Energy Research and Development Division
FINAL PROJECT REPORT

DEMONSTRATION OF THE CLIMATE ACTION RESERVE FORESTRY PROTOCOLS AT LATOUR DEMONSTRATION STATE FOREST

WESTCARB Final Report

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

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Demonstration of the Climate Action Reserve Forestry Protocols at LaTour Demonstration State Forest, WESTCARB Final Report is the final report for the LaTour State Forest Carbon Registry Demonstration Project (Contract Number 500-05-029) conducted by the California Department of Forestry and Fire Protection. The information from this project contributes to Energy Research and Development Division's Energy-Related Environmental Research Program

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ABSTRACT

The Climate Action Reserve is a national nonprofit program that issues and tracks credits called "certified reserve tonnes" for projects that reduce or offset greenhouse gas emissions. They developed a forest project protocol that describes a formal process for determining the number of credits allowed for reforestation projects or improved forest management. These credits can then be sold to emitters. This report presents case studies of improved forest management and reforestation projects for two sites in the LaTour Demonstration State Forest using Version 3.1 of the forest project protocol. Each site was evaluated as if it were in public or private ownership. Certified reserve tonnes were calculated for a 100-year period.

The reforestation projects produced net certified reserve tonnes of 118 tonnes to 216 tonnes of carbon dioxide per acre but were not economically feasible without subsidies. To guard against risk from fire and pests, 10-12 percent of carbon credits must be held in reserve on public lands and 18-20 percent on private lands. Using the improved forest management project on public lands generated no certified reserve tonnes. The improved forest management projects on private lands produced net certified reserve tonnes of from 162 to 178 tonnes of carbon dioxide per acre. At a $9 per tonne price, projects where initial carbon stocks were well above average yielded a net present value of $617 per acre. If the price were $20 per tonne, the net present value would be $1,536 per acre. An improved forest management project with below average starting stocks yielded net present values of $65 and $393 for the $9 per tonne and $20 per tonne prices, respectively. Reforestation projects produced more certified reserve tonnes over the 100-year project life, but improved forest management projects produced more credits earlier without upfront costs.

Keywords: Sequestration, forest, reforestation, forest management, carbon offset, climate change, mitigation, Climate Action Reserve, protocol

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Introduction

The Climate Action Reserve (CAR) is a private nonprofit national offsets program headquartered in Los Angeles that focuses on regulatory emissions reporting and reductions of greenhouse gases (GHGs). Verified reduction credits are called certified reserve tonnes (CRTs) and can be sold to GHG emitters. Formal accounting methods or protocols are required to ensure these credits are rigorously monitored and verified so that the market will be effective and reliable. Among CAR's protocols is the Forest Project Protocol, which underwent a major revision with the release of Version 3.1, which was approved by the CAR Board on September 1, 2009 and adopted by the California Air Resources Board on September 24, 2009.

Project Purpose

The goal of this project was to apply the revised Forest Project Protocol using examples of the reforestation and improved forest management project types that could be undertaken by a land owner that wanted to earn and sell offset credits. A reforestation project type replants trees on a site that formerly was forest but has had less than 10 percent forest cover for at least 10 years or which sustained a catastrophic event in the last 10 years. Both public and private lands may use this project type. A baseline must be established for the project. The baseline uses the current conditions and projects the likely outcome without the project 100 years into the future. CRTs are counted after reforestation has occurred and total tree volume has increased following an initial lag while seedlings become established. For this reason, reforestation tends not to be profitable at least until later in the life of the forest stand. The improved forest management project type requires use of native species and activities such as increasing the overall age or density of the forest to absorb more carbon. The forest may or may not be managed for timber production and may occur on private or public lands. A 100-year baseline must be established.

Project Results

Two neighboring areas within the LaTour Demonstration State Forest in Shasta County in the Southern Cascade Mountains were considered as separate projects for this demonstration. The Sunset Project site had a relatively high ponderosa pine component relative to the other mixed conifer species, partly due to the planting that occurred after the 1978 Whitmore Fire. The McMullen Mountain Project site was dominated by white fir stands with higher biomass and lower fire risk than Sunset. Each project area contained a mix of reforestation and improved forest management project types. The projects were treated as if they were public and private lands in separate scenarios so that the implications of land ownership to CRTs and the economics could be compared.

The baselines, project activity, and Certified Reserve Tonnes were calculated for 100-year periods based on site inventories of forest biomass and the guidance in the protocol. An economic analysis provided cost and revenue estimates to evaluate the economic feasibility of the reforestation and improved forest management project types using these projects as examples. Two carbon dioxide (CO_2) prices were considered: the prevailing over-the-counter price for voluntary market CAR project CRTs of $9 per tonne and a realistic long-term compliance CRT price of $20 per tonne. The impact of fuels treatments on the carbon accounting of the treated and surrounding stands was an area of research and policy debate at the time this demonstration was conducted. The study simulated the planned implementation of a shaded fuel break that ties in with the treatments implemented as part of this project.

The reforestation project type produced net CRTs of 118 tonnes to 216 tonnes of CO_2 per acre but was not economically viable at either project site without subsidies. The improved forest management project type was not appropriate for either project on public lands since the baseline could not be shown to differ from the project activity. The improved forest management projects on private lands produced net CRTs of 162 to 178 tonnes of CO_2 per acre. To guard against risk from fire and pests, 10-12 percent of carbon credits must be held in reserve (called buffer pools) on public lands and 18-20 percent must be held in reserve on private lands.

Improved forest management project types on private lands had economic returns of $65 and $617 per acre ($159 and $1,524 per hectare) for the Sunset and McMullen Mountain demonstration project areas, respectively, assuming a price of $9 per tonne CO_2. The returns were $393 and $1,536 per acre ($972 and $3,794 per hectare) at $20 per tonne CO_2. The McMullen Mountain improved forest management project had initial carbon stocks well above the assessment area average, which resulted in CRTs being immediately created. Reforestation projects produced more CRTs over the 100-year project life, but improved forest management projects produced higher CRTs earlier without establishment costs. The fire risk modeling analysis showed that a strategically placed shaded fuel break bisecting the project area would likely provide a net benefit to carbon sequestration.

This project successfully demonstrated the application of the revised CAR Forest Project Protocol for reforestation and improved forest management project types. The results illustrated how the potential carbon credits and their economic costs and revenues could differ among project sites, land ownership types, and project types. The analysis of the fuel reduction project effects showed that the project appeared beneficial to carbon management when carbon benefits from avoided fire to adjacent acres were included in the calculation. More work is needed in this area. Another area needing more work is modeling the probabilities of landscape disturbances to specific areas.

The timing of the protocol revisions made it impossible to take this project through the verification process, as these revisions were necessary to have a valid project on public lands. However, the timing of this report and associated products coincided with the release of the revised protocols, providing an excellent opportunity to make these project results available to subsequent project developers.

Project Benefits

This project has direct benefits for several groups. For regulators of cap-and-trade emissions reduction programs, the demonstration showed how the CAR Forest Project Protocol can be applied in rigorous carbon accounting that is fair, transparent, and effective. Forest landowners can benefit by knowing they can implement the protocol to determine if and where they should propose offset projects and which project types would be most effective. The CAR protocol benefits California ratepayers by providing cost-effective methods for meeting state GHG reduction goals.

CHAPTER 1:
Overview of the Climate Action Reserve Forestry Protocols

The Climate Action Reserve (CAR) is a private non-profit national offsets program headquartered in Los Angeles that focuses on regulatory quality emissions reporting and reductions. CAR also accredits and oversees independent project verifiers. Verified reduction credits, which are serialized and tracked by CAR, are called Certified Reserve Tonnes or CRTs.

A project that has CRTs may, as of this writing, sell them on the voluntary over the counter market or hold them for later trading in either a voluntary market or as offsets under emerging cap and trade market mechanisms. Cap and trade programs are proposed and in various stages of development, including already active, at the state (California), regional (Western Climate Initiative [WCI], Regional Greenhouse Gas Initiative [RGGI]), and national and international levels. The Voluntary Carbon Standard Association (VCS), an international standards group focused on project-based voluntary greenhouse gas (GHG) reductions, has recognized CAR offsets as meeting their criteria for protocols, verification and tracking. This allows CRTs to also be traded as Voluntary Carbon Units (VCUs).

Two CAR protocols exist that are related to trees and forests; the Forest Project Protocol (version 3.1) and the Urban Forest Project Protocol (version 1.1). These are reporting protocols for use by project developers. Each reporting protocol has an associated verification protocol that is used by the third-party verifier. The Urban Forest Project Protocol has only one project type, tree planting and maintenance. The Forest Project Protocol has three project types:

- Improved Forest Management
- Reforestation
- Conservation

This demonstration project includes examples of the forest management and reforestation project types. A fuels treatment analysis, not related to the current CAR protocols, is also included in this report.

- The CAR has recently undergone a major revision (version 3.1, approved by the CAR Board on September 1, 2009, adopted by the California Air Resources Board (CARB) on September 24, 2009) of the Forestry Project Protocols to address the following objectives. Allow greater landowner participation, particularly publicly-owned lands and industrial working forests.

- Make improvements that improve the protocol’s clarity, accuracy, conservatism, environmental integrity, and cost-effectiveness (where doing so does not infringe on other principles).

- Design to allow use outside of California with minimal additional analysis.

The timing of the protocol revisions made it impossible to take this project through the verification process, as these revisions were necessary to have a valid project on public lands. Revision to the easement requirement and an appropriate baseline for public lands not subject to the California Forest Practice Act was required. However, the timing of this report and associated products coinciding with the release of the revised protocols provides an excellent opportunity to use this project as information for subsequent project developers. The rest of this section covers the specific guidelines for a reforestation and forest management project, data requirements, and permanence and leakage risk assessments.

There are protections in place to ensure that the project is not causing an effect that counteracts the sequestration benefits occurring directly from the project For example, a project implementation agreement must be executed between the project developer and the Reserve when the project is on private land. Additionally, there is a native species test and a requirement to maintain or increase on-site live pool carbon stocks. Furthermore, a project assessment boundary must be identified and a secondary-effects (leakage) assessment performed.

1.1 Reforestation Project Type

A reforestation project type may be defined as being out of forest cover (10 percent threshold) for at least ten years or as having sustained a catastrophic event in the last ten years. The project has to have been in forest cover in the past. This project uses the definition of being out of forest cover for over ten years. Both public and private lands may use this project type.

A baseline must be established for the project. The baseline uses the current conditions and projects those into the future for 100 years using a qualitative assessment as the guide. The qualitative assessment is based on the likely outcome in the absence of the project.

As with all forest projects, the CRTs are accrued after they have occurred. Since stand biomass generally follows a sigmoidal curve, most CRTs will be realized after the initial lag phase of stand development. For this reason, inventories are likely not profitable or reasonable to expect until later in the life of the stand.

1.2 Improved Forest Management Project Type

This project type may apply to private or public lands. The use of native species with natural forest management, as defined by the protocol, is required. The forest may or may not be managed for timber. As with the reforestation project type, a 100 year baseline must be established. The following steps are required to construct the baseline for the private lands scenarios.

1. Determine the applicable forest type to look up the average stocking (common practice) from the provided tables (Appendix F).
2. Look up the average per acre live biomass carbon stocking, which was derived from the USDA Forest Service, Forest Inventory and Analysis (FIA) data.

3. Calculate the average per acre current carbon stocking for the live biomass in the project.

4. Decide if you are below or above the common practice (FIA average). How to calculate reductions will be based on this.

5. Check for additional constraints on management from legal, physical and economic feasibility perspectives. These may increase the baseline if they are more restrictive than current stocking levels or the FIA average. When the starting stocks are below the common practice, a high stocking reference will be used instead of the initial carbon stocks, if a look-back of 10 years indicates that stocks have decreased. In this case 80 percent of the highest stocking is used.

6. Model the baseline but do not drop below the legal, physical and economic limits or either the common practice or historical levels for the project area, depending on starting point. The baseline for the onsite and offsite dead wood (forest products) is averaged over the 100 year projection period and kept as separate values so that on-site carbon stocks cannot be reduced due to wood products.

7. If the average wood products landfill pool in the baseline is greater than the landfill pool for a given period then this difference of this amount is subtracted from allowable reductions.

The public lands baseline requires a more qualitative assessment up front before it can be quantified. Planning and budgets are part of this assessment.

1.3 Permanence Risk Analysis

Permanence is defined by the CAR as a period of 100 years from the date credits are issued. A risk analysis provides information to calculate a buffer pool requirement or alternatively, private insurance against reversals of CRTs. A separate risk assessment was conducted for both of the projects under a private and public lands scenario. Appropriate reductions in the form of a buffer pool will be applied and carried through the economic analysis.

1.4 Leakage Risk Analysis

There are separate leakage analyses for reforestation and forest management project types. For reforestation, an assessment of activity shifting leakage is required where crop lands or grazing is an issue. Using the flowchart provided it is quickly determined that the leakage risk is zero for reforestation. Decreases in harvest amounts over the 100 year period that are due to the project, relative to the baseline, are multiplied by 20 percent to derive the penalty for leakage on improved forest management projects. This is to account for market leakage or that the wood product demand will be partially met from other sources.

CHAPTER 2: Demonstration Projects

Two contiguous areas within LaTour Demonstration State Forest (LDSF) were considered as separate projects for the purposes of this demonstration, Figure 1. The projects were treated as public and private lands in separate scenarios, so that the implications to CRTs and the economics could be compared. Figure 2 shows the locations of the project areas on the Forest. LDSF is located in Shasta County in the Southern Cascade Mountains. The forest is at the headwaters of the South Cow Creek drainage, which eventually flows into the Sacramento River. White fir and mixed conifer are the primary forest types with some ponderosa/Jeffery pine types where planting has occurred.

The forest was acquired in an essentially uncut condition in 1946 with single tree harvesting that focused on improving forest health commencing in the 1950s. Small group selection harvests were started in the 1990s to begin to regenerate mature forest and to address pest issues. A wildfire (Whitmore Fire) burned approximately 500 acres of the lower end on the west side in 1978, Figure 1. Salvage operations occurred at that time and the area was planted. Shrub competition severely retarded the growth of the regeneration, either slowing conifer growth or killing the trees, Figure 3. Some portions of the Forest have been brush fields for as long as the State has had the property. Some of these are around McMullen Mountain and some of the area burned in 1978 was in brush.

