements contained in Appendix A of the Protocol, with plots which are no more than 12 years old.

Updating the Project's carbon stocks from year to year will involve the following steps:

1. Any newly installed inventory plots will be incorporated into the inventory estimate for the stratum in which they are located.
2. Existing inventory plots will be updated using FORSEE as described in the modeling plan.
3. Updating the forest inventory for harvests or disturbances that have occurred during the previous year through the installation of new plots, or adjustments to previous plot data.
4. Where necessary, the inventory update process may result in restratification of portions of the timber strata.
5. Inventory updates following harvest or disturbance will be re-

measured within 12 months of the harvest or disturbance.

- a. Partial harvests, such as selections and thinnings are updated in two phases:
 - i. Phase1: within one month of harvest completion, the inventory is depleted by modeling removals such that:
 1. The inventory forester selects one of the stands underlying the harvest unit to represent the new stand.
 2. The inventory plots from the selected are projected from time-of-cruise to time-of-harvest.
 3. Based on the forester's prescription for the harvest, plots are 'thinned' by removing trees from the projected tree lists.
 4. The 'thinned' plots are aggregated to estimate a stand-level inventory for the thinned stand.
 5. Based on the stand-level inventory estimate, the stand is evaluated against the stratification rules, and is assigned a strata.
 - ii. Phase 2: within one year of completion, the stand is resampled. Resampling will include a random selection of plots within the harvested area.

Volume Calculations:

Conifer board foot volume calculations presented in Table 5a below utilize the standard FORSEE volume equations. Reported volumes are in board feet Scribner Scale for all conifers 8.5 inches DBH and larger. The FIA volume and biomass equations described in the Listing Application are used for the calculation of all carbon stock values presented below.

Biomass Calculations:

Biomass calculations utilized in the modeling are described in detail in the Listing Application. The Listing Application lists all of the species specific volume and biomass equations utilized which are in compliance with the Forest Project Protocol.

Adjusting the Inventory Data to 6/13/2007 and 12/31/2014:

The Listing Application and Inventory Methodology describe the method by which a stratified inventory was constructed for the purpose of identifying

timber strata. The cruise data generated by the 2015 inventory will be used to represent the Project's carbon stocks as of 12/31/2014. The 2015 cruise data will be adjusted to the Project's start date of 6/13/2007 by adjusting the height and diameter of each tree in the inventory database based on applying seven and one half times the average height and diameter increment produced by growing the plot data forward five years in FORSEE.

Calibration:

The FORSEE model allows the assignment of 'calibration' factors to each species for height, DBH, and crown growth and mortality. Calibration factors are applied to certain harvest regimes in order to adjust the model output to local conditions. The harvest regimes described in Table 3b below do not use calibration with the exception of the "No-Harvest" regime (R9). As FORSEE was never designed to perform 100-year no-harvest analyses, a basal area calibration of 0.75 was applied to all species. If the "No-Harvest" regime were allowed to run uncalibrated, the resulting carbon stocking levels at the end of the 100-year baseline analysis period would be unrealistically high.

Missing Volume:

The inventory data upon which the baseline growth and yield analysis is based gathered data on missing volume from trees with broken tops, or from trees that included defects that reduced the tree's net carbon value. FORSEE outputs all growth and yield results in terms of gross volume or biomass. The carbon stock values presented in the Listing Application as of the project commencement date, and the end of the initial reporting period are net of the missing volume recorded in the inventory data. In order to represent this missing volume in the baseline analysis, the average percentage of missing standing live carbon stocks as of the Project start date are used to reduce the baseline growth and yield output from FORSEE.

Ingrowth:

Ingrowth in FORSEE is handled through the sprouting of species such as tanoak, madrone, black oak and white oak, and the addition of regeneration to bring the stand up to a minimum Forest Practice point count. The sprouting function in FORSEE (FSE.fsprout) was set to sprout 20% of sprouting species, as well as bringing the point count up to a minimum of 150 points per acre using the FORSEE point count regeneration function (FSE.fRegen_PtCount).

Site Index:

Douglas-fir and/or redwood site trees are sampled as a part of each inventory for stands at least 30 years old. Douglas-fir is often preferred in mixed stands because of the sureness of counting rings. From the sample, site index is computed for Douglas-fir and redwood following the guidance set forth in “Wensel, L. and Krumland, B. 1986. A Site Index System for Redwood and Douglas-fir in California’s North Coast Forest, *Hilgardia* Vol 54 Number 8, November 1986.”

