

Pine Creek Improved Management Project
Initial Offset Project Data Report: Modelling Methodology
Meets Forest Offset Protocol 2015 §7.2.1(24)(D)

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CARBON QUANTIFICATION METHODS – COMPLETE MODELLING PLAN METHODOLOGY

Forest Offset Protocol §5.2.1(e), §7.1.1(a)(25, 26, 27), Appendix B

The baseline above-ground standing live carbon stocks were determined by modeling above-ground standing live carbon stocks through a series of growth and harvesting scenarios over 100 years beginning in 2019 and averaging the model results over the 100-year timeframe, so that the baseline is expressed as a single (average) value for above-ground standing live carbon stocks per acre in every year. The baseline simulation incorporates all legal and financial constraints. Consideration was given to financial, legal, and regulatory constraints by assigning acres constrained for various reasons to certain silvicultural prescriptions.

The baseline modelling included all plots within the project area measured during the 2017-18 inventory, while the actual onsite carbon stocks included these same plots, plus four (4) hazard plots not measured. The not-measured hazard plots were included as empty plots for the onsite carbon stocks calculations. The difference in the total number of plots used for the project baseline and actual onsite carbon stocks was done as requested by Paul Cheng at the California Air Resources Board (CARB) during CARB's Project Review, and was an option specific to this project.

Please note: Section 5 in this document is the same as Section 8 in the attachment inventory-methodology.pdf

1 SILVICULTURAL METHODS MODELLED

Forest Offset Protocol Appendix B(h)(1)

For prescriptions applicable to the constrained areas (stream zones, NSO) where maintaining a certain canopy cover and/or minimum diameters was a constraint, the 'STRCLASS' keyword was applied. This keyword sends calculated canopy cover data to a spreadsheet where it can be averaged across the plots to verify that post-harvest canopy cover exceeds the minimum specified in Table 1.

FVS will report at a minimum cubic volume, board foot volume, trees per acre and basal area of live and harvested trees over time. The individual tree data output by FVS to the treelist is the basis for calculating individual tree biomass. Simulations were conducted in 5-year increments with harvests simulated at the start of the period and pre-harvest stocking reported at the start of the period.

The FVS treelist output for each strata/prescription/timing choice combination was then run through the FVS Cloud scripts to generate yield streams containing plot-level tree data and harvest data, including above-ground live CO₂/acre and harvest volumes. These plot-level yield streams were imported into Excel and analyzed through a series of pivot tables, which averaged the plot-level data by strata/prescription/timing choice. The baseline harvest schedule then allocated strata acres to silvicultural prescriptions with the objective of optimizing the baseline such that the 100-

year average aboveground live tree pool was equal to or greater than the minimum baseline level (MBL). For the baseline modeling, common and legal harvesting practices were assigned to strata. **Table 2** shows the acreage allocation to each prescription by stratum in the baseline. In the project scenario, all acres were allocated to the let grow prescription.

Table 1. Silvicultural Prescriptions Modelled for Baseline and Project Activity

STRATUM	SITE CLASS	RX ID	RX DESCRIPTION	MINIMUM COMMERCIAL HARVEST VOLUME	RESIDUAL STOCKING OF GROUP A SPECIES (UNLESS OTHERWISE NOTED)	SPECIES RETENTION PREFERENCES	REGENERATION	SPROUTING (ON/OFF)	USE IN BASELINE (BL), PROJECT ACTIVITY (PA)
HWDF	III	X3a, X3b, X3c	X3a - H&S period 1, CC period 3; X3b - H&S period 1, CC period 4; X3c - H&S period 2, CC period 5; thin regen stand at 45 or 50 years; CC again at age 60	4 MBF/ac hvst for thinning	0 for CC (except trees < 3"); 100 for thin	H&S hdwd 6-24" as soon as feasible, spray hdwd sprouts after CC; otherwise retain species in proportion to pre-harvest stand	Plant 375 DF per acre post clearcut	On	BL
DFR	IV	X3a, X3b, X3c, X3d	X3a - Selection period 1 & 4, CC period 7, thin regen stand at 50 yrs, selection at 60 yrs; X3b - Selection period 2 & 5, CC period 8, comm. thin regen stand at 55 yrs; X3c - Selection period 2 & 6, CC period 9, comm. thin regen stand at 55 yrs; X3d - Selection period 1 & 4 & 7, CC period 10, thin regen stand at 50 yrs	4 MBF/ac hvst for thinning	0 for CC (except trees < 3"); 75 ft2 for thin, selection 50 ft2 BA total, 12 ft2 >= 18"	Spray hdwd sprouts after CC; otherwise retain species in proportion to pre-harvest stand	Plant 200 DF per acre post clearcut	On	BL