Figure 1: Whitmore (1978) Fire Boundary Showing Extent onto LDSF

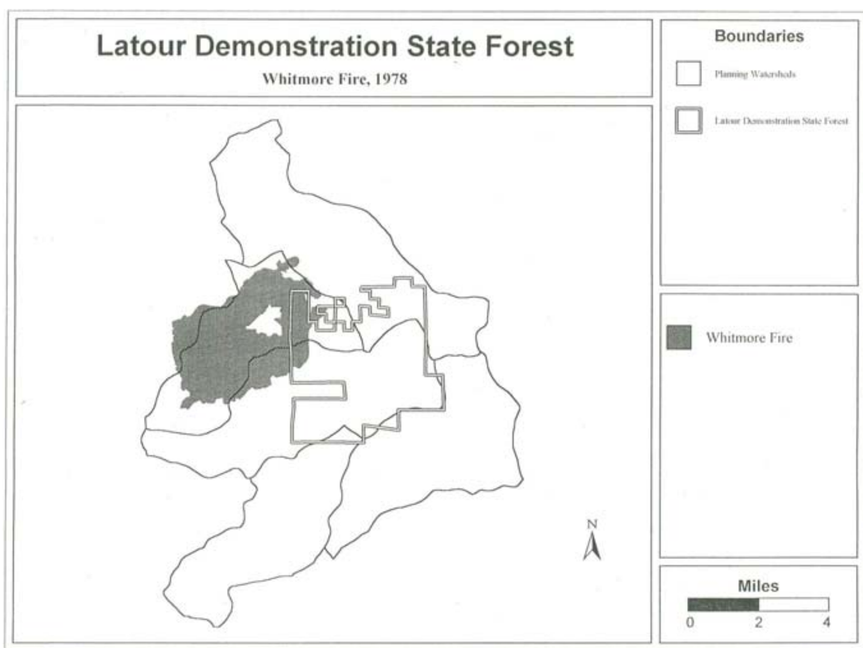


Figure 2: Map of LaTour Demonstration State Forest Showing the Two Project Areas

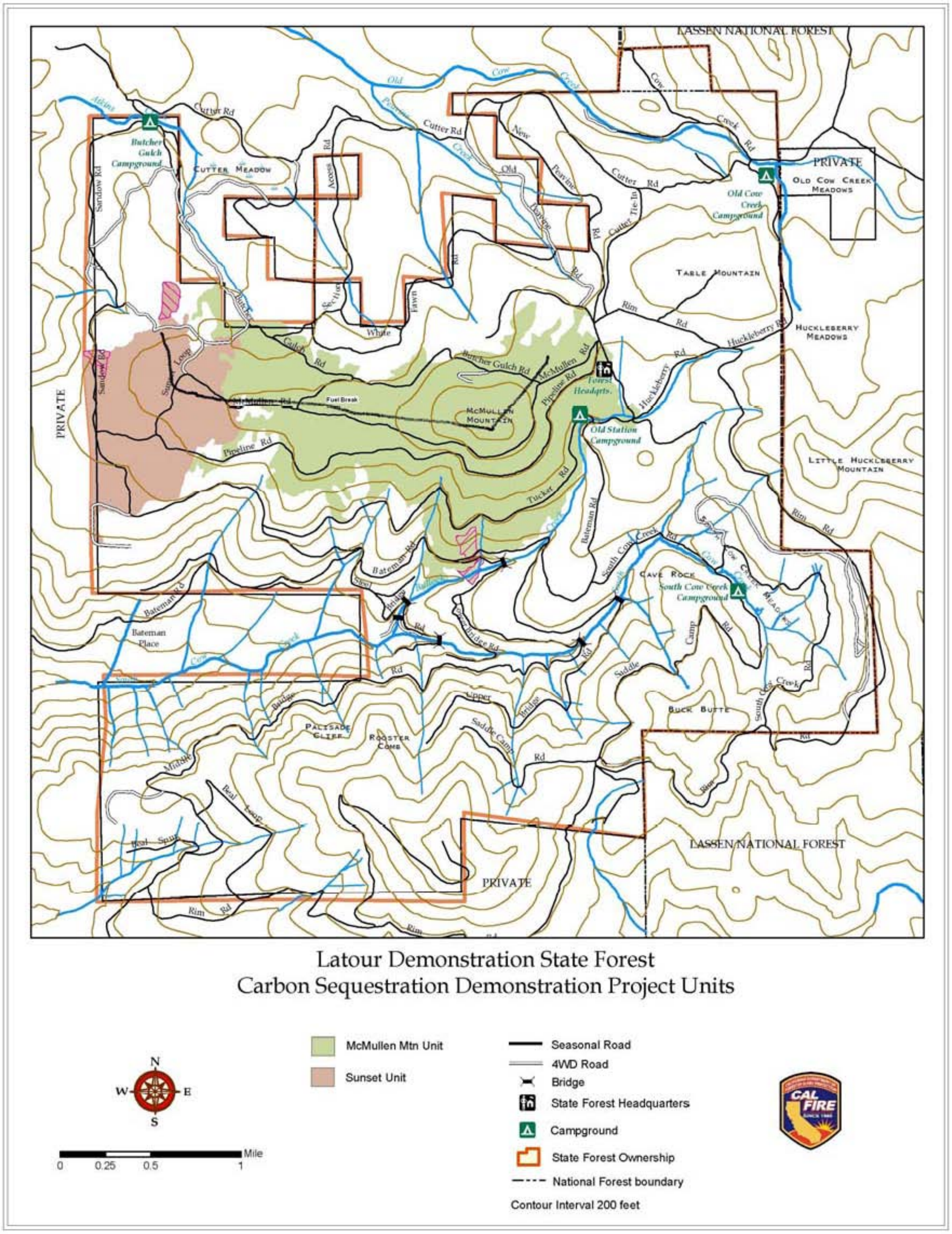


Figure 3: Example of 1978 Whitmore Burn in 2007 Showing Mix of Survivor Trees, Planted Pine Regeneration, Competing Shrubs and Naturally Seeded White Fir Regeneration

A number of areas were treated as part of this project, Figure 4. Approximately 200 acres were treated, Table 1. Units 2, 5 and a corner of 4 were the reforestation areas, but most of the treatments were improved forest management that fully occupied the sites with conifers and improved stand growth. These treatments were not necessary to have improved forest management projects, but aided in demonstrating reforestation. Initially, we estimated that more of the treated acres would be allocated to the reforestation project type, but subsequent measurements and analysis showed that the areas were appropriately considered as improved forest management.

Reforestation project eligibility was evaluated using Appendix E of the protocols where the project developer walks through a decision matrix to arrive at an eligibility determination. Site preparation costs were high due to the existing brush that was treated. The value of the harvested products was determined from looking up the Southern Cascade mixed conifer type in Appendix F, which gave a medium value. Rotation age was also taken from Appendix F and was 60 years. Site class was not needed as all projects in this category were eligible.

Figure 4: Treatment Units, Except Unit 7 which was not Installed Units 2, 5, and Part of 4 are the Regeneration Units

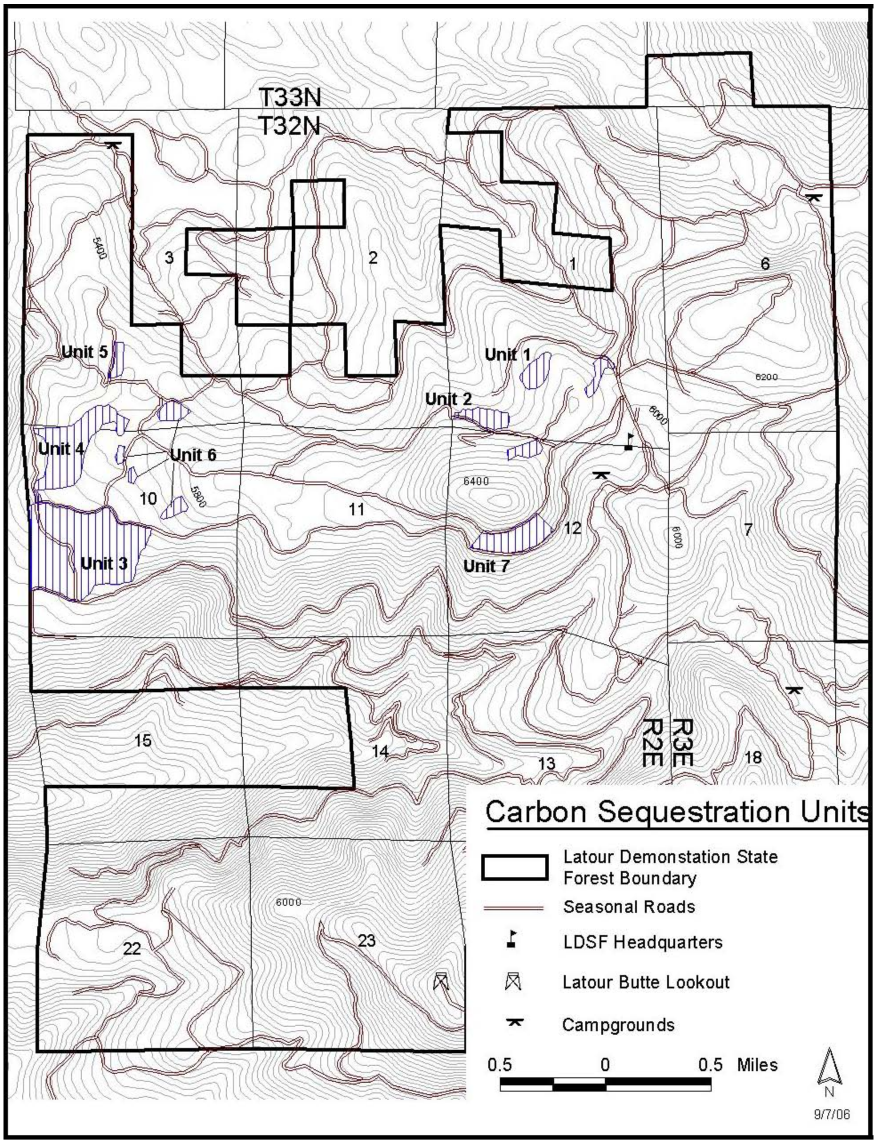


Table 1: Treatment Descriptions

UNIT #	LOCATION	ACREAGE (APPROXIMATE)	TYPE OF WORK	SCHEDULE
1	OLD PEAVINE SPUR (SE/4Sec. 1)	20 acres	Brush piling, Spraying, Planting	June 2007 Spray spring 2008 Plant Fall 08/Spring09
2	UPPER BUTCHER GULCH ROAD (SW/4, Sec. 1)	20 acres	Brush Mastication, Spraying, Planting	June 2007 Spray spring 2008 Plant Fall 08/Spring09
3	SANDOW RD. TO PIPELINE RD (Sw/4, Dec. 10)	80 acres	Brush Release/Hand Spray	June to October 2007
4	BETWEEN SANDOW RD. AND SUNSET RD. (NW/4, Sec. 10)	35 to 40 acres	Release hand spray of 2000 Brush piled Unit	June to October 2007
5	SPUR ROAD OFF SANDOW RD.(NW/4 of SE/4, Sec. 10)	7 to 10 acres	Brush piling, Spraying, Planting	June 2007 Spray spring 2008 Plant Fall 08/Spring09
6	SCATTERED SMALL GROUPS OPENINGS BETWEEN McMULLEN RD. AND TUCKER RD.	20 to 25 acres	Hand spray	June 2007

2.1 Sunset Project Description

This unit is on the west side of the Forest, is about 428 acres (173 hectares) at 40.656° N and 121.743° W. The unit has an average elevation of 5,544 feet (1,690 m) with a range of 5,369 feet (1,636 m) to 5,749 feet (1,752 m) and has a relatively high ponderosa pine (*Pinu*s *ponderosa*) component relative to the other mixed conifer species, partly due to the planting that occurred after the 1978 Whitmore Fire. The other dominant conifer species are sugar pine (*Pinu*s *lambertiana*), incense-cedar (*Calocedru*s *decurrens*), white fir (*Abie*s *concolor*), and red fir (*Abie*s *magnifica*). The average climate (PRISM 2009) from 1971 through 2007 for this unit was 58.4 inches (148 cm) precipitation falling as rain and snow with an average January daily minimum temperature of 24.8° Fahrenheit (-4.0° C) and average July daily maximum temperature of 82.5° Fahrenheit (28.1° C). Table 2 shows the acres (Table 3, hectares) by forest type and project type.

Table 2: Acres for Each Unit by Forest Type and Project Type

	Sunset			McMullen Mtn.		
Forest Type	Reforestation	Management	Total	Reforestation	Management	Total
Ponderosa Pine	10.2	243.6	253.8	0.0	30.5	30.5
Mixed Conifer	0.0	7.8	7.8	8.5	104.4	112.9
White Fir	0.0	174.4	174.4	10.1	1,010.1	1,020.2
Red Fir	0.0	0.0	0.0	0.0	47.1	47.1
Total	**10.2**	**425.8**	**436.0**	**18.6**	**1,192.1**	**1,210.7**

Table 3: Hectares for Each Unit by Forest Type and Project Type

Forest Type	Sunset Reforestation	Sunset Management	Sunset Total	McMullen Mtn. Reforestation	McMullen Mtn. Management	McMullen Mtn. Total
Ponderosa Pine	4.1	98.6	102.8	0.0	12.3	12.3
Mixed Conifer	0.0	3.2	3.2	3.4	42.3	45.7
White Fir	0.0	70.6	70.6	4.1	408.9	413.0
Red Fir	0.0	0.0	0.0	0.0	19.1	19.1
Total	**4.1**	**172.4**	**176.5**	**7.5**	**482.6**	**490.2**

2.2 McMullen Mountain Project Description

This unit (figures 5 -7) is centered on McMullen Mountain in the north/center of the Forest, is about 1,211 acres (490 hectares) at 40.640° N and 121.703° W. The unit has an average elevation of 5,850 with a range of 4,970 feet (1,515 m) to 6,411 feet (1,954 m) and is dominated by white fir stands. The average climate (PRISM 2009) from 1971 through 2007 for this unit was 56.1 inches (142 cm) precipitation falling mostly as rain and snow with an average January daily minimum temperature of 23.8° Fahrenheit (-4.6° C) and average July daily maximum temperature of 81.4° Fahrenheit (27.4° C). Table 2 shows the acres (Table 3, hectares) by forest type and project type.

Figure 5: White Fir Stand that Grew Up Through Shrubs through Natural Succession over Many Decades; Shrub Skeletons are Visible on Ground

Figure 6: Before Mastication Treatment of Reforestation Unit on McMullen Mountain. Evidence of Past Burning in Unit, Which May Explain Lack of Advanced Regeneration

Figure 7: Post treatment of Reforestation Unit on McMullen Mountain Showing Mastication and Planted Seedling

CHAPTER 3:
Sunset Project GHG Analysis: Private Land Scenario

This project is mostly a forest management project, Table 2 and Table 3. The protocols specify that the required carbon pools for a forest management project are the above ground and below ground living biomass, standing and down dead biomass and off-site dead biomass. The down dead biomass was changed to optional in the final version. The optional pools are shrubs and herbaceous understory, litter, and soil carbon. Only the required pools will be included in this analysis. The reforestation unit in this project requires that shrubs and herbaceous understory also be estimated. The above ground and below ground live tree biomass is required for reforestation, where they exist. They are rarely present for this unit and will be tracked at future inventory periods, Figure 8 through Figure 10.

Figure 8: Reforestation Unit in Sunset Project, Pre-Treatment

Figure 9: Reforestation Unit in Sunset Project Showing Dead Brush and Exposed Mineral Soil with Planted Conifers, Post-Treatment

Figure 10: Reforestation Unit in Sunset Project Showing Grove of Residual Trees near Road, Post-Treatment

3.1 Inventory Description and Results

The inventory design and calculation methods are described in appendix I. Table 4 shows the starting carbon inventory estimate for the project along with the sampling error. The sampling error was calculated as 1.645 times the standard error estimate. The protocol calls for a reduction in CRTs where percent sampling errors are between 5 percent and 20 percent. This is calculated on the above and below ground live tree carbon. The result was a percent sampling error of 7.9 percent, which would give a 7.9 percent reduction to CRTs.