The stand data maintained within the GIS with the exception of the “recent clearcut” stands are assigned a 50-year Douglas-fir site index (DFSI). To calculate the DFSI for each stratum, each stand was weighted by the ratio of its net acreage to the total net acreage of the strata. These stand weights were multiplied by the stands’ average DFSIs, then summed to calculate the weighted average Douglas-fir site indices for each stratum. Stands without DFSI values were assigned the average DFSI for the stratum in which they are located. A table of strata and DFSI was constructed as an input to FORSEE and is included as Table 3a below.

Table 3a: Average Douglas-fir Site Index by Stand

Stratum	DFSI
Conifer Low	106
Conifer Medium Low	108
Conifer Medium High	114
Conifer High	116
Hardwood Low	104
Hardwood Medium Low	103
Hardwood Medium High	102
Hardwood High	101

Project Acreage:

The Usal Redwood Forest Improved Forest Management Project is comprised of 47,979.24 acres of timberland. The topographic map included in Attachment E of the Project Application shows the Project Area boundary. Attachment E also includes GIS data in the form of a geodatabase that includes the Project Area boundary.

Baseline Modeling:

The baseline modeling utilizes the above-described June 30, 2007 dataset, and an unevenaged management harvesting strategy employing selection and transition combined with small group openings not exceeding 2.5 acres in size. Portions of the Usal Redwood Forest timber stands are dominated by hardwoods species, or are in an understocked condition. The baseline modeling assumes some treatment of hardwood species in order to release existing conifer regeneration, and convert areas dominated by hardwoods to conifer occupation.

At the Project's initiation on 6/13/2007 there were no approved Timber Harvest Plans (THPs) on the Project Area.

Baseline Harvest Strategy:

The baseline harvest strategy relies on the application of a series of harvest regimes across the Project Area timber stands. The regimes are modeled for each stand, and a group-selection harvest strategy results in the eventual harvest in small groups of those areas of the property located outside of WLPZs and no-harvest reserve areas within an 80-year period. Table 3b below describes the harvest regimes applied across the Usal Redwood Forest timber stands. The final baseline growth and yield analysis is determined by applying a percentage of each regime to each timber stand type.

The silvicultural prescriptions incorporated into the regimes are designed to best accommodate local timber stand conditions, while complying with the Forest Practice Rules. To accomplish this, a harvest strategy has been developed that evaluates each stand's stocking status in square feet of basal area per acre and point count stocking. Tables 3a-3c below illustrate the silviculture decision matrix upon which the growth and yield modeling is based. Harvesting under selection-transition, utilizes a BDq harvest strategy.

The "Bdq" formula is commonly used to describe the stand structure of uneven-aged forest stands and has been described extensively in the scientific literature. BDq refers to the stand structure with, in order of relative importance: B, the residual basal area; D, the maximum retained diameter class; and q, the ratio of the number of trees in adjacent (one inch) diameter classes.

Table 3b: Harvest Regime Descriptions

Regime Name	Harvest Scenario Description
R1	Simulates group selection in the first period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R2	Performs a transition harvest in the first period, then simulates group selection in the second period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R3	Performs a selection harvest in the first and second periods, then simulates group selection in the third period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R4	Performs a selection harvest in the first and second periods, selection in the third period then simulates group selection in the fourth period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R5	Performs a selection harvest in the first and second periods, selection in the third period through the fourth period, then simulates group selection in the fifth period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R6	Performs a selection harvest in the first and second periods, selection in the third period through the fifth period, then simulates group selection in the sixth period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R7	Performs a selection harvest in the first and second periods, selection in the third period through the sixth period, then simulates group selection in the seventh period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R8	Performs a selection harvest in the first and second periods, selection in the third period through the seventh period, then simulates group selection in the eighth period as a clearcut, grows the stand for 30 years without harvest, then harvests as selection for each decade until stand age of 80 years at which time the stand is clearcut.
R9	No-harvest prescription applied to watercourse core zones and NSO activity centers. Assumes a basal area calibration of 0.75 for all species.
R10	WLPZ harvest prescription. Performs selection harvest every decade while retaining higher conifer and hardwood stocks per acre.

General Harvest Constraints:

Harvest on the Usal Redwood Forest is constrained by several factors. Firstly, the California Forest Practice Rules (FPR) create a minimum set of silvicultural standards below which harvest cannot occur.