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STRATUM	SITE CLASS	RX ID	RX DESCRIPTION	MINIMUM COMMERCIAL HARVEST VOLUME	RESIDUAL STOCKING OF GROUP A SPECIES (UNLESS OTHERWISE NOTED)	SPECIES RETENTION PREFERENCES	REGENERATION	SPROUTING (ON/OFF)	USE IN BASELINE (BL), PROJECT ACTIVITY (PA)
MHC3	III	X3a, X3b, X3c, X3d	X3a - H&S period 1, CC period 4; X3b - H&S period 2, CC period 5; X3c - H&S period 3, CC period 6; X3d - H&S period 2, selection period 4, CC period 7; thin regen stand at 50 years; CC again at age 60	4 MBF/ac hvst for thinning	0 for CC (except trees < 3"); 100 for thin; selection 75 ft2 BA total, 15 ft2 >= 18"	H&S hdwd 6-24" as soon as feasible, spray hdwd sprouts after CC; otherwise retain species in proportion to pre-harvest stand	Plant 350 DF per acre post clearcut	On	BL
MHC4	IV	X3a, X3b, X3c, X3d	X3a - H&S period 1, Selection period 4, CC period 8; X3b - H&S period 2, Selection period 5, CC period 9; X3c - H&S period 1, Selection period 4 & 7, CC period 10; X3d - H&S period 2, Selection period 5 & 8, CC period 11; comm. thin regen stand at 40 or 45 & 50 or 55 yrs	4 MBF/ac hvst for thinning	0 for CC (except trees < 3"); selection 50 ft2 BA total, 12 ft2 >= 18"; comm. Thin 75 ft2 BA	H&S hdwd 6-24" as soon as feasible, spray hdwd sprouts after CC; otherwise retain species in proportion to pre-harvest stand	Natural regen DF 75/acre after selection; Plant 200 DF per acre post clearcut	On	BL

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STRATUM	SITE CLASS	RX ID	RX DESCRIPTION	MINIMUM COMMERCIAL HARVEST VOLUME	RESIDUAL STOCKING OF GROUP A SPECIES (UNLESS OTHERWISE NOTED)	SPECIES RETENTION PREFERENCES	REGENERATION	SPROUTING (ON/OFF)	USE IN BASELINE (BL), PROJECT ACTIVITY (PA)
ALL STRATA		X1	Let Grow						BL, PA
DFR & MHC4 - WLPZ & NSO	IV	X2	selection for outer zone of Class 1 and Class 2s & NSO forage acres - no harvest occurs if insufficient conifer to meet minimum stocking	No minimum, timing coincident with adjacent harvest	50% overstory canopy cover (all spec); 75 BA selection minimum; 15 sqft BA > 18"; > 25% existing overstory conifers	hack & squirt hdwds 6-24" when done in adjacent stand but only kill 50%; assume 20% of hdwds knocked down when harvesting DF in MHC4	Natural Regen 75 DF per acre after adjacent even-aged harvest	ON	BL
HWDF & MHC3 - WLPZ & NSO	III	X2	selection for outer zone of Class 1 and Class 2s & NSO forage acres - no harvest occurs if insufficient conifer to meet minimum stocking	No minimum, timing coincident with adjacent harvest	50% overstory canopy cover (all spec); 75 BA selection minimum; 15 sqft BA > 18"; > 25% existing overstory conifers	hack & squirt hdwds 6-24" when done in adjacent stand but only kill 50%; assume 20% of hdwds knocked down when harvesting DF	Natural Regen 75 DF per acre after adjacent even-aged harvest	ON	BL

Table 2. Baseline acreage allocation by prescription and stratum

Stratum	Prescription	Acres
DFR	Grow (X1)	110.9
	WLPZ & NSO Selection (X2)	252.2
	Clearcut & thin (X3)	1,663.9
	Subtotal	2,027.0
HWDF	Grow (X1)	30.6
	WLPZ & NSO Selection (X2)	115.4
	Clearcut & thin (X3)	557.8
		-
	Subtotal	703.7
MHC3	Grow (X1)	661.0
	WLPZ & NSO Selection (X2)	438.6
	Clearcut & thin (X3)	1,983.0
		-
	Subtotal	3,082.6
MHC4	Grow (X1)	70.6
	WLPZ & NSO Selection (X2)	264.6
	Clearcut & thin (X3)	1,856.7
	Subtotal	2,192.0
Total		8,005.3

2 MATRIX DOCUMENTING LEGAL CONSTRAINTS AFFECTING FOREST MANAGEMENT ACTIVITIES IN THE PROJECT AREA

Forest Offset Protocol Appendix B(h)(2)

Table 3. Matrix of all legal constraints affecting forest management activities in the management area