Table 4: Starting Carbon Inventory for Forest Management on the Sunset Project

Attribute	Reforestation	Forest Management
No. of Plots	3	141
Mean Trees per Acre	0	95.60
Mean Trees per Hectare	0	236.14
Mean Bole Cubic Feet per Acre (ground to tip)	0	614.41
Mean Bole Cubic Meters per Hectare (ground to tip)	0	1,517.58
Mean Bole C per Acre (tonnes)	0	18.96
Mean Bole C per Hectare (tonnes)	0	46.84
Mean Bark C per Acre (tonnes)	0	8.97
Mean Bark C per Hectare (tonnes)	0	22.15
Mean Crown Branches C per Acre (tonnes)	0	4.17
Mean Crown Branches C per Hectare (tonnes)	0	10.29
Mean Tree Live Aboveground C per Acre (tonnes)	0	32.10
Mean Tree Live Aboveground C per Hectare (tonnes)	0	79.28
Mean Tree Live Belowground C per Acre (tonnes)	0	11.10
Mean Tree Live Belowground C per Hectare (tonnes)	0	27.42
Mean Tree Live C per Acre (tonnes)	0	43.21
Mean Tree Live C per Hectare (tonnes)	0	106.72
Acres	10.2	425.8
Hectares	4.1	172.4
Total Live Tree C (tonnes)	0	18,099.80
Total Lying Dead C (tonnes)	0.04	0.89
Total Standing Dead C (tonnes)	0.14	3.37
Total C (tonnes)	0.18	18,104.05
Standard Error C (tonnes)	na	871.74
Sampling Error (tonnes)	na	1,434.02
Sampling Error (%)	na	7.92%
Mean Shrub Aboveground C per Acre (tonnes)	14.60	na
Mean Shrub Aboveground C per Hectare (tonnes)	36.06	na
Mobile Combustion C per Acre (tonnes)	0.12	na
Mobile Combustion C per Hectare (tonnes)	0.29	na
Total Shrub Aboveground C (tonnes)	148.92	na
Total Reforestation C (tonnes)	150.29	na

3.2 Baseline Calculations

The baseline for the reforestation project type is the existing aboveground shrub carbon, which will be assumed to be a steady stock for the 100 year projection period. In this case, it is 148.92 tonnes of C, which is 14.6 tonnes C per acre (36.1 t/h). No dead wood is assumed since the area was a brush field and no large dead wood was accumulating. No harvests were simulated. The reforestation unit is a brush field that will undergo a slow natural succession process if left undisturbed. Given the fire frequency for the area and the high fuel load and combustion potential of this fuel type, a high-severity disturbance would be likely in a 100 year timeframe, therefore natural reforestation was not assumed. There are no legal requirements to reforest this unit.

The baseline for forest management project types bifurcates depending on whether the starting stocks of carbon are above or below the average for the applicable assessment area (common practice), based on the FIA average. LDSF is located in the Sierra Nevada Southern Cascades assessment area, which is 39 tonnes per acre in above ground and below ground live trees for private ownerships (CAR 2009, Appendix F). Since the inventory shows 43.57 tonnes per acre in total live tree carbon, the forest management baseline shall be based on a steady flow from the FIA mean of 39 tonnes per acre. The current inventory will be the starting condition, which is 2005 in this case since that is when the project starts. The resulting baseline will have to be shown to be economically and legally feasible, given that there are not significant constraints to management of the unit. Economic feasibility is demonstrated by the historic and continued timber sales to local mills from the project area. The area is well roaded, of low to moderate steepness, at the upper end of watersheds and not in habitat that significantly constrains management. The legal constraints are primarily the California Forest Practice Act and associated regulations, which the property has successfully operated under since the creation of the Act. The application of the Maximum Sustained Production (MSP) of High Quality Timber Products constraint could be a significant factor depending on landowner status. In this scenario we consider the project to be private land operated by a non-industrial owner, which allows us to use the MSP option C safe-harbor rules. The management of LDSF has shown a steady increase in inventory over time, including the last 10 year, which may be verified from the permanent plots and periodic management reports. The resulting average stocks over a 100 year period must be at or above the common practice figure of 39 tonnes per acre C.

If a harvest schedule uses optimization, such as a linear program, and the carbon yields are incorporated into it, then the baseline may be easily modeled by changing the optimization function to match the FIA baseline figure. Otherwise, and this is the case here, modeling the harvest schedule must be done by trial and error to approach the FIA figure but end at or above it. The trial and error approach is time consuming unless the project is very small; we recommend optimization or other operations research approaches given the complexity of the carbon accounting rules. This complexity is increased when financial accounting of carbon and timber is included.

A mix of small group clearings and clearcuts along with commercial thinnings from below were used. These silvicultural prescriptions are consistent with current practices on the Forest and produce wood products that may be utilized for dimensional lumber and peelers for plywood, both of which are in demand in the area. In general, the clearfelling, whether as small group selections less than or equal to 2.5 acres (1 hectare) or clearcuts up to 20 acres (8 hectares) in size, was moved up in time and commercial thinnings with a residual basal area of 100 ft^2/acre (22.9 m^2/h) were used to maintain the stocking over time. These opening sizes and residual stocking meet the minimum requirements of the California forest practice regulations. Where clearcuts were implemented, the minimum age requirements of the rules were met. Table 5 shows a summary of the silvicultural treatments simulated for the baseline.

Table 5: Acres of Silvicultural Prescriptions for the Baseline Simulation of the Sunset Unit for Private Lands Forest Management

Year Treatment	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	*Total Acres*
Clearfell (Group Selection and Clearcut)	69.7	12.3	6.4	34.9	69.5	0.0	16.0	2.0	203.4	10.9	0.0	*425.1*
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	14.1	0.0	57.2	252.9	261.0	269.3	312.4	144.2	166.2	31.1	*1,508.4*
Commercial Thin with 120 sq. ft. Residual Basal Area	0.0	0.0	0.0	9.5	0.0	0.0	0.0	0.0	22.0	0.0	0.0	*31.5*
Commercial Thin with 140 sq. ft. Residual Basal Area	0.0	65.6	22.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*88.1*
Commercial Thin with 160 sq. ft. Residual Basal Area	0.0	4.5	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*26.5*
Single Tree Selection with 70% Basal Area Retention	0.0	0.0	0.0	117.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*117.0*
Sanitation and Salvage	0.0	52.7	0.0	44.8	0.0	18.9	0.0	6.2	0.0	0.0	0.0	*122.6*
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	0.0	0.0	0.0	19.1	0.0	19.1	0.0	19.1	0.0	19.1	0.0	*76.4*
Total Acres	*69.7*	*149.2*	*28.9*	*304.5*	*322.4*	*299.0*	*285.3*	*339.7*	*369.6*	*196.2*	*31.1*	*2,395.6*

The amount of carbon associated with the live and dead wood, on-site and off-site, for the baseline is shown in Table 6. The project portion of Table 6 is explained in the next section, but is presented here so that the two tables may be viewed together for comparison. The landfill pool is not used for reductions calculations unless the baseline average exceeds the project pool, but it is always required to report it. Figure 11 and Figure 12 show the onsite and offsite baseline estimates for the 100 year planning period. The year 2010 is the only 5 year reporting with the rest being 10-year periods. When averaging the baseline only the 10 year periods were used.

Table 6: Tonnes per Acre of Carbon in the Baseline and Project Activity Projections for the Sunset Unit Forest Management Scenario

	Baseline									Project					
Year	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	FIA Live Tree Average	On-site Live and Dead C Baseline	On-site Live and Dead C Avg Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	Sum of On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	42.86	3.33	40.88	39.00	46.19	43.21	1.03	0.68	0.17	42.86	4.13	46.98	0.00	0.00	0.00
2010	31.23	2.78	40.88	39.00	34.01	43.21	1.82	0.68	0.29	33.31	3.46	36.78	1.10	1.10	0.18
2015	38.16	2.91	40.88	39.00	41.07	43.21	2.22	1.36	0.36	48.42	3.46	51.88	1.53	0.44	0.25
2025	54.68	4.16	40.88	39.00	58.85	43.21	4.30	1.36	0.69	66.46	4.18	70.64	3.41	1.88	0.55
2035	53.25	3.77	40.88	39.00	57.02	43.21	6.58	1.36	1.06	68.51	3.84	72.35	3.71	0.30	0.60
2045	41.50	2.69	40.88	39.00	44.19	43.21	7.60	1.36	1.22	88.79	3.37	92.17	6.16	2.45	0.99
2055	45.25	3.02	40.88	39.00	48.27	43.21	8.70	1.36	1.40	75.37	3.41	78.78	6.44	0.27	1.03
2065	50.29	3.33	40.88	39.00	53.62	43.21	9.74	1.36	1.56	93.63	3.55	97.19	8.56	2.12	1.37
2075	53.60	4.36	40.88	39.00	57.96	43.21	12.70	1.36	2.04	85.22	3.97	89.18	8.83	0.27	1.42
2085	18.91	1.74	40.88	39.00	20.65	43.21	13.41	1.36	2.15	102.02	4.49	106.51	11.05	2.21	1.77
2095	19.38	1.77	40.88	39.00	21.15	43.21	13.49	1.36	2.17	90.40	4.41	94.80	11.28	0.23	1.81
2105	31.80	3.72	40.88	39.00	35.52	43.21	13.63	1.36	2.19	104.93	4.47	109.41	11.39	0.11	1.83

Figure 11: Sunset Unit On-Site Baseline for Private Lands Forest Management Scenario

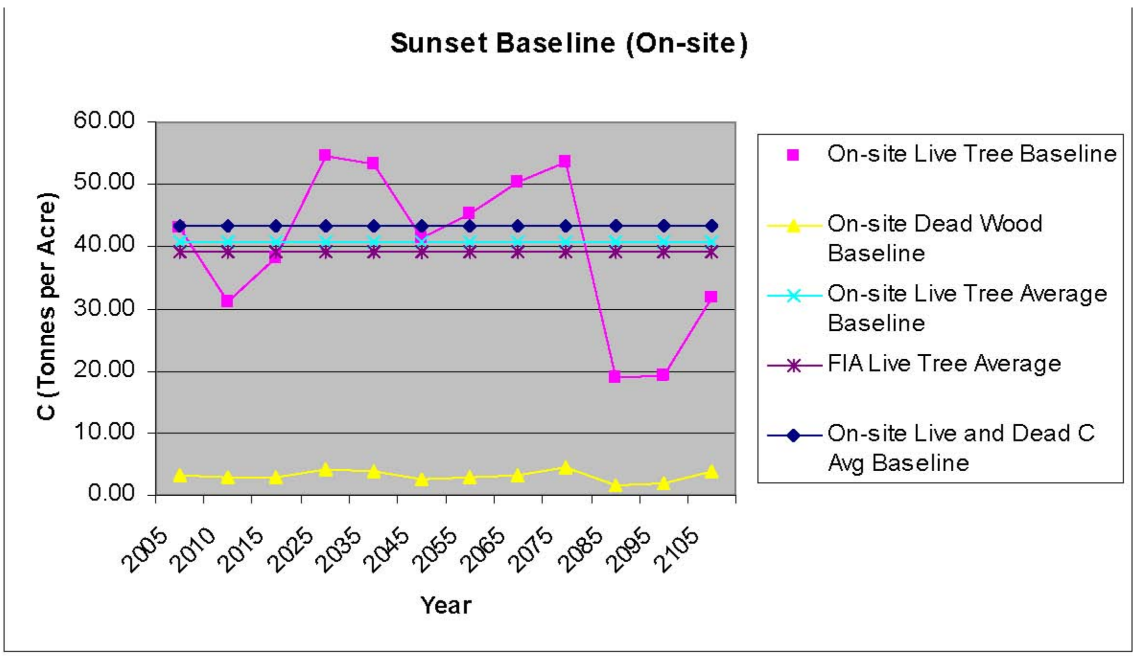
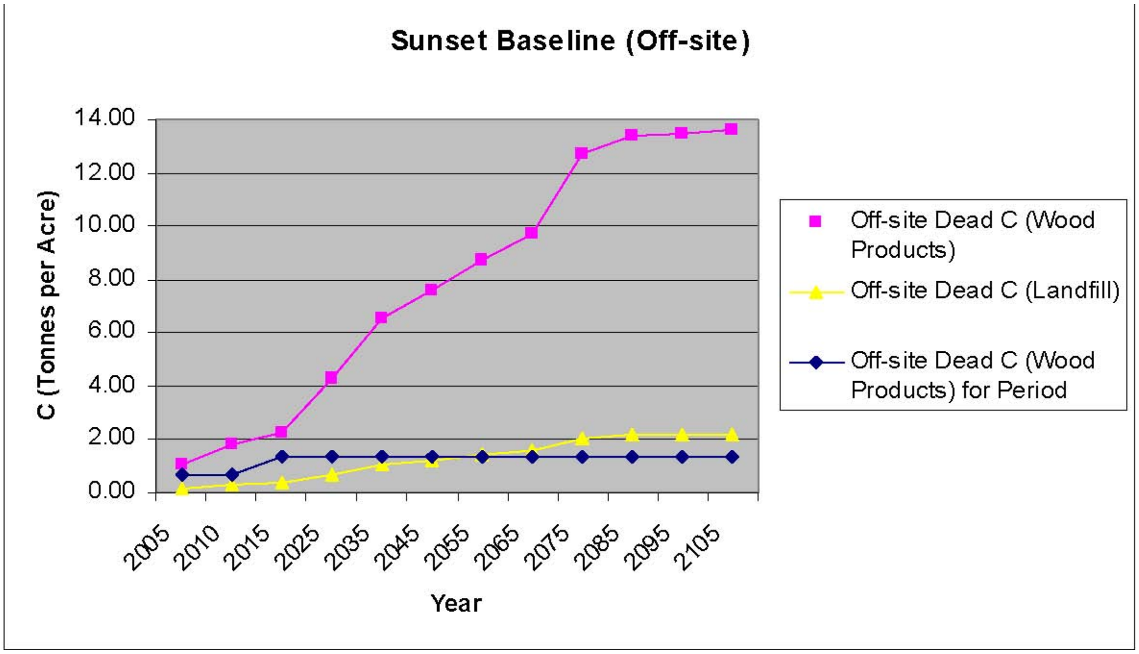


Figure 12: Sunset Unit Off-Site Baseline for Private Lands Forest Management Scenario



The results of the forest management baseline analysis were that the average on-site stocking was 40.88 tonnes of C per acre (100.97 tonnes C per hectare). Offsite wood products storage (based on 100 year storage in-use) increased over time and had an average over the period of 0.136 tonnes/acre/year C. This equated to a total of 3,765 thousand cubic feet (106,600 m^3) of timber over the 100 year period. Assuming six board feet per cubic foot, this equates to 22,590 thousand board feet (MBF) total or 531 board feet per acre per year over the 100 year period.

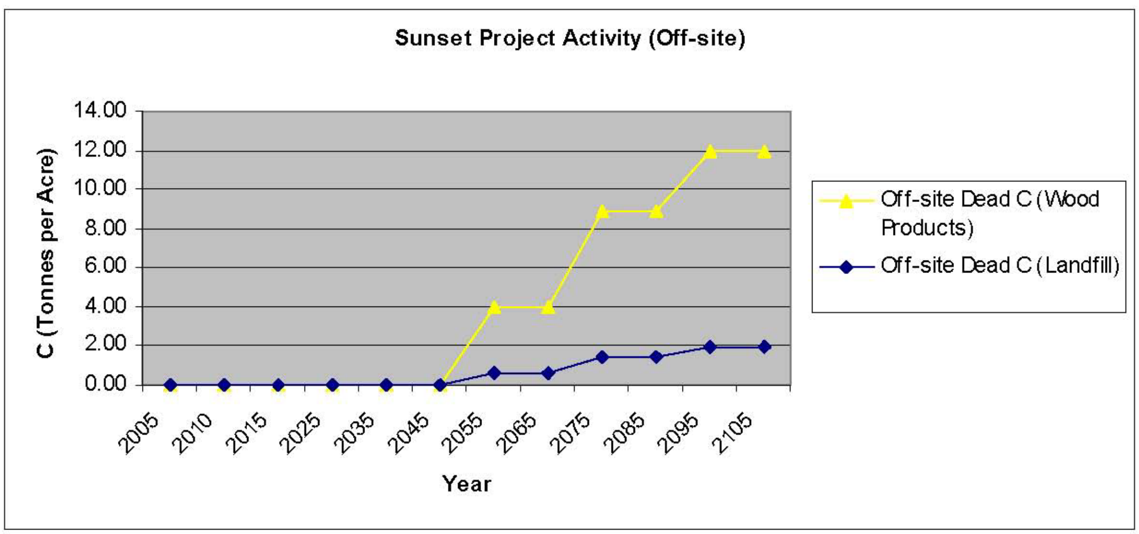
3.3 Project Activity Calculations

The project activity for the reforestation project type was modeled as a 10x10 foot spacing of 1-0 planted seedlings of a pine and fir mix, which resulted in 436 trees per acre (1,077 trees/h). Commercial thinnings from below leaving a residual basal area of 120 ft2/ac (27.5 m2/h) were simulated in 2050, 2070, and 2090. The result of the project activity was to increase on-site carbon stocks to 76.3 tonnes C per acre (188.5 t/h) after 100 years, Table 7. The total wood products pool, Figure 13, projected over the 100 year period was 11.9 tonnes C per acre (29.4 t/h), which was 7.8 thousand cubic feet (MCF) per acre (546 m3/h). No shrub carbon was assumed for the project activity, a conservative assumption.