Legal requirements include all laws, regulations, and legally-binding commitments applicable to the Project Area at the time of the project's initiation that could affect standing live carbon stocks. The Usal Forest is subject to the Z'berg- Nejedly Forest Practice Act of 1973 (FPA) and the corresponding Forest Practice Rules (FPR).

The rules that specifically effect the determination of baseline are those that include limits to silviculture activities. This includes the requirements for minimum basal area retention, rotation ages, harvest adjacency restrictions, watercourse buffer widths and sustained yield requirements.

The pertinent rules include the following:

- 14 CCR 913.11(c): Maximum Sustained Production of High Quality Timber Products;
- 913.2: minimum basal area retention standards for Unevenaged Regeneration Methods;
- 913.2 (a)(2)(B): Group selection harvest limitations;
- 913.2 (b)(6): Minimum post-harvest residual basal area retention standards for the Transition method;
- 913.3; minimum basal area retention standards for Intermediate Treatments;
- 913.4 (b): standards for rehabilitation of Understocked Areas;
- 913.1 (c): standards for Seed Tree Seed Step;
- 916.9: details harvest limitations for Watercourse and Lake Protection Zones around Class 1, 2 and 3 streams;

The methods by which the Forest Practice Rule constraints listed above as well as other legally binding constraints are incorporated into the baseline harvest scenario are described in the following sections.

Constraints Analysis

Northern Spotted Owl:

22 NSO activity centers are associated with the Usal Redwood Forest Project Area. Harvest activity is restricted using the following parameters:

- Within 1000' of the activity center – No Harvest
- Retain 150 ac. of Foraging habitat outside the 1000-ft buffer, but within 0.5 miles of the activity center – Utilize primarily unevenaged selection silviculture with small groups.

Application of the above listed harvest restrictions associated with NSO activity centers results in approximately 5,450.36 acres of no-harvest NSO buffers associated with the Usal Redwood Forest Project, or approximately 11.4% of the timbered acres net of roads.

These constraints are modeled by calculating the acreage constrained by timber stand, and applying a 100-year no-harvest regime (Regime R9 in Table 3b above). The yield stream from this reduced harvest is weighted by the constrained acreage and combined with the baseline harvest regime weighted by the unconstrained acreage to determine the final baseline carbon stocks through the 100-year analysis period.

Table 3c: Acres Constrained for NSO by Stratum

Stratum	Net Acres	Percentage
Conifer High	795.73	48.97%
Conifer Medium High	1812.16	20.00%
Conifer Medium Low	847.06	6.59%
Conifer Low	156.20	3.73%
Hardwood High	595.47	27.67%
Hardwood Medium High	738.03	9.76%
Hardwood Medium Low	433.37	5.22%
Hardwood Low	72.33	3.23%
	5450.36	11.36%

Harvesting WLPZ Areas:

Utilizing the Usal Redwood Forest GIS the acreage associated with class I and II WLPZs was determined. Utilizing horizontal buffers per the requirements of the FPR, there are 5,025.69 acres located within class I or II WLPZs. This represents approximately 10.4% of the total timbered acreage.

These WLPZ acres are harvested using the selection silvicultural prescription R10. Harvest levels within the WLPZ are designed to meet FPR standards for shade canopy retention. FPR requirements for the retention of the largest trees, and restrictions on harvests within the channel zone are addressed given the basal area retention standards applied in the model.

Table 3d: Acres Constrained for WLPZ by Stratum

Stratum	Net Acres	Percentage
Conifer High	354.50	21.81%
Conifer Medium High	2202.57	24.31%
Conifer Medium Low	1669.82	12.98%
Conifer Low	167.30	3.99%
Hardwood High	25.46	1.18%
Hardwood Medium High	159.05	2.10%
Hardwood Medium Low	364.53	4.39%
Hardwood Low	82.46	3.68%
	5025.69	10.47%

Hardwood Harvest:

The Usal Redwood Forest's hardwood reduction program calls for the manipulation of hardwood stocking levels through, manual or mechanical treatments or commercial harvest, or basal herbicide treatments as appropriate.