Description of Constraint	Applicable Geographical Range	Agency Associated with Constraint	Effect of Constraint on Forest Management	Description of Modelling Techniques use to Simulate Constraint
Watercourse and lake protection zones (WLPZ) - Anadromous Salmonid Protection rules	Watersheds in the coastal zone	Cal Fire	Varying levels of canopy retention required depending on proximity to stream; leave 25% of existing conifer overstory	Used the 'STRCLASS' keyword to track canopy closure; examined output to ensure minimums were met
Northern Spotted Owl (NSO) habitat requirements - Attachment A	Northern Forest District & eastern portion of Coast District w/out redwood	US Fish & Wildlife Service	Required to maintain minimum acreage of Nest/roost and foraging habitat according to definitions in Attachment A - determined by basal area canopy % of trees $\geq 11"$ dbh	Habitat typing was done for current NSO needs; harvest scheduling assigned nest/roost acres to let grow and forage acres to selection
Silviculture requirements	Coast Forest District	Cal Fire	Sets minimum age for clearcutting (60 or 80 yrs); minimum post-harvest stocking standards and leave tree requirements for selection & commercial thin; Selection retains 12 or 15 ft ² BA $> 18"$	Examine the FVS output tables each time Rx was run & adjust the parameters in the key file
Alternative Rx designated in THP 1-14-112-HUM described on p.52	253 acres not yet operated in the THP	Cal Fire	Commercial thinning (~80% of area) and sanitation salvage in the remainder leaving 100 sq. ft. BA/acre in comm thin and 50 sq. ft. BA/acre in salvage.	Allocate >253 acres to the DFR X3a prescription, which includes selection in the first period leaving 82 sqft per acre on average – simulates mix of comm thin & salvage.

Description of Constraint	Applicable Geographical Range	Agency Associated with Constraint	Effect of Constraint on Forest Management	Description of Modelling Techniques use to Simulate Constraint
Adjacency rules for even-aged management	California	Cal Fire	Even-aged cut blocks can't be created next to other cut blocks < 5 yrs old	Restrict any 5-year period to no more than 25 percent area harvested
Aesthetic Roads	California	Cal Fire	Special consideration for aesthetic enjoyment for silvicultural treatments and timber operations within 200 feet of the edge of the travelled surface of any permanent road maintained by the County or State, or within 200 feet of adjacent non-federal lands not zoned TPZ	Allocated acres to WLPZ constrained acres which were assigned the selection prescription

3 PROJECT AREA SITE INDICES & SITE CLASSES

Forest Offset Protocol §7.1.1(a)(15)(I), Appendix B(h)(2)

Field data collected during the 2017-19 inventory was used to estimate the site index of soil types in the Project Area. Site tree sampling included tree height, species, diameter and age. Site index was derived from Douglas-fir site trees near 89 of the 316 plots within the project area to determine an average site index for each soil type. Site index is measured as the height of a tree at a given age (50 years is the typical standard base age used in California, although 100 years used to be more common). These values can then be assigned a site class. Site classes are productivity classes defined by ranges of site index. Site index is used in the growth and yield modeling program FVS as one of the variables affecting tree growth rates. Site class is used for common practice determination and applying Forest Practice Rule standards.

Forestry in California is regulated by the California Forest Practice Rules (FPRs) which require site class to be assigned according to the system used in the FPRs (14 CCR §1060). The 100-year base age site classes referenced in the California Forest Practice Rules (14 CCR §1060) have been converted to 50-year breast-high age base equivalent break points by Krumland and Eng in California Forestry Report No. 4, April 2005. **Table 4** is from that report. For determining FPR constraints, site index was assigned to each tree using the CA_SITEINDEX ExcelSIExample.xls spreadsheet and CA_SITEINDEX Users Guide and Programming Notes explanatory document (Krumland and Eng, 2005b) which are provided by CALFIRE on their website (see citation for weblink). The appropriate site class break points for this project are in the column titled North Coastal Douglas-fir.

Table 4. Fifty-year breast-high age site index ranges for common site class systems in California

Site Class	Site Index Range (height in feet)		
	Redwood	North Coastal Douglas-fir	Mixed Conifer
I	122 +	140 +	80 +
II	102-122	120-140	67 – 80
III	80-102	100-120	55- 67
IV	60-80	80-100	42 – 55
V	< 60	< 80	< 42

In order to determine the Common Practice value for the Project according to the proportion of high vs. low site class, the 2015 Forest Protocol requires projects to define site classes according to the USFS 7-site class system. Site classes I-IV are considered high under the 2015 COP. The average measured FPR site index and estimated USFS site class by soil type are shown below in **Table 5** which indicates all soil types are considered High site class.