Table 7: Tonnes per Acre of Carbon in the Baseline and Project Activity Projections for the Sunset Unit Reforestation Scenario

	Baseline					Project					
Year	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	Sum of On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	14.60	0.00	14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2015	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2025	14.60	0.00	14.60	0.00	0.00	19.31	4.40	23.71	0.00	0.00	0.00
2035	14.60	0.00	14.60	0.00	0.00	47.76	4.40	52.16	0.00	0.00	0.00
2045	14.60	0.00	14.60	0.00	0.00	61.13	4.40	65.53	0.00	0.00	0.00
2055	14.60	0.00	14.60	0.00	0.00	49.78	2.80	52.58	4.02	4.02	0.64
2065	14.60	0.00	14.60	0.00	0.00	72.19	2.80	74.99	4.02	0.00	0.64
2075	14.60	0.00	14.60	0.00	0.00	55.56	2.80	58.36	8.84	4.83	1.42
2085	14.60	0.00	14.60	0.00	0.00	69.59	5.80	75.39	8.84	0.00	1.42
2095	14.60	0.00	14.60	0.00	0.00	60.12	5.80	65.92	11.92	3.08	1.91
2105	14.60	0.00	14.60	0.00	0.00	70.50	5.80	76.30	11.92	0.00	1.91

Figure 13: Reforestation Project Activity Projections of Off-Site Dead Wood Pools



The project activity for the forest management project type was projected using the stand level treatments identical to the long-term harvest schedule approved by the State of California under 14 CCR 933.11(a), also known as an option a plan. The modeling was done using a stand level projection of treatments over a 100 year period that was then summarized across the forest. Adjustments were made to some stands to meet regulatory requirements for long-term planning. The overall goal was to move over-mature stands to younger age classes over time to create a balance of stand ages. Dead wood was modeled using the mortality functions of FVS with an assumed decay rate of 10 percent per year. Table 8 shows the silvicultural prescriptions. The project proposes less intensive treatments and fewer acres treated relative to the baseline.

Table 8: Acres of Silvicultural Prescriptions for the Project Activity Simulation of the Sunset Unit for Private Lands Forest Management

Year / Treatment	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	*Total Acres*
Clearfell (Group Selection and Clearcut)	0.0	90.4	6.4	21.7	6.5	21.8	6.4	17.1	6.3	11.9	3.3	*191.8*
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	13.1	0.0	15.8	0.0	60.7	0.0	39.1	0.0	61.2	0.0	*189.9*
Commercial Thin with 120 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	6.9	0.0	6.9	0.0	6.9	0.0	*20.7*
Commercial Thin with 140 sq. ft. Residual Basal Area	0.0	0.0	25.8	70.5	27.8	58.1	27.8	84.3	28.0	69.1	31.1	*422.5*
Commercial Thin with 160 sq. ft. Residual Basal Area	0.0	4.5	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	*92.5*
Commercial Thin with 180 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	*5.7*
Commercial Thin with 200 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	*2.7*
Single Tree Selection with 70% Basal Area Retention	0.0	20.3	0.0	143.1	0.0	143.1	0.0	137.3	0.0	143.1	0.0	*586.9*
Sanitation and Salvage	0.0	65.5	0.0	59.7	0.0	31.7	0.0	37.5	0.0	31.7	0.0	*226.1*
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	0.0	0.0	0.0	19.1	0.0	19.1	0.0	19.1	0.0	19.1	0.0	*76.4*
Total Acres	*0.0*	*193.8*	*32.2*	*351.9*	*34.3*	*363.4*	*34.2*	*366.0*	*34.3*	*370.7*	*34.4*	*1,815.2*

The results of the C stocking may be seen in Table 6 under Project. Notice that there is a near-term decrease in carbon stocks, which is a reflection of the near-term harvesting that has occurred in this unit as per the existing harvest schedule. An approximate 20year cutting cycle is implemented on LDSF. This will have an effect on the reductions calculation that is shown below.

The result of the project activity projection was to increase on-site carbon stocks from an average of 42.86 tonnes/acre (105.9 tonnes/hectare) to 104.93 tonnes/acre (259.2 tonnes/hectare) at the end of the 100 year period. Off-site wood products storage grew to 11.93 tonnes/acre C (29.5 t/h), which was 12 percent less than the 13.63 tonnes/acre C (33.7 t/h) in the baseline. The harvest is projected to total 3,146 MCF (89,088 m3) of timber over the 100 year period. Figure 14 and Figure 15 show the project activity for the onsite and offsite carbon over time.

Figure 14: Sunset Unit on-Site Project Activity for the Forest Management Project Type

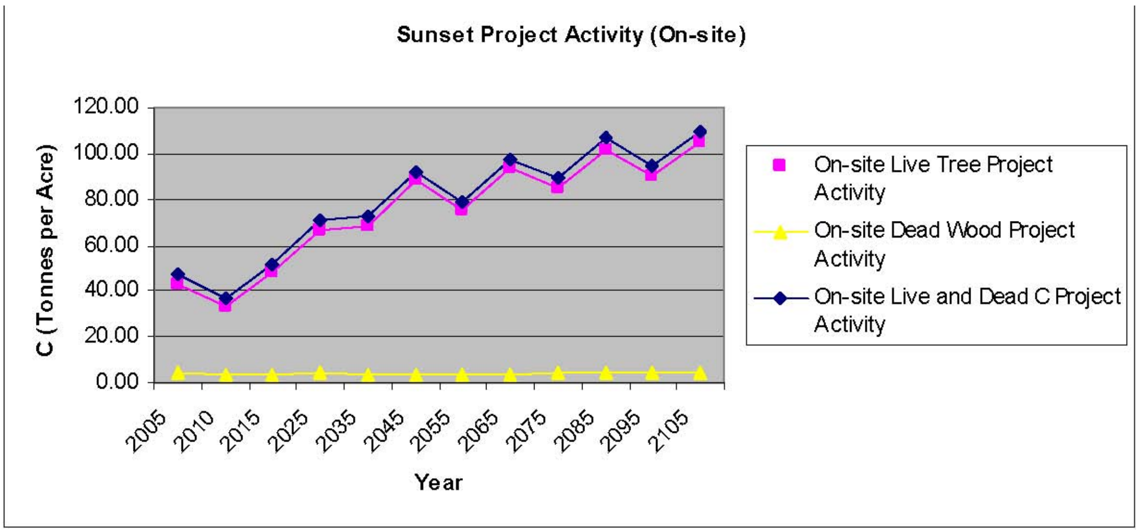
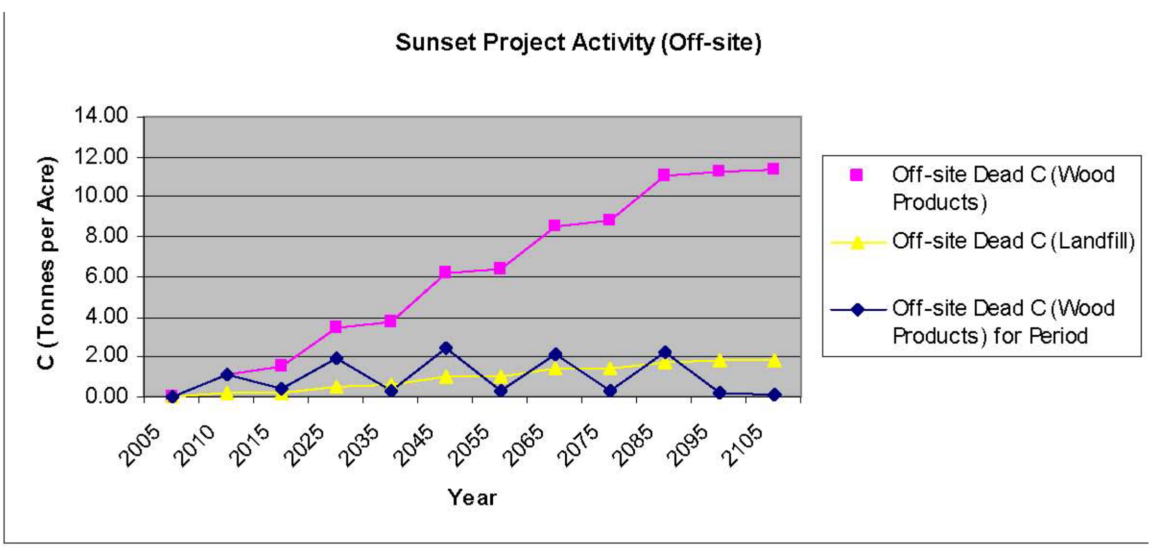


Figure 15: Sunset Unit Off-Site Project Activity for the Forest Management Project Type



3.4 Gross Biological Reductions

The difference between the project activity and baseline projections is the gross reduction, which is shown in Table 9 and Tables 10 for the 100 year planning period and the two project types. Figure 16 and Figure 17 show the gross reductions and the smoothed reductions whereby a reversal due to near-term harvests does not occur. For example, if 100 CRTs were created in decade 2 but due to harvest cycles there were 10 CRTs in decade 3, then only 90 CRTs would be claimed for decade 2. This leads to an estimate of the decadal gross new CRTs, before any deductions for inventory precision, permanence or leakage.

Table 9: Tonnes of Carbon in Gross Reductions before Deductions, Deductions, and Net Reductions; for the Sunset Unit Reforestation Scenario

	Gross Additionality						Deductions			Net Reductions			
Year	On-Site Reductions	Off-site Dead C Reductions (Wood Products)	Sum of On and Off-site Reductions	Total Marginal Reductions	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	9.11	0.00	9.11	23.71	9.11	9.11	0.00	0.00	1.82	7.29	7.29	1.82	1.82
2035	37.56	0.00	37.56	13.85	37.56	28.45	0.00	0.00	5.69	22.76	30.05	5.69	7.51
2045	50.93	0.00	50.93	37.08	42.00	4.44	0.00	0.00	0.89	3.55	33.60	0.89	8.40
2055	37.98	4.02	42.00	4.92	42.00	0.00	0.00	0.00	0.00	0.00	33.60	0.00	8.40
2065	60.39	0.00	64.41	59.49	52.60	10.61	0.00	0.00	2.12	8.49	42.08	2.12	10.52
2075	43.76	4.83	52.60	-6.89	52.60	0.00	0.00	0.00	0.00	0.00	42.08	0.00	10.52
2085	60.79	0.00	69.63	76.52	63.24	10.64	0.00	0.00	2.13	8.51	50.59	2.13	12.65
2095	51.32	3.08	63.24	-13.28	63.24	0.00	0.00	0.00	0.00	0.00	50.59	0.00	12.65
2105	61.70	0.00	73.62	86.90	73.62	10.38	0.00	0.00	2.08	8.30	58.90	2.08	14.72

Figure 16: Reforestation, Sunset Unit Gross Reductions and CRTs

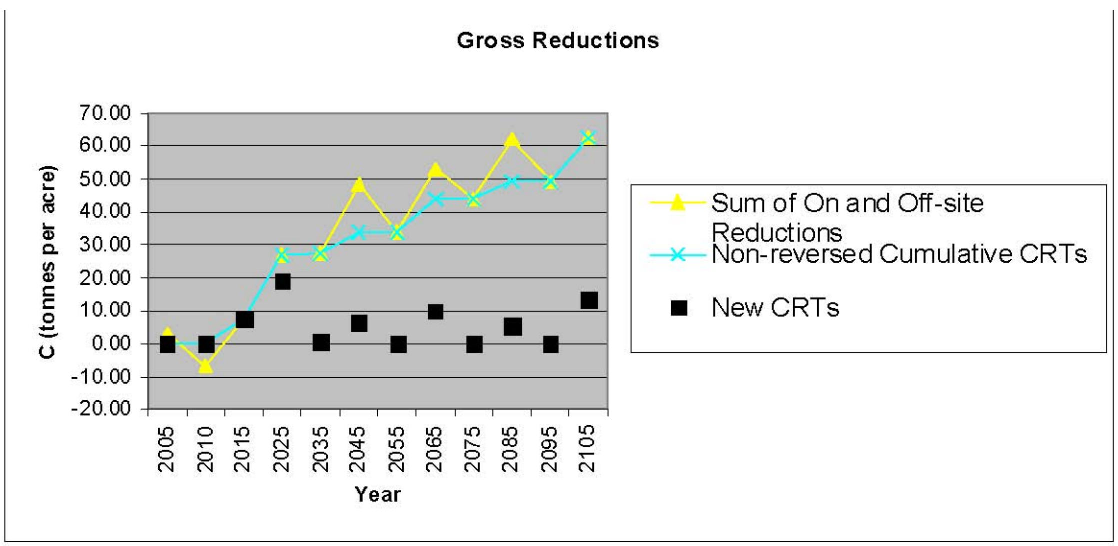
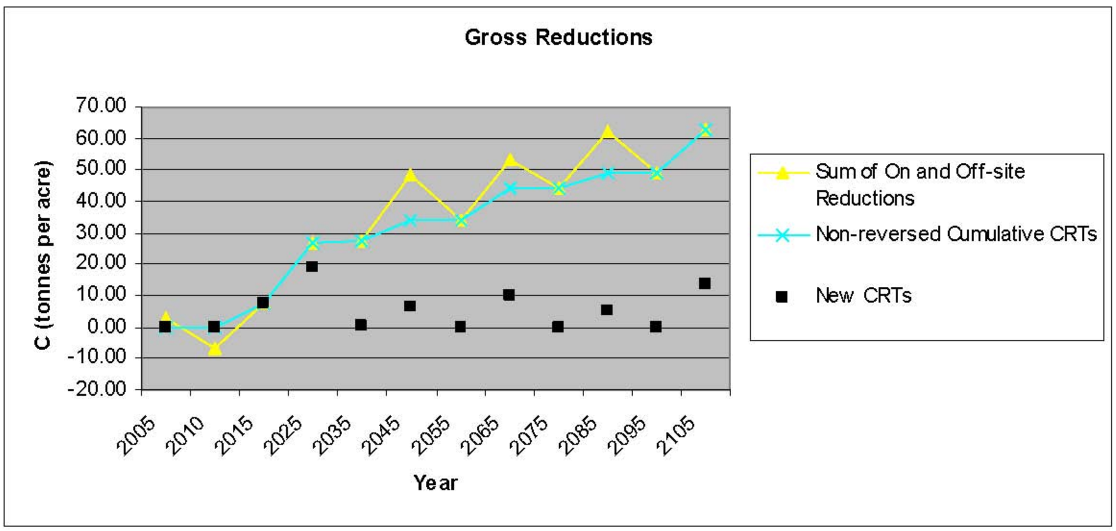


Table 10: Tonnes of Carbon in the Gross Reductions Before Deductions, Deductions, and Net Reductions; for the Sunset Unit Forest Management Scenario

	Gross Reductions						Deductions			Net Reductions			
Year	On-Site Reductions	Off-site Dead C Reductions (Wood Products)	Sum of On and Off-site Reductions	Total Marginal Reductions	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	3.78	-0.68	3.10	3.10	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00
2010	-6.43	0.42	-6.70	-9.79	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00
2015	8.68	-0.93	7.48	17.28	7.48	7.48	-0.16	0.59	1.50	5.24	5.24	1.50	1.50
2025	27.43	0.52	26.76	9.48	26.76	19.27	-0.16	1.52	3.85	13.74	18.97	3.85	5.35
2035	29.14	-1.06	27.40	17.92	27.40	0.64	-0.16	0.05	0.13	0.30	19.27	0.13	5.48
2045	48.96	1.09	48.31	30.39	33.84	6.44	-0.16	0.51	1.29	4.48	23.76	1.29	6.77
2055	35.57	-1.09	33.84	3.45	33.84	0.00	-0.16	0.00	0.00	0.00	23.76	0.00	6.77
2065	53.98	0.76	53.00	49.55	43.91	10.07	-0.16	0.80	2.01	7.10	30.86	2.01	8.78
2075	45.98	-1.09	43.91	-5.65	43.91	0.00	-0.16	0.00	0.00	0.00	30.86	0.00	8.78
2085	63.30	0.85	62.08	67.73	49.24	5.34	-0.16	0.42	1.07	3.69	34.55	1.07	9.85
2095	51.60	-1.13	49.24	-18.49	49.24	0.00	-0.16	0.00	0.00	0.00	34.55	0.00	9.85
2105	66.20	-1.25	62.59	81.08	62.59	13.35	-0.16	1.05	2.67	9.47	44.01	2.67	12.52

Figure 17: Forest Management, Sunset Unit Gross Reductions and CRTs



3.5 Permanence Analysis

This is a risk analysis, with the details provided in appendix D of the protocol. The analysis is identical for the reforestation and improved forest management project types.