Standing Dead

The standing dead carbon pool represents approximately 1.14% of the total carbon found on the Project Area; however, standing dead levels are below the one metric ton test in the structural elements evaluation criteria under section 3.10.2 (Table 3.2) of the protocol. The standing dead carbon pool is treated as a static pool after increasing the baseline standing dead stocks to one metric ton per acre so as to meet the structural elements criteria as a part of the baseline analysis. As the level of the standing dead carbon pool on the Usal Redwood Forest was raised to meet the minimum standards for Standing Dead per the Natural Forest Management requirements of the protocol, and as the baseline analysis involves ongoing forest management and maintenance of young and vigorous stands, standing dead levels are expected to be maintained at the estimated level. It could be argued that the baseline harvesting scenario would remove poorly formed and suppressed trees, thus capturing mortality that would have otherwise occurred under a harvest scenario that removed fewer trees and less volume over time.

Silvicultural Prescriptions

The following tables show the silvicultural constraints designed to demonstrate conformance with the requirements of the Forest Practice Rules.

Table 4a: Silvicultural Prescriptions used by the Usal Redwood Forest

Prescription		Description
Uneven-Aged Management		
	Single Tree Selection	The goal of this prescription is to create and maintain, multistoried, uneven-aged stands with varied diameter classes.
	Single Tree Selection (WLPZ)	The goal of this prescription is to create and maintain dense, multistoried, uneven-aged stands with varied diameter classes.
	Group Selection	The goal of this prescription is to create and maintain, multistoried, uneven-aged stands with varied diameter classes. Groups are 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.
	Commercial Thinning	To promote timber growth and improve forest health through the harvest of trees in a manner that results in a stand capable of being managed using single tree or group selection.
Even-Aged Management		
	Rehabilitation	The goal of this prescription is to regenerate stands that are primarily experiencing excessive hardwood competition, and that also do not meet minimum stocking standards. Successive harvests will utilize uneven-aged silviculture.
	Hardwood Release	The goal of this prescription is to improve growth in stands that are primarily experiencing excessive hardwood competition, and that are also well stocked with conifer seedlings. Successive harvests will utilize uneven-aged silviculture.

Table 4b: Pre-harvest Stand Conditions by Silvicultural Prescription

Prescription		Pre-Harvest Conifer Basal Area (Square Feet per Acre)		Other Pre-Harvest Considerations
		Lower Limit	Upper Limit	
Uneven-Aged Management				
	Single Tree Selection	75	None	
	Single Tree Selection (WLPZ)	140	None	
	Group Selection	75	None	
	Transition	50	75	
Even-Aged Management				
	Rehabilitation	0	50	Less than 300 point count
	Hardwood Release	0	50	

Table 4c: Post-harvest Stocking by Silvicultural Prescription

Prescription		Stocking Considerations	Conifer Basal Area Retention (sq. ft. per acre)	Hardwood Basal Area Retention (sq. ft. per acre)	Time to Next Treatment
Uneven-Aged Management					
	Single Tree Selection	All age, evenly distributed	>75	7	At Least 10 Years
	Single Tree Selection Low Stocking (WLPZ)	All age, evenly distributed	140	30	At Least 10 Years
	Group Selection	Less than 20% of stand in group openings	>75	7	At Least 10 Years
	Transition	Less than 20% of stand in group openings, at least 15 sq. ft. >12" DBH	>50	7	Selection within 10-20 Years
	Commercial Thinning	Equal to or Greater average stand diameter than pre-harvest stand	>100 if QMD >14" and 100 4"+ trees if QMD <14"	7	Selection within 10-20 Years
Even-Aged Management					
	Rehabilitation	Retain/recruit 2-3 snags per acre	>8 where conifer >8 pre-harvest	7	Selection within 30-40 Years
	Hardwood Release	No Commercial Conifer Harvest	No Commercial Conifer Harvest	7	Selection within 20-40 Years

Growth and Yield Analysis:

The baseline growth and yield analysis was modeled using the FORSEE model utilizing the above described harvest strategy. Table 5a shows the results of the growth and yield analysis in terms of conifer yields, while table 5b shows the results in terms of tonnes of live carbon for all species. Table 6 shows the results in terms of average basal area per acre over the 100 year planning horizon.