Table 5. Site Class by Soil Type

Soil Type Map Unit	Area (acres)	Number of Plots	Number of Site Trees	Mean Site Index	USFS Site Class
465	3,020.7	127	33	93.0	III
465	3,020.7	127	33	93.0	III
464	1,807.0	61	22	105.6	II
463	1,746.0	71	18	100.6	II
462	845.3	31	11	96.3	II
446	368.1	15	4	99.5	II
447	134.0	4	0	*	
445	58.7	3	1	113.1	II
693	7.1				
482	5.2				
480	4.1				
240	3.1				
484	2.6				
242	2.0				
481	1.4				
Total	8,005	312	89		

*Plots were assigned mean Site Index from the largest soil type

4 MODEL USED

Forest Offset Protocol Appendix B(h)(4)

The ICASCA variant of the Forest Vegetation Simulator (FVS) was used to model forest growth, mortality and harvest over time (Keyser 2014). FVS is an ARB approved growth and yield model designed for these sorts of applications. FVS is an individual tree growth model that accepts direct input of the inventory data, including measured diameter and height data, once the data has been formatted correctly. The documentation for the model requires the use of the Hann & Scrivani site index equations (Hann and Scrivani, 1987). Douglas-fir site trees were calculated using these equations, and strata were assigned site index using the average value of site indices from plots within each stratum. The FVS model applied built-in conversions to assign site index to the other species in the inventory.

5 PROCEDURES FOR UPDATING THE FOREST CARBON INVENTORY

Documented Procedures to Account for Harvest, Growth, Mortality, Disturbance, Incorporating New Inventory & Plot Data, Retiring Older Sample Plots, Changes in Modelling, Appropriate Confidence Deduction

Forest Offset Protocol Appendix A(b)(10)

For reporting stocks on an annual basis until the next inventory, the inventory update procedure will rely on growth projections from FVS. If any timber harvesting occurs in the project area, the timber harvest area will be re-inventoried within 3 years. A simulation of the harvest to update the inventory may be utilized in the interim. Timber harvests in the project area shall be designed to treat plots the same as the surrounding stand. Effort will be made to limit knowledge of exact plots locations from the foresters designing and implementing timber harvests, so that the risk of bias is minimized during harvest planning. In addition, a post-harvest review of recent harvested areas shall be conducted by a RPF and if a plot appears, based on professional judgment, to no longer be representative of the surrounding stand due to being treated differently than prescribed in the harvest plan, then the plot will be moved to a random distance and direction within a 2.5-acre area around the original plot.

At the occasion of a disturbance event other than planned timber harvest, such as fire or windthrow, that appears to alter a significant portion of the project acreage, or results in a reversal under the protocol (e.g. reduction is greater than annual growth if project is verified annually) then the plots in the affected area will be re-measured. If the disturbance appears to meet the specified threshold but does not affect any of the permanent plots in the inventory, new plots will be established in the affected area in sufficient quantity and distribution to account for the disturbance. The newly measured plots will be installed consistent with the inventory manual used to establish the original inventory; any improvements or changes to inventory methods or calculations would be documented and justified in the change log. Once the plot data has been gathered, a new calculation of the Actual On-Site Carbon Stocks will be completed in order to revise the GHG Reductions and Removals as well as a new calculation of the confidence deduction. The effects of disturbances on the carbon stocks of the project area will be estimated by monitoring the acreage affected utilizing the average per acre carbon stocks for the applicable strata. If the disturbance affects a significant portion of the strata acreage, then a new stratum will be delineated, and the project stocks and confidence deduction calculated using the new strata.

Disturbance events will be monitored as part of normal management activities, as well as through an annual review of aerial imagery and local and state disturbance reports (e.g., fire maps) if available and applicable. Given the plot density (approximately 1 plot/26 acres) any disturbance that affects less than 26 acres (e.g. salvage of burned trees) is assumed to have a diminutive effect on project carbon stocks given that each plot represents approximately 0.3% of the entire stock calculation. Thus, any disturbance that is not large enough in scope to affect a plot, by definition would only affect less than 0.3% of the carbon stocks on the project area.

If, in the process of re-measuring plots, the plots cannot be relocated, new plots will be established in the same locations as the old plots. The replacement plot data will replace the old plot data for the purposes of calculating project carbon stocks.

6 REFERENCES CITED

- Hann, David and John Scrivani. 1987. Dominant-height-growth and site-index equations for Douglas-fir and Ponderosa pine in southwest Oregon. Forest Research Laboratory, Oregon State University, Corvallis, Research Bulletin 59. 13 p.
- Keyser, Chad E. comp. 2008 (revised May 30, 2014). Inland California and Southern Cascades (CA) Variant Overview –Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 64 p