Financial Risk: The financial risk for this private lands scenario assumes a PIA only and no conservation easement, which requires a 5 percent buffer contribution.

Management Risk: Management risk consists of three types of risks. Illegal removals are given a 0 percent risk for property in the United States. Conversion to an alternate land use is a function of whether development rights are encumbered by an easement or deed restriction, which is not the case here, incurring a 2 percent deduction. Overharvesting is the final management risk and is also a function of having a legal restriction on harvesting, which is not the case here and therefore incurs a 2 percent deduction.

Social Risk: This is a flat 2 percent for the United States.

Natural Disturbance Risk: There are three components to this risk category. Wildfire risk is a function of fire frequency and burn severity, which may be reduced using specified categories of fuels treatment activity. Default values will be given in Appendix F of the protocols for the assessment areas, but are not yet provided. In this case the risk is given as 3 percent and is based on the location of the unit on the front country where significant fires occur down elevation to the west every 10 years or so and present a risk of expansion into the unit, as occurred in the 1978 Whitmore Fire. While shaded fuel breaks are planned and the treatments that occurred as part of this project provide tie-in points for that break, it does not yet constitute a large enough percentage on the landscape to merit a deduction in risk.

Disease or insect outbreak is given a blanket 3 percent risk rating. Other episodic catastrophic events are given a default value of 3 percent.

The total permanence risk deduction is 20 percent, Table 11.

Table 11: Risk Deductions for the Sunset Unit, Private Lands Forest Management Scenario

Risks	Deduction
Financial	5.0%
Management	4.0%
Social	2.0%
Natural Dist.	9.0%
Total	20.0%

3.6 Leakage Analysis

The leakage analysis is also referred to as secondary effects analysis and is covered in section 6.2.6 for forest management project types. A leakage analysis is conducted each year based on actual harvest relative to the modeled average baseline harvest. If the total harvest level is reduced in the project activity relative to the baseline, then 20 percent of the difference between the two is the reduction applied to the carbon reductions. The value is provided on an annual and per acre basis. Table 12 shows the effect for the Sunset unit forest management scenario, which is 0.02 tonnes per acre per year. While the baseline is calculated once and is fixed for the project life, leakage is calculated each year based on actual harvest.

Table 12: Secondary Effects (SE) for Sunset Unit, Private Lands Forest Management Scenario. Units are in Tonnes of C

Project Harvested	17,268.36
Baseline Harvested	20,666.09
Gross Total Effect	3,397.74
Secondary Effect	679.55
Annual SE	-6.80
Annual SE (per acre)	-0.02

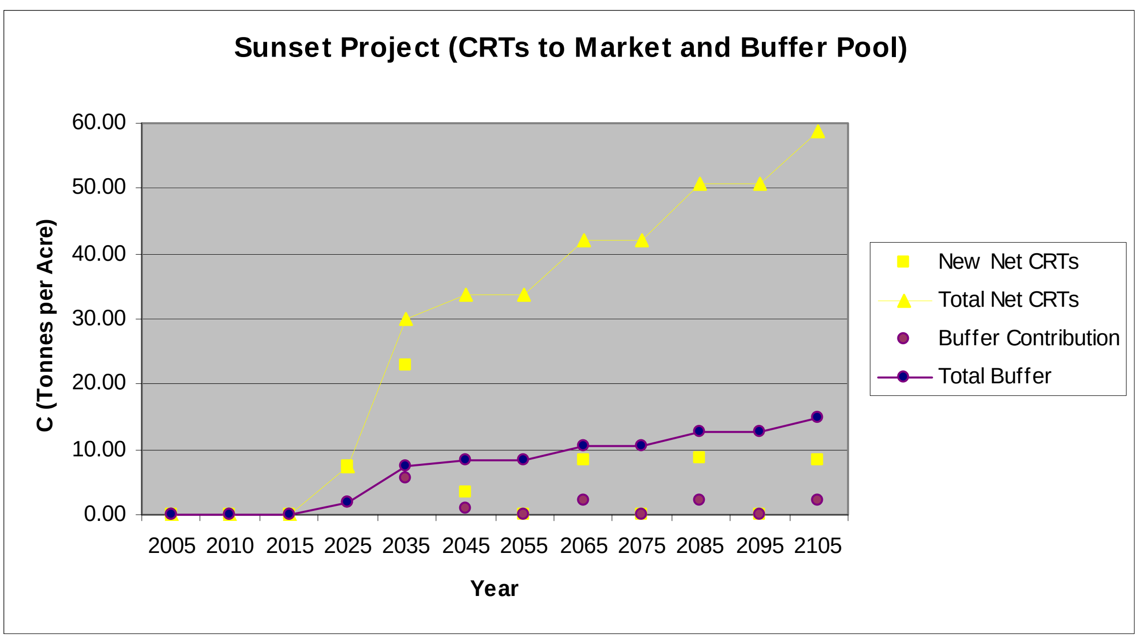
For the reforestation project type the secondary effects are specified in Table 6.1 of the protocol, mobile combustion emissions for reforestation projects and are a function of three categories of brush cover. We used the heavy category and converted the CO_2 to C to keep the units consistent at this stage of the analysis. This resulted in a one-time secondary effect of 0.12 tonnes per acre (0.3 t/h) of C that is applied the first year and C (Tonnes per Acre) carries over until there are CRTs to deduct it from.

3.7 Net Biological Reductions

The three types of deductions are shown in Table 9 and Table 10, as is the resulting net reductions and buffer contributions. Figure 18 and Figure 19 illustrate the resulting marketable CRTs and the buffer pool over the project period. For the forest management project type there is a substantial salable amount of CRTs in 2025 with the first salable CRTs in 2015. The reforestation project type is surprisingly similar, on a per acre basis, with a large amount of CRTs available in 2035 and beginning in 2025.

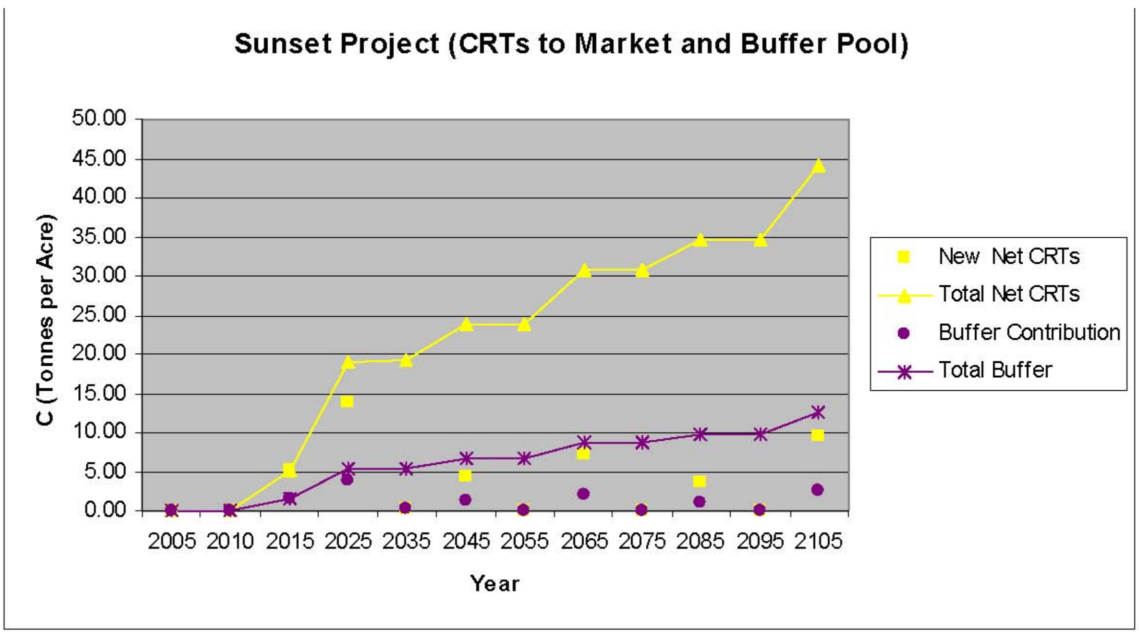
The forest management project has two factors that make it a questionable project without modification. First, the stocking levels are just above the FIA mean. Second, the project activity plan was for harvesting between 2005 and 2015 that reduced on-site stocking. An evaluation should be made to determine whether it would be more beneficial to the landowner to delay project initiation. The requirement in the protocol to maintain or increase on-site carbon stocks over time allows for the case where a long-term management plan decreases stocks temporarily.

Figure 18: Net CRTs and Buffer Pool Contributions for the Sunset Unit, Reforestation



Over the 100 year life of this project the off-site long-term wood products contribution to salable gross CRTs was 3.6 tonnes per acre for the forest management type. The amount is negative because more wood products were produced in the baseline than in the project activity. There is also a reduction for this in the secondary effects calculation. The effect of the 3.6 tonne reduction from long-term wood product storage was about 1 percent of the total gross reductions. For the reforestation project type, projected wood products contribution to the total CRTs products was only 3.2 percent. The inventory deduction of 7.9 percent was applied to estimated CRTs for the entire 100 year period. However, if the sampling error were reduced to 5 percent or less in a future inventory then the deducted reductions could be recouped.

Figure 19: Net CRTs and Buffer Pool Contributions for the Sunset Unit, Forest Management



CHAPTER 4: Sunset Project GHG Analysis: Public Land Scenario

Projects are allowed on public lands for the first time with version 3 of the protocols. There is a requirement that the project be approved by the managing agency and that Congressional approval for carbon projects be in place for federal lands. In this case we will use LDSF as it is, a demonstration state forest. In this case the approval for a project rests with the California Department of Forestry and Fire Protection (CAL FIRE) under a management plan approved by the California Board of Forestry and Fire Protection. CAL FIRE, as the forest manager, would have to decide to implement the project.

The project activity and baseline for a public lands reforestation project are the same as for a private lands project. Refer to the private lands scenario for reforestation (above) for the baseline, project activity and projected reductions. There are some differences to the buffer pool contribution from the risk analysis. The financial risk is 1 percent instead of 5 percent, conversion risk is 0 percent rather than 2 percent, and overharvesting risk is 0 percent rather than 2 percent. This results in a buffer contribution that is 12 percent for a public land project, reduced from 20 percent for the private lands project, Table 14. Table 15 shows the net reductions for the project.

Table 13: Risk deductions for the Sunset Unit Public Lands Reforestation Scenario

Risks	Deduction
Financial	1.0%
Management	0.0%
Social	2.0%
Natural Dist.	9.0%
Total	12.0%

Table 14: Tonnes of Carbon in the Gross Reductions Before Deductions, Deductions, and Net Reductions; for the Sunset Unit Reforestation Public Lands Scenario

	Gross Reductions						Deductions			Net Reductions			
Year	On-Site Reductions	Off-site Dead C Reductions (Wood Products)	Sum of On and Off-site Reductions	Total Marginal Reductions	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	9.11	0.00	9.11	23.71	9.11	9.11	0.00	0.00	1.09	8.02	8.02	1.09	1.09
2035	37.56	0.00	37.56	13.85	37.56	28.45	0.00	0.00	3.41	25.04	33.05	3.41	4.51
2045	50.93	0.00	50.93	37.08	42.00	4.44	0.00	0.00	0.53	3.90	36.96	0.53	5.04
2055	37.98	4.02	42.00	4.92	42.00	0.00	0.00	0.00	0.00	0.00	36.96	0.00	5.04
2065	60.39	0.00	64.41	59.49	52.60	10.61	0.00	0.00	1.27	9.34	46.29	1.27	6.31
2075	43.76	4.83	52.60	-6.89	52.60	0.00	0.00	0.00	0.00	0.00	46.29	0.00	6.31
2085	60.79	0.00	69.63	76.52	63.24	10.64	0.00	0.00	1.28	9.36	55.65	1.28	7.59
2095	51.32	3.08	63.24	-13.28	63.24	0.00	0.00	0.00	0.00	0.00	55.65	0.00	7.59
2105	61.70	0.00	73.62	86.90	73.62	10.38	0.00	0.00	1.25	9.13	64.79	1.25	8.83

The improved forest management project type for public lands has a baseline characterization that is different from private lands. The initial inventory is to be projected for 100 years by extrapolating from historical trends and anticipating how current and future public policy will affect onsite carbon stocks. Trends for the last ten years have been for increasing stocks, which then requires that stands free of harvest for 60 years be used as a guide. Policy on state forests is to maximize timber yields, which implies operating near culmination of mean annual increment, to use an even-aged indicator. Considering that this baseline scenario will likely be near the project activity scenario, there is little or no biological reductions to be realized from a public lands scenario on LDSF. Therefore, this scenario will not be analyzed further.

CHAPTER 5: McMullen Project GHG Analysis: Private Land Scenario

Like the Sunset project, this project is mostly a forest management project, Table 2 and Table 3. The protocols specify that the required carbon pools for a forest management project are the above ground and below ground living biomass, standing and down dead biomass (down dead biomass was changed to optional in the final version), and off-site dead biomass. The optional pools are shrubs and herbaceous understory, litter, and soil carbon. Only the required pools will be included in this analysis. The reforestation unit in this project also requires that shrubs and herbaceous understory be estimated. The above-and below-ground live tree biomass is required for reforestation where they exist. They are rarely present for this unit and will be tracked at future inventory periods, Figure 6 and Figure 7.

There is an assumption here that it is permissible to stratify a project into reforestation and improved forest management types and apply the appropriate carbon pools to each. If this is not permissible then the shrub and herbaceous pools would have to be included with the improved forest management inventory or the project types would have to be separate projects.