Table 5a: Average Annual per Acre Conifer Growth and Yield through the Planning Horizon (Scribner Board Feet per Acre)

Elapsed Time (year)	Beginning Inventory (board feet)	Average Decadal Growth (board feet)	Average Decadal Harvest (board feet)	Ending Inventory (board feet)
10	9,739	568	406	11,360
20	11,360	725	357	15,041
30	15,041	655	453	17,057
40	17,057	636	511	18,309
50	18,309	612	481	19,618
60	19,618	601	476	20,865
70	20,865	596	464	22,178
80	22,178	588	484	23,214
90	23,214	580	497	24,038
100	24,038	572	479	24,965

Table 5b: Average Annual per Acre Total Live Carbon Growth and Yield through the Planning Horizon (Mg C per Acre)

Elapsed Time (year)	Beginning Inventory (Mg Carbon)	Average Decadal Growth (Mg Carbon)	Average Decadal Harvest (Mg Carbon)	Ending Inventory (Mg Carbon)
10	66.10	1.81	3.48	49.40
20	49.40	1.79	1.43	52.99
30	52.99	1.76	1.27	57.95
40	57.95	1.68	1.38	60.96
50	60.96	1.67	1.31	64.56
60	64.56	1.68	1.37	67.70
70	67.70	1.71	1.40	70.82
80	70.82	1.76	1.51	73.39
90	73.39	1.83	1.59	75.84
100	75.84	2.10	1.81	61.99

Table 6: Average Basal Area per Acre through the Planning Horizon^[PR1]^[JC2]

Elapsed Time (years)	0	10	20	30	40	50	60	70	80	90	100
Conifer	97	111	113	117	120	124	129	133	137	142	147
Hardwood	94	21	22	24	22	23	22	22	22	22	22
Total	192	132	135	141	142	147	151	156	160	164	169

Table 7 presents the percentage of each silvicultural regime applied to the various timber stands for the entire baseline modeling analysis.

Table 7: Application of Silvicultural Regimes through the 100-year Planning Horizon

Stand	Regime										Total
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	
Conifer High	5.0%	5.2%	5.0%	4.0%	4.0%	4.0%	2.0%	0.0%	49.0%	21.8%	100%
Conifer Medium High	8.7%	6.0%	7.0%	7.0%	7.0%	7.0%	7.0%	6.0%	20.0%	24.3%	100%
Conifer Medium Low	10.0%	10.5%	11.0%	11.0%	10.5%	10.0%	10.3%	10.0%	3.7%	13.0%	100%
Conifer Low	12.0%	11.4%	11.0%	11.0%	11.0%	11.0%	11.0%	11.0%	6.6%	4.0%	100%
Hardwood High	10.0%	10.0%	9.0%	9.0%	9.0%	8.0%	8.0%	8.2%	27.7%	1.2%	100%
Hardwood Medium High	11.0%	12.0%	11.0%	11.0%	11.0%	11.0%	10.1%	11.0%	9.8%	2.1%	100%
Hardwood Medium Low	10.0%	12.0%	11.4%	12.0%	12.0%	11.0%	11.0%	11.0%	5.2%	4.4%	100%
Hardwood Low	12.0%	12.0%	12.0%	12.0%	12.0%	11.1%	11.0%	11.0%	3.2%	3.7%	100%

Table 8 below shows the modeled standing live carbon stocks over the 100-year baseline analysis period, the projected standing dead carbon pool, and the resulting average baseline carbon stocks on a per acre basis. These figures are plotted in Figure 1 as well.

Baseline Carbon Stocks

The baseline modeling scenario defined in this document follows the guidelines presented in section 6.2 of the Compliance Offset Protocol U.S. Forest Projects, October 20, 2011.