5.1 Inventory Description and Results

The inventory design and calculation methods are described in appendix I. Table 16 shows the starting carbon inventory estimate for the project along with the percent sampling error. The protocol specifies that a reduction in CRTs occur for percent sampling errors between 5 percent and 20 percent. This is calculated on the above and below ground live tree carbon. Since the percent sampling error is less than 5 percent there are no deductions.

Table 15: Starting Carbon Inventory for Forest Management on the McMullen Mountain Project

Attribute	Reforestation	Forest Management
No. of Plots	0	459
Mean Trees per Acre	0	141.00
Mean Trees per Hectare	0	348.27
Mean Bole Cubic Feet per Acre (ground to tip)	0	925.08
Mean Bole Cubic Meters per Hectare (ground to tip)	0	2,284.95
Mean Bole C per Acre (tonnes)	0	30.24
Mean Bole C per Hectare (tonnes)	0	74.69
Mean Bark C per Acre (tonnes)	0	13.33
Mean Bark C per Hectare (tonnes)	0	32.92
Mean Crown Branches C per Acre (tonnes)	0	6.49
Mean Crown Branches C per Hectare (tonnes)	0	16.02
Mean Tree Live Aboveground C per Acre (tonnes)	0	50.05
Mean Tree Live Aboveground C per Hectare (tonnes)	0	123.62
Mean Tree Live Belowground C per Acre (tonnes)	0	17.36
Mean Tree Live Belowground C per Hectare (tonnes)	0	42.88
Mean Tree Live C per Acre (tonnes)	0	67.41
Mean Tree Live C per Hectare (tonnes)	0	166.51
Acres	18.6	1192.1
Hectares	7.5	482.6
Total Live Tree C (tonnes)	0	80,364.30
Total Lying Dead C (tonnes)	0.00	0.89
Total Standing Dead C (tonnes)	4.86	3.37
Total C (tonnes)	4.86	80,368.55
Standard Error C (tonnes)	na	1,748.36
Sampling Error (tonnes)		2,876.05
Sampling Error (%)	na	3.58%
Mean Shrub Aboveground C per Acre (tonnes)	14.46	na
Mean Shrub Aboveground C per Hectare (tonnes)	35.71	na
Mobile Combustion C per Acre (tonnes)	0.12	na
Mobile Combustion C per Hectare (tonnes)	0.29	na
Total Shrub Aboveground C (tonnes)	268.90	na
Total Reforestation C (tonnes)	275.94	na

There is an assumption here that it is permissible to stratify a project into reforestation and improved forest management types and apply the appropriate carbon pools to each. If this is not permissible then the shrub and herbaceous pools would have to be included with the improved forest management inventory or the project types would have to be separate projects.

5.2 Baseline Calculations

The baseline for the reforestation project type is the existing aboveground shrub carbon, which will be assumed to be a steady stock for the 100 year projection period. In this case it is 268.9 tonnes of C, which is 14.5 tonnes C per acre (35.7 t/h). No dead wood is assumed since the area was a brush field and no large dead wood was accumulating. No harvests were simulated. The reforestation unit is a brushfield that will undergo a slow natural succession process if left undisturbed. Given the fire frequency for the area and the high fuel load and combustion potential of this fuel type, a high-severity disturbance would be likely in a 100 year timeframe, therefore natural reforestation was not assumed. There are no legal requirements to reforest this unit.

The baseline for forest management project types bifurcates depending on whether the starting stocks of carbon are above or below the average for the applicable assessment area (common practice), based on the FIA average. LDSF is located in the Sierra Nevada Southern Cascades assessment area, which is 39 tonnes per acre in above-and below-ground live trees for private ownerships (CAR 2009, Appendix F). Since the inventory shows 67.41 tonnes per acre in total live tree carbon, the forest management baseline shall be based on a steady flow from the FIA mean of 39 tonnes per acre. The current inventory will be the starting condition, which is 2005 in this case since that is when the project starts. The resulting baseline will have to be shown to be economically and legally feasible, which it is, given that there are not significant constraints to management of the unit. Economic feasibility is demonstrated by the historic and continued timber sales to local mills from the project area. The area is well roaded, of low to moderate steepness, at the upper end of watersheds and not in habitat that significantly constrains management. The legal constraints are primarily the California Forest Practice Act and associated regulations, which the property has successfully operated under since the creation of the Act. The application of the Maximum Sustained Production (MSP) of High Quality Timber Products constraint could be a significant factor depending on landowner status. In this scenario we consider the project to be private land operated by a non-industrial owner, which allows us to use the MSP option C safe-harbor rules. The resulting average stocks over a 100 year period must be at or above the common practice figure of 39 tonnes per acre C.

If a harvest schedule uses optimization, such as a linear program, and the carbon yields are incorporated into it then the baseline may be easily modeled by changing the optimization function to match the FIA baseline figure. Otherwise, and this is the case here, modeling the harvest schedule must be done by trial and error to approach the FIA figure but end at or above it. The trial and error approach is time consuming unless the project is very small; we recommend optimization or other operations research approaches given the complexity of the carbon accounting rules. This complexity is increased when financial accounting of carbon and timber is included.

A mix of small group clearings and clearcuts along with commercial thinnings from below were used. These silvicultural prescriptions are consistent with current practices on the Forest and produce wood products that may be utilized for dimensional lumber and peelers for plywood, both of which are in demand in the area. In general, the clearfelling, whether as small group selections less than or equal to 2.5 acres (1 hectare) or clearcuts up to 20 acres (8 hectares) in size, was moved up in time and commercial thinnings with a residual basal area of 100 ft^2/acre (22.9 m^2/h) were used to maintain the stocking over time. These opening sizes and residual stocking meet the minimum requirements of the California forest practice regulations. Where clearcuts were implemented the minimum age requirements of the rules were met. Table 17 shows a summary of the silvicultural treatments simulated for the baseline.

Table 16: Acres of Silvicultural Prescriptions for the Baseline Simulation of the McMullen Mountain Unit for Private Lands Forest Management

Year Treatment	2005	2010	2030	2040	2050	2060	2070	2080	2090	2100	*Total Acres*
Clearfell (Group Selection and Clearcut)	0.0	273.8	221.4	0.0	224.2	0.0	228.1	0.0	186.3	0.0	*1,133.8*
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	563.2	671.7	0.0	14.1	0.0	0.0	0.0	0.0	0.0	*1,249.0*
Commercial Thin with 140 sq. ft. Residual Basal Area	0.0	285.2	0.0	0.0	265.4	0.0	404.3	0.0	742.7	0.0	*1,697.6*
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	0.0	54.6	16.1	39.6	16.1	39.6	16.1	39.6	16.1	35.2	*273.0*
Total Acres	*0.0*	*1,176.8*	*909.2*	*39.6*	*519.8*	*39.6*	*648.5*	*39.6*	*945.1*	*35.2*	*4,353.4*

The amount of carbon associated with the live and dead wood, on-site and off-site, for the baseline is shown in Table 18. The project portion of Table 18 is explained in the next section but is presented here so the two may be viewed together for comparison. The landfill pool is not used for reductions calculations unless the baseline average exceeds the project pool, but it is always required to report it. Figure 20 and Figure 21 show the onsite and offsite baseline estimates for the 100 year planning period. The year 2010 is the only 5-year reporting with the rest being 10-year periods. When averaging the baseline only the 10-year periods were used.

Table 17: Tonnes per Acre of Carbon in the Baseline and Project Activity Projections for the McMullen Mountain Unit Forest Management Scenario

	Baseline									**Project**					
Year	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	FIA Live Tree Average	On-site Live and Dead C Baseline	On-site Live and Dead C Avg Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	Sum of On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	67.41	2.79	39.47	39.00	70.20	41.96	0.00	0.73	0.00	67.41	2.80	70.21	0.00	0.00	0.00
2010	31.16	2.72	39.47	39.00	33.89	41.96	4.79	0.73	0.77	65.24	2.75	67.98	0.76	0.76	0.12
2015	31.16	2.79	39.47	39.00	33.96	41.96	4.79	1.46	0.77	71.80	2.81	74.61	2.45	1.69	0.39
2025	43.46	3.14	39.47	39.00	46.60	41.96	7.59	1.46	1.22	69.35	3.13	72.49	2.83	0.38	0.45
2035	28.77	3.70	39.47	39.00	32.47	41.96	7.65	1.46	1.23	77.92	3.45	81.37	4.94	2.11	0.79
2045	37.60	3.69	39.47	39.00	41.29	41.96	9.20	1.46	1.48	79.16	3.71	82.87	5.27	0.33	0.84
2055	34.28	3.36	39.47	39.00	37.64	41.96	9.22	1.46	1.48	94.27	3.66	97.93	5.75	0.49	0.92
2065	44.54	3.37	39.47	39.00	47.90	41.96	11.86	1.46	1.90	97.73	3.98	101.71	6.08	0.33	0.98
2075	31.34	2.84	39.47	39.00	34.18	41.96	11.88	1.46	1.91	109.89	3.86	113.75	7.23	1.14	1.16
2085	42.12	3.29	39.47	39.00	45.41	41.96	14.40	1.46	2.31	101.95	3.79	105.74	7.49	0.26	1.20
2095	31.03	3.30	39.47	39.00	34.33	41.96	14.41	1.46	2.31	111.19	4.01	115.20	7.83	0.34	1.26
2105	42.49	3.15	39.47	39.00	45.64	41.96	14.55	1.46	2.34	109.42	4.04	113.47	7.91	0.08	1.27

Figure 20: McMullen Mountain Unit On-Site Baseline for Private Lands Forest Management Scenario

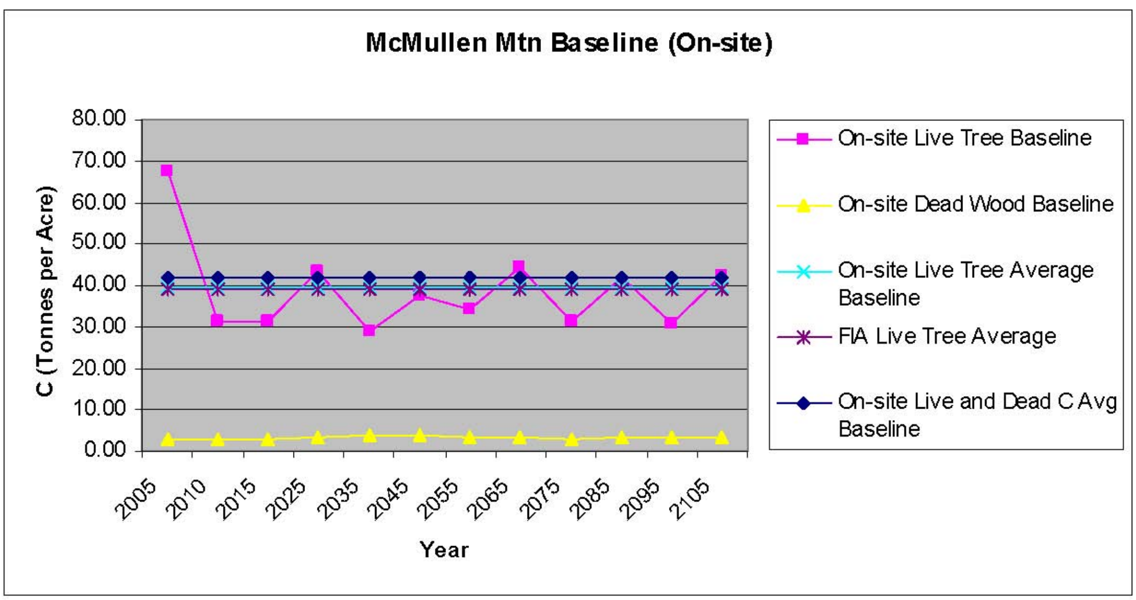
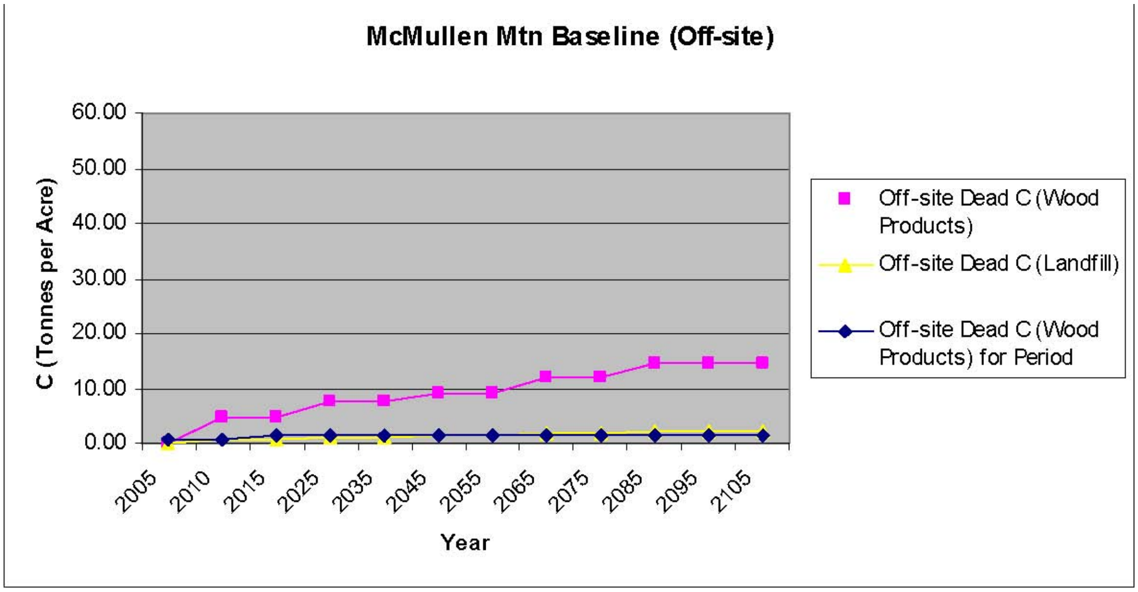


Figure 21: McMullen Mountain Unit Off-Site Baseline for Private Lands Forest Management Scenario



The results of the forest management baseline analysis were that the average on-site stocking was 39.47 tonnes of C per acre (97.5 tonnes C per hectare). Off-site wood products storage (based on 100 year storage in-use) increased over time and had an average over the period of 0.079 tonnes/acre/year C. This equated to a total of 11,257 thousand cubic feet (318,759 m^3) of timber over the 100 year period. Assuming six board feet per cubic foot, this equates to 67,541 MBF total or 567 board feet per acre per year over the 100 year period.

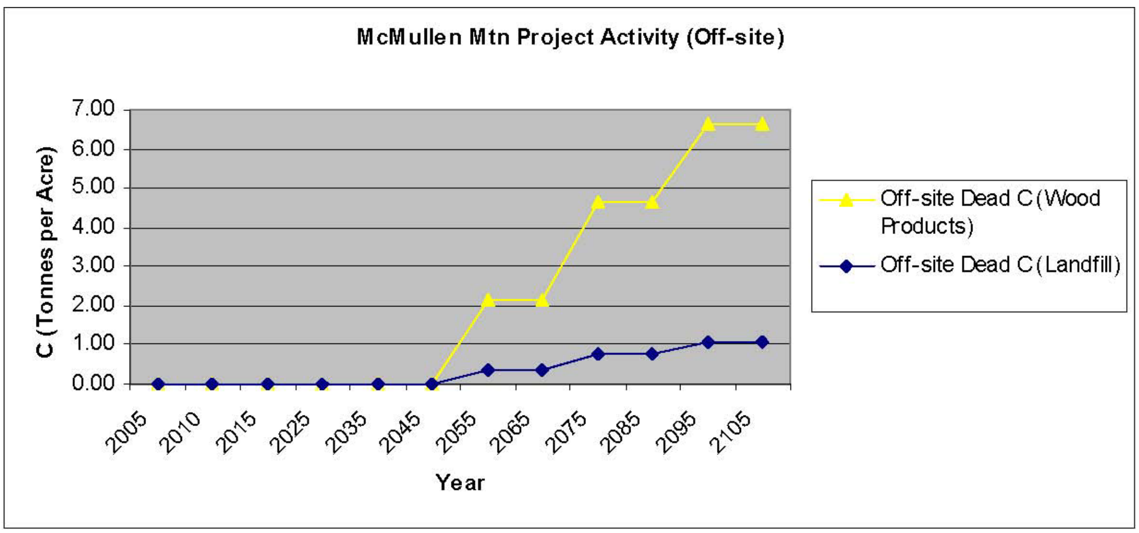
5.3 Project Activity Calculations

The project activity for the reforestation project type was modeled as a 10x10 foot spacing of 1-0 planted seedlings of a pine and fir mix, which resulted in 436 trees per acre (1,077 trees/h). Commercial thinnings from below leaving a residual basal area of 120 ft^2/ac (27.5 m^2/h) were simulated in 2050, 2070, and 2090. The result of the project activity was to increase on-site carbon stocks to 45.4 tonnes C per acre (112.1 t/h) after 100 years (Table 19). This is a substantially reduced projection of carbon stocks relative to the Sunset reforestation unit due to the site quality, which is 55 feet (16.8 m) high at base age 50 at McMullen relative to 110 feet (33.5 m) high at Sunset. The total wood products pool, Figure 22, projected over the 100 year period was 6.7 tonnes C per acre (16.5 t/h), which was 4.4 thousand cubic feet (MCF) per acre (305 m^3/h).

Table 18: Tonnes per Acre of Carbon in the Baseline and Project Activity Projections for the McMullen Unit Reforestation Scenario

	Baseline					Project					
Year	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	Sum of On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	14.60	0.00	14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2015	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2025	14.60	0.00	14.60	0.00	0.00	2.65	0.20	2.85	0.00	0.00	0.00
2035	14.60	0.00	14.60	0.00	0.00	19.20	2.50	21.70	0.00	0.00	0.00
2045	14.60	0.00	14.60	0.00	0.00	36.04	4.42	40.46	0.00	0.00	0.00
2055	14.60	0.00	14.60	0.00	0.00	29.58	4.42	34.00	2.13	2.13	0.34
2065	14.60	0.00	14.60	0.00	0.00	43.64	4.42	48.06	2.13	0.00	0.34
2075	14.60	0.00	14.60	0.00	0.00	33.93	4.42	38.36	4.64	2.50	0.74
2085	14.60	0.00	14.60	0.00	0.00	44.68	3.55	48.23	4.64	0.00	0.74
2095	14.60	0.00	14.60	0.00	0.00	37.39	2.82	40.21	6.66	2.02	1.07
2105	14.60	0.00	14.60	0.00	0.00	45.39	2.82	48.20	6.66	0.00	1.07

Figure 22: Reforestation Project Activity Projections of Off-Site Dead Wood Pools for McMullen Reforestation Project



The project activity for the forest management project type was projected using the stand level treatments identical to the long-term harvest schedule approved by the State of California under 14 CCR 933.11(a), also known as an option a plan. Table 20 shows the silvicultural prescriptions. The modeling was done using a stand level projection of treatments over a 100 year period that was then summarized across the Forest. Adjustments were made to some stands to meet regulatory requirements for long-term planning. The overall goal was to move over-mature stands to younger age classes over time to create a balance of stand ages. Dead wood was modeled using the mortality functions of FVS with an assumed decay rate of 10 percent per year. The silvicultural prescriptions for the proposed project activity use substantially less intensive management and harvest far fewer acres over the 100 year period.

The results of the C stocking may be seen in Table 18 under Project. Notice that there is a small near-term decrease in carbon stocks, which is a reflection of the near-term harvesting that has occurred in this unit as per the existing harvest schedule. An approximate 20-year cutting cycle is implemented on LDSF. This will have an effect on the reductions calculation that is shown below, but because the starting stocks are well above the FIA mean the effect will not be nearly as severe as was the case with the Sunset unit.

Table 19: Acres of Silvicultural Prescriptions for the Project Activity Simulation of the McMullen Mountain Unit for Private Lands Forest Management

Year Treatment	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	*Total Acres*
Clearfell (Group Selection and Clearcut)	30.4	193.2	30.3	180.5	30.1	29.4	30.7	75.0	14.2	14.1	*627.9*
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	0.0	4.4	0.0	10.3	0.0	0.0	0.0	0.0	0.0	*14.7*
Commercial Thin with 140 sq. ft. Residual Basal Area	84.8	0.0	59.6	42.9	77.0	42.9	81.8	42.9	102.8	65.4	*600.1*
Commercial Thin with 160 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	0.0	0.0	*22.5*
Single Tree Selection with 70% Basal Area Retention	42.5	0.0	81.8	0.0	14.1	0.0	0.0	0.0	0.0	0.0	*138.4*
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	55.7	0.0	16.1	42.5	16.1	42.5	16.1	42.6	16.1	38.1	*285.8*
Total Acres	*213.4*	*193.2*	*192.2*	*265.9*	*147.6*	*114.8*	*128.6*	*183.0*	*133.1*	*117.6*	*1,689.4*

The result of the project activity projection was to increase on-site carbon stocks from an average of 67.41 tonnes/acre (166.5 tonnes/hectare) to 109.42 tonnes/acre (270.3 tonnes/hectare) at the end of the 100 year period. Off-site wood products storage grew to 7.91 tonnes/acre C (19.5 t/h), which was 46 percent less than the 14.55 tonnes/acre C

(35.9 t/h) in the baseline. The harvest was projected to total 6,118 MCF (173,251 m^3) of timber over the 100 year period. Figure 23 and Figure 24 show the project activity for the onsite and offsite carbon over time.

Figure 23: McMullen Mountain Unit On-Site Project Activity for the Forest Management Project Type

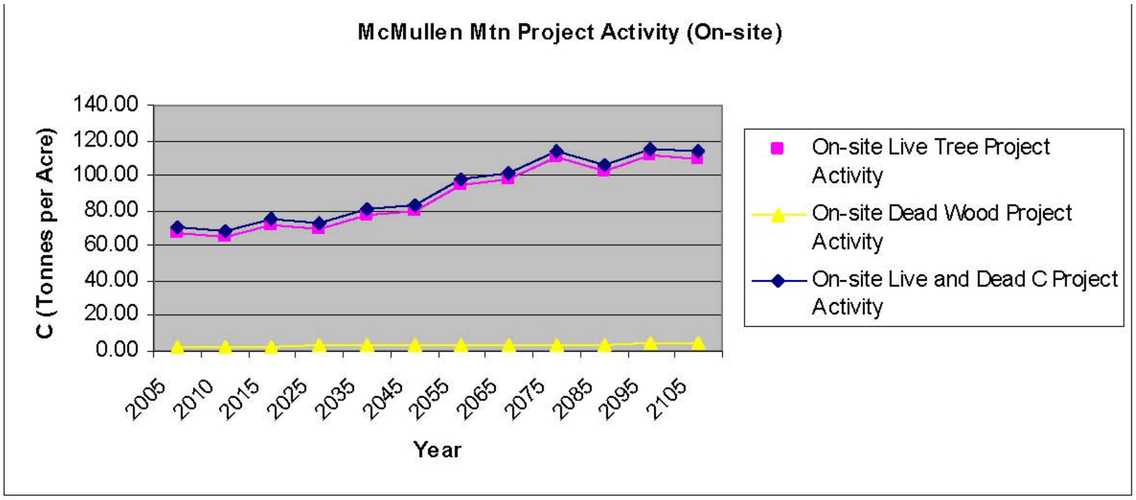
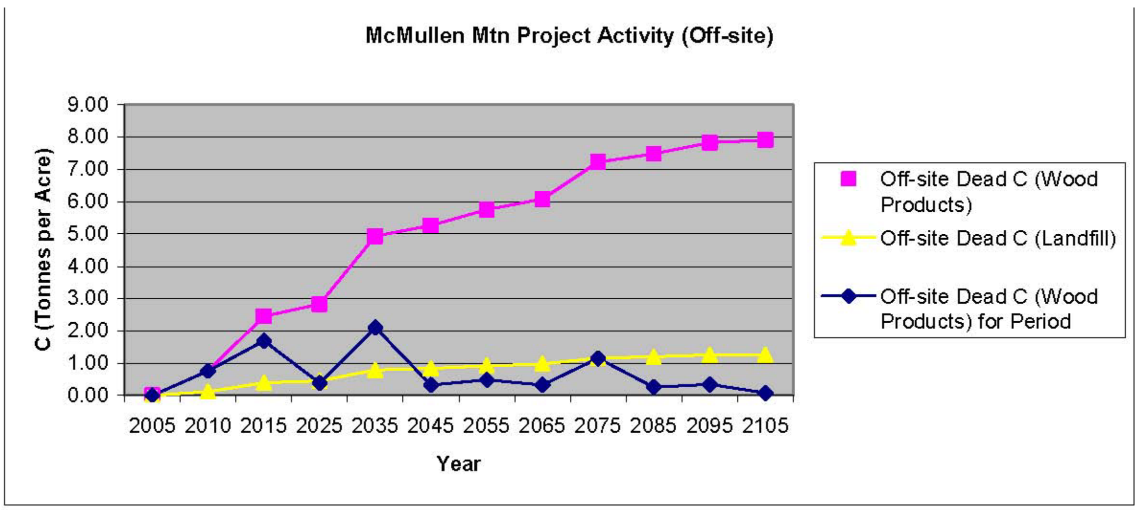


Figure 24: McMullen Mountain Unit Off-Site Project Activity for the Forest Management Project Type



5.4 Gross Biological Reductions

The difference between the project activity and baseline projections is the gross reduction, which is shown in Table 21 and Table 22 for the 100 year planning period and the two project types. Figure 25 and Figure 26 show the gross reductions and the smoothed reductions whereby a reversal due to near-term harvests does not occur. For example, if 100 CRTs were created in decade 2 but due to harvest cycles there were 10 CRTs in decade 3, then only 90 CRTs would be claimed for decade 2. This leads to an estimate of the decadal gross new CRTs, before any deductions for inventory precision, permanence or leakage.

Table 20: Tonnes of Carbon per Acre in the Gross Reductions before Deductions, Deductions, and Net Reductions; for the McMullen Mountain Unit Reforestation Scenario

	Gross Reductions						Deductions			Net Reductions			
Year	On-Site Reductions	Off-site Dead C Reductions (Wood Products)	Sum of On and Off-site Reductions	Total Marginal Reductions	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	-11.75	0.00	-11.75	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2035	7.10	0.00	7.10	4.25	7.10	7.10	0.00	0.00	1.42	5.68	5.68	1.42	1.42
2045	25.86	0.00	25.86	21.61	21.54	14.43	0.00	0.00	2.89	11.55	17.23	2.89	4.31
2055	19.40	2.13	21.54	-0.07	21.54	0.00	0.00	0.00	0.00	0.00	17.23	0.00	4.31
2065	33.46	0.00	35.60	35.67	28.40	6.86	0.00	0.00	1.37	5.49	22.72	1.37	5.68
2075	23.76	2.50	28.40	-7.27	28.40	0.00	0.00	0.00	0.00	0.00	22.72	0.00	5.68
2085	33.63	0.00	38.27	45.54	32.26	3.87	0.00	0.00	0.77	3.09	25.81	0.77	6.45
2095	25.61	2.02	32.26	-13.28	32.26	0.00	0.00	0.00	0.00	0.00	25.81	0.00	6.45
2105	33.60	0.00	40.26	53.54	40.26	8.00	0.00	0.00	1.60	6.40	32.21	1.60	8.05

Figure 25: Reforestation, McMullen Mountain Unit Gross Reductions and CRTs

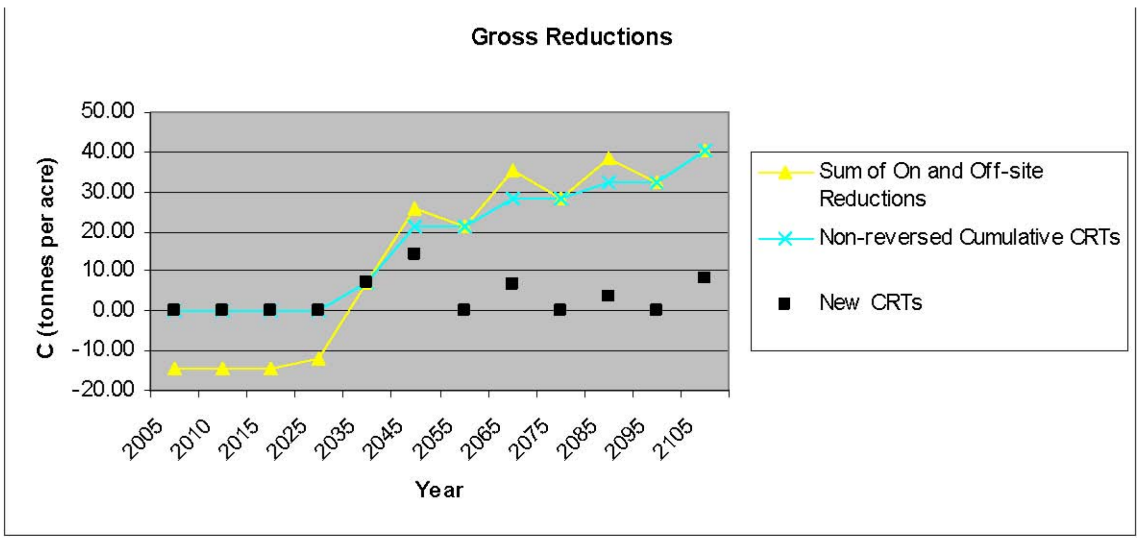
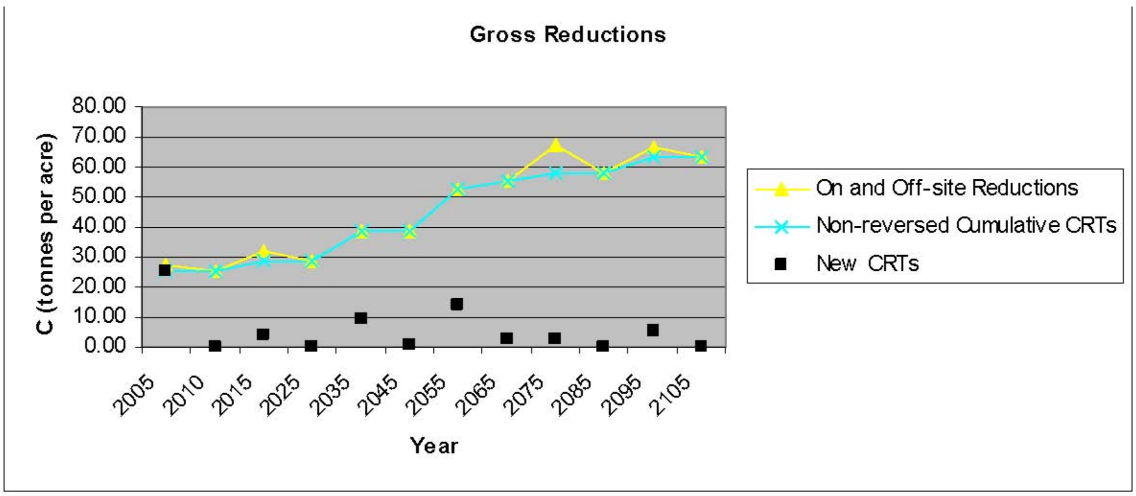