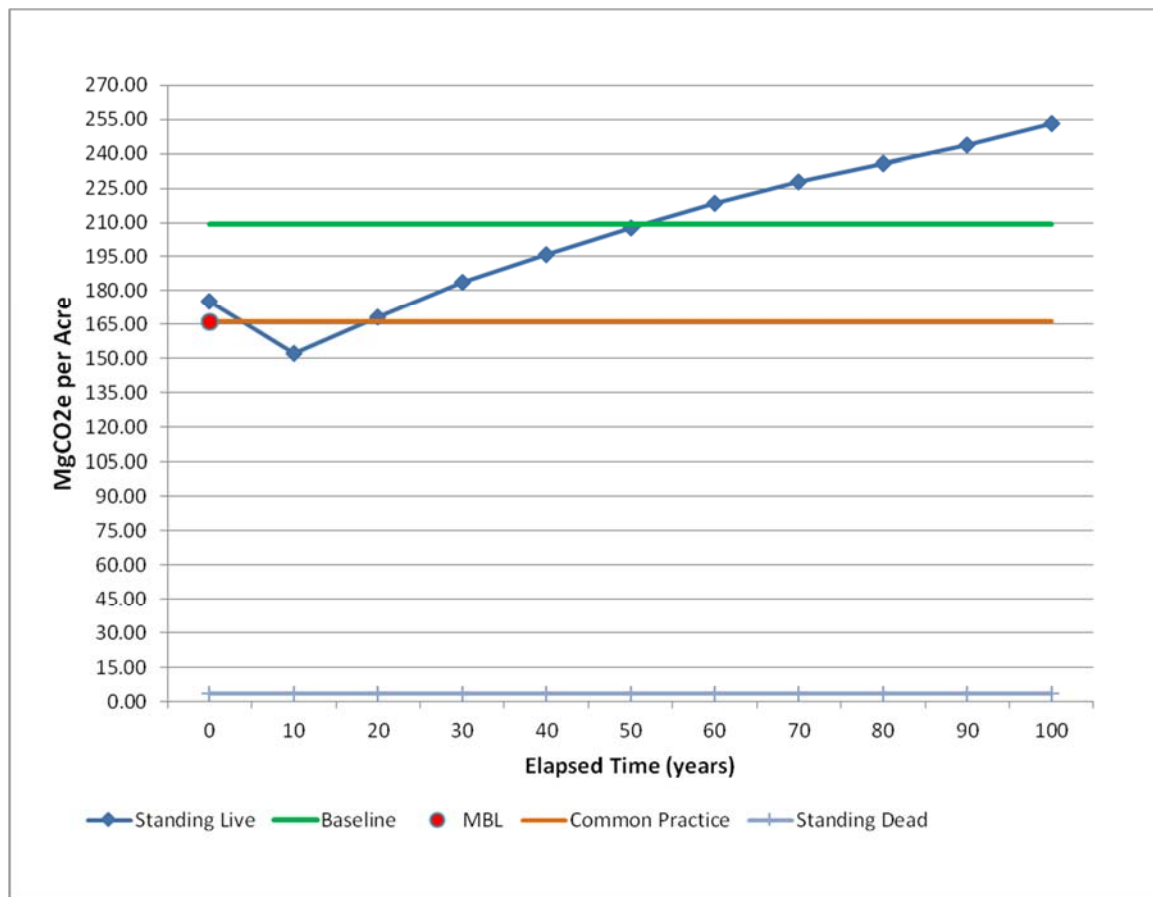
Key components of the calculated baseline are as follows:

1. Initial Project live carbon stocks are above Common Practice.
2. The Project is not subject to the High Stocking Reference calculation.
3. Initial live carbon stocks have been modeled subject to all legal and financial constraints for a 100-year period.
4. The average carbon stocks of the 100-year baseline growth and yield modeling scenario have been calculated.
5. The average stocks of standing dead carbon over the 100-year period have been calculated.
6. The average production of In-Use carbon, landfill carbon, and harvested carbon prior to delivery to a mill have been calculated from the 100-year baseline growth and yield scenario.

Table 8: Average Baseline Carbon Stocks per acre Generated by the Baseline Harvest Scenario (Mg CO₂e per Acre).

Elapsed Time	Standing Live Carbon Pool IFM-1	Standing Live Above Ground	Standing Live Below Ground	Standing Dead Carbon Pool IFM-3	Baseline
0	175.64	141.00	34.64	3.60	209.34
10	152.62	122.26	30.36	3.60	209.34
20	168.40	135.32	33.08	3.60	209.34
30	183.86	148.12	35.74	3.60	209.34
40	195.62	157.91	37.72	3.60	209.34
50	207.59	167.84	39.75	3.60	209.34
60	218.30	176.76	41.55	3.60	209.34
70	227.67	184.57	43.09	3.60	209.34
80	235.84	191.41	44.43	3.60	209.34
90	244.17	198.36	45.81	3.60	209.34
100	253.44	206.05	47.38	3.60	209.34
Average	205.74	166.33	39.41	3.60	209.34

Figure 1: Baseline Carbon Stocks



Wood Products

The baseline growth and yield modeling produces a flow of wood products over the 100-year planning period. Table 9 below shows the average wood products generated over the 100-year period. Three average wood products numbers are presented: average wood products In-use, average wood products stored in landfills, and the average amount of carbon in standing live carbon stocks prior to delivery to a mill.

Table 9: Average Wood Products Carbon per acre Generated by the Baseline Harvest Scenario.

Woods Products		Mg C/ acre	Total Mg CO ₂ e
Average Annual Carbon 100-year In-Use		0.156	27,484.68
Average Annual Carbon 100-year Landfill		0.101	17,756.91
Average Annual Carbon in Harvested Trees Prior to Delivery to the M		1.260	221,892.68