Table 21: Tonnes of Carbon per Acre in the Gross Reductions before Deductions, Deductions, and Net Reductions; for the McMullen Mountain Unit Forest Management Scenario

	Gross Reductions						Deductions			Net Reductions			
Year	On-Site Reductions	Off-site Dead C Reductions (Wood Products)	On and Off-site Reductions	Total Marginal Reductions	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	28.25	-0.73	27.52	27.52	25.33	25.33	-0.24	0.00	4.56	20.53	20.53	4.56	4.56
2010	26.02	0.03	25.33	-2.20	25.33	0.00	-0.24	0.00	0.00	0.00	20.53	0.00	4.56
2015	32.65	0.24	32.19	34.38	28.99	3.67	-0.47	0.00	0.66	2.53	23.06	0.66	5.22
2025	30.53	-1.07	28.99	-5.39	28.99	0.00	-0.47	0.00	0.00	0.00	23.06	0.00	5.22
2035	39.41	0.65	38.53	43.92	38.53	9.54	-0.47	0.00	1.72	7.35	30.41	1.72	6.94
2045	40.92	-1.13	38.90	-5.02	38.90	0.37	-0.47	0.00	0.07	0.00	30.41	0.00	6.94
2055	55.97	-0.97	52.99	58.01	52.99	14.09	-0.47	0.00	2.54	11.08	41.49	2.54	9.47
2065	59.75	-1.12	55.64	-2.36	55.64	2.65	-0.47	0.00	0.48	1.70	43.19	0.48	9.95
2075	71.79	-0.31	67.38	69.74	58.17	2.52	-0.47	0.00	0.45	1.60	44.79	0.45	10.40
2085	63.78	-1.19	58.17	-11.57	58.17	0.00	-0.47	0.00	0.00	0.00	44.79	0.00	10.40
2095	73.24	-1.11	66.52	78.09	63.41	5.24	-0.47	0.00	0.94	3.83	48.61	0.94	11.35
2105	71.51	-1.38	63.41	-14.68	63.41	0.00	-0.47	0.00	0.00	0.00	48.61	0.00	11.35

Figure 26: Forest Management, McMullen Mountain Unit Gross Reductions and CRTs



5.5 Permanence Analysis

This is a risk analysis with the details provided in appendix D of the protocol. The analysis is identical for the reforestation and improved forest management project types.

Financial Risk: The financial risk for this private lands scenario assumes a PIA only and no conservation easement, which requires a 5 percent buffer contribution.

Management Risk: Management risk consists of three types of risks. Illegal removals are given a 0 percent risk for property in the United States. Conversion to an alternate land use is a function of whether development rights are encumbered by an easement or deed restriction, which is not the case here, incurring a 2 percent deduction. Overharvesting is the final management risk and is also a function of having a legal restriction on harvesting, which is not the case here and therefore incurs a 2 percent deduction.

Social Risk: This is a flat 2 percent for the United States.

Natural Disturbance Risk: There are three components to this risk category. Wildfire risk is a function of fire frequency and burn severity, which may be reduced using specified categories of fuels treatment activity. Default values will be given in Appendix F of the protocols for the assessment areas, but are not yet provided. In this case the risk is given as 1 percent. This is less frequent than the Sunset unit and is based on the location of the unit at a higher elevation centered on McMullen Mountain where ridge top fire lines would increase the probability of halting fire spread. While shaded fuel breaks are planned and the treatments that occurred as part of this project provide tie-in points for that break, it does not yet constitute a large enough percentage on the landscape to merit a deduction in risk.

Disease or insect outbreak is given a blanket 3 percent risk rating. Other episodic catastrophic events are given a default value of 3 percent. The total permanence risk deduction is 18 percent, Table 23.

Table 22: Risk Deductions for the McMullen Mountain Unit, Private Lands Forest Management Scenario

Risks	Deduction
Financial	5.0%
Management	4.0%
Social	2.0%
Natural Dist.	7.0%
Total	18.0%

5.6 Leakage Analysis

The leakage analysis is also referred to as secondary effects analysis and is covered in section 6.2.6 of the protocol for forest management project types. A leakage analysis is conducted each year based on actual harvest relative to the modeled average baseline harvest. If the total harvest level is reduced in the project activity relative to the baseline then 20 percent of the difference is the reduction applied to the carbon reductions. The value is provided on an annual and per acre basis. Table 24 shows the effect for the McMullen Mountain unit forest management scenario, which is 0.05 tonnes per acre per year.

Table 23: Secondary Effects (SE) for McMullen Mountain Unit, Private Lands Forest Management Scenario. Units are in Tonnes of C

Project Harvested	33,582.21
Baseline Harvested	61,786.94
Gross Total Effect	28,204.73
Secondary Effect	5,640.95
Annual SE	-56.41
Annual SE (per acre)	-0.05

For the reforestation project type the secondary effects are specified in Table 6.1 of the protocol, mobile combustion emissions for reforestation projects, and are a function of three categories of brush cover. We used the heavy category and converted the CO_2 to C to keep the units consistent at this stage of the analysis. This resulted in a one-time secondary effect of 0.12 tonnes per acre (0.3 t/h) of C that is applied the first year and carries over until there are CRTs to deduct it from.

5.7 Net Biological Reductions

The three types of deductions are shown in Table 21 and Table 22 as is the resulting net reductions and buffer contributions. Figure 27 and Figure 28 illustrate the resulting marketable CRTs and the buffer pool over the project period. For the forest management project type there is a substantial salable amount of CRTs immediately with substantial amounts also in 2035 and 2065. The reforestation project type is similar to the Sunset reforestation project at a lower level and a decade later, on a per acre basis, with a large amount of CRTs available in 2045 and beginning in 2035.

Figure 27: Net CRTs and Buffer Pool Contributions for the McMullen Mountain Unit, Reforestation

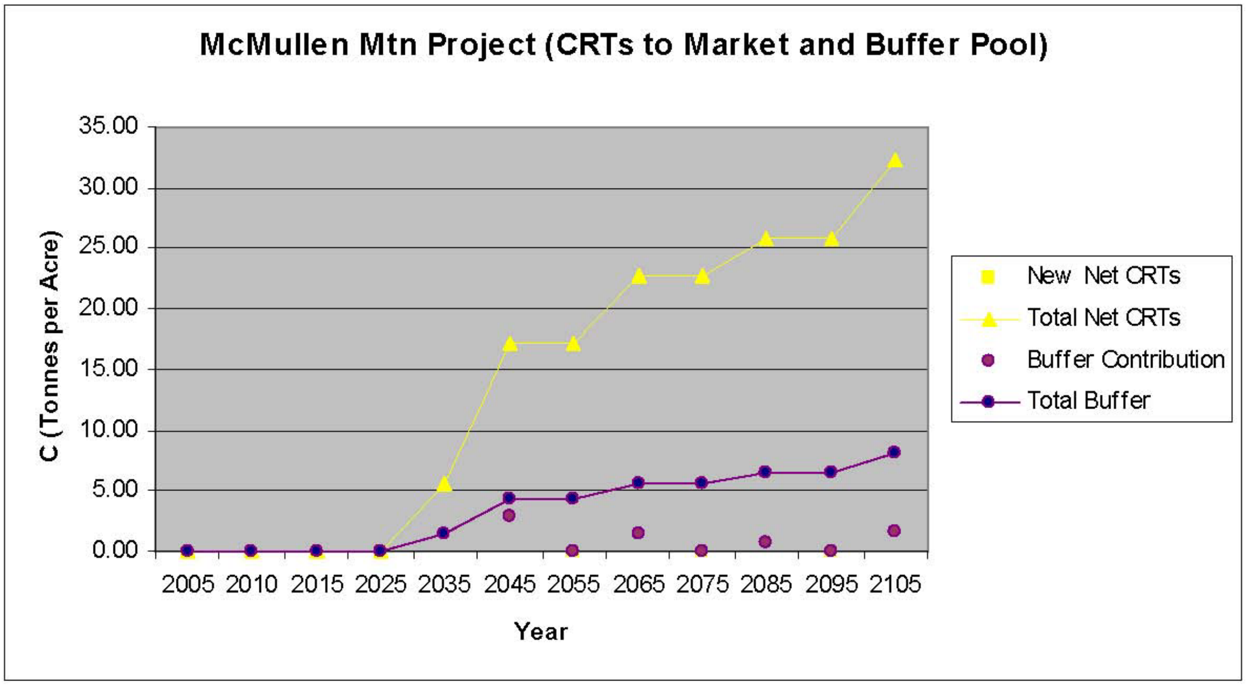
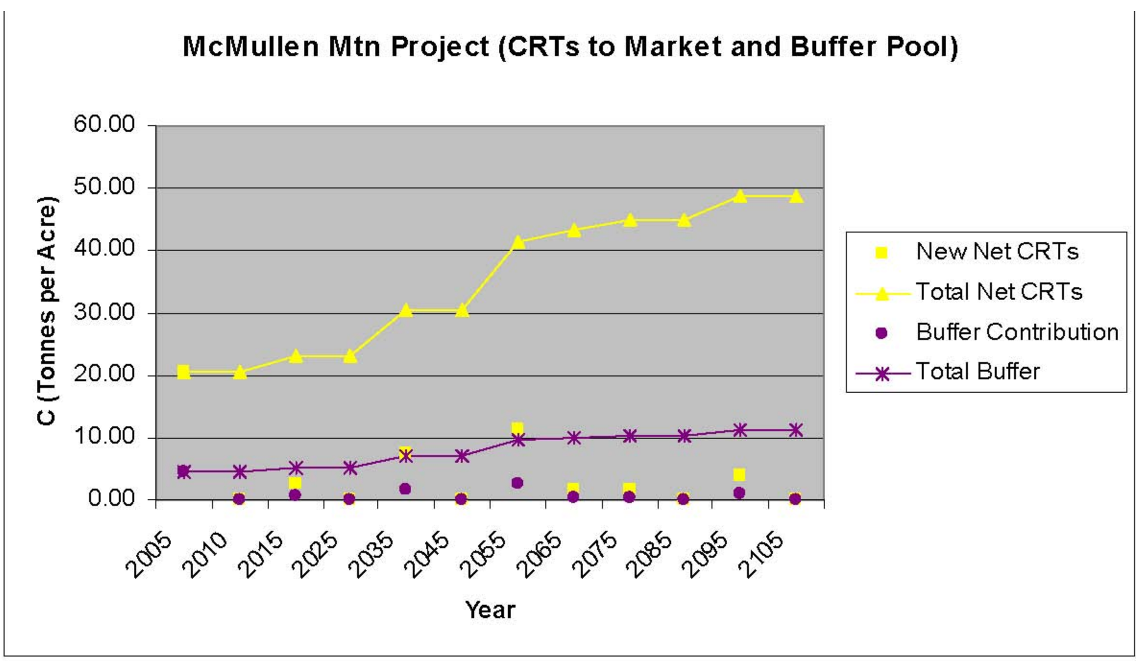


Figure 28: Net CRTs and Buffer Pool Contributions for the McMullen Mountain Unit, Forest Management



Over the 100 year life of this project the off-site long-term wood products contribution to salable gross CRTs was 8.1 tonnes per acre for the forest management type. The amount is negative because more wood products were produced in the baseline than in the project activity. There is also a reduction for this in the secondary effects calculation. The effect of the 8.1 tonne reduction from long-term wood product storage was about 13 percent of the total gross reductions. For the reforestation project type, projected wood products contribution to the total CRTs products was only 4.5 percent.

CHAPTER 6:
McMullen Project GHG Analysis: Public Land Scenario

Projects are allowed on public lands for the first time with version 3 of the protocols. There is a requirement that the project be approved by the managing agency and that U.S. Congressional approval for carbon projects to be in place for federal lands. In this case we will use LDSF as it is, a demonstration state forest. In this case the approval for a project rests with the California Department of Forestry and Fire Protection (CAL FIRE) under a management plan approved by the California Board of Forestry and Fire Protection. CAL FIRE, as the forest manager, would have to decide to implement the project.

The project activity and baseline for a public lands reforestation project are the same as for a private lands project. Refer to the private lands scenario for reforestation presented earlier for the baseline, project activity and projected reductions. There are some differences to the buffer pool contribution from the risk analysis. The financial risk is 1 percent instead of 5 percent, conversion risk is 0 percent rather than 2 percent, and overharvesting risk is 0 percent rather than 2 percent. This results in a buffer contribution that is 10 percent for a public land project, reduced from 18 percent for the private lands project, Table 25. Table 26 shows the net reductions for the project.

Table 24: Risk Deductions for the McMullen Mountain Unit, Public Lands Reforestation Scenario.

Risks	Deduction
Financial	1.0%
Management	0.0%
Social	2.0%
Natural Dist.	7.0%
Total	10.0%

Table 25: Tonnes of carbon in the Gross Reductions Before Deductions, Deductions, and Net Reductions; for the McMullen Mountain Unit Reforestation Public Lands Scenario

	Gross Reductions						Deductions			Net Reductions			
Year	On-Site Reductions	Off-site Dead C Reductions (Wood Products)	On and Off-site Reductions	Total Marginal Reductions	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	-11.75	0.00	-11.75	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2035	7.10	0.00	7.10	4.25	7.10	7.10	0.00	0.00	0.71	6.39	6.39	0.71	0.71
2045	25.86	0.00	25.86	21.61	21.54	14.43	0.00	0.00	1.44	12.99	19.38	1.44	2.15
2055	19.40	2.13	21.54	-0.07	21.54	0.00	0.00	0.00	0.00	0.00	19.38	0.00	2.15
2065	33.46	0.00	35.60	35.67	28.40	6.86	0.00	0.00	0.69	6.17	25.56	0.69	2.84
2075	23.76	2.50	28.40	-7.27	28.40	0.00	0.00	0.00	0.00	0.00	25.56	0.00	2.84
2085	33.63	0.00	38.27	45.54	32.26	3.87	0.00	0.00	0.39	3.48	29.04	0.39	3.23
2095	25.61	2.02	32.26	-13.28	32.26	0.00	0.00	0.00	0.00	0.00	29.04	0.00	3.23
2105	33.60	0.00	40.26	53.54	40.26	8.00	0.00	0.00	0.80	7.20	36.23	0.80	4.03

The improved forest management project type for public lands has a baseline characterization that is different from private lands. The initial inventory is to be projected for 100 years by extrapolating from historical trends and anticipating how current and future public policy will affect onsite carbon stocks. Trends for the last ten years have been for increasing stocks, which then requires that stands free of harvest for 60 years be used as a guide. Policy on state forests is to maximize timber yields, which implies operating near culmination of mean annual increment, to use an even-aged indicator. Considering that this baseline scenario will likely be near the project activity scenario, there is little or no biological reduction to be realized from a public lands scenario on LDSF. Therefore, this scenario will not be analyzed further.

CHAPTER 7: Economic Analysis

This section provides costs and revenue estimates, provides a spreadsheet tool to evaluate the economics of the reforestation and improved forest management project types using these projects as examples, and shows the economic feasibility of these projects. The CVal spreadsheet program (Bilek et al. 2009), originally developed for Chicago Climate Exchange (CCX) forestry protocols, was adapted for the CAR forestry protocols, version 3.1.

7.1 Costs of the Projects

Project costs for the two project areas, forest management and reforestation are shown in Table 27 through Table 30. These tables are taken directly from the modified CVal spreadsheet (Bilek et al. 2009). Many of these costs will vary substantially from project to project and will depend on if an acceptable inventory already exists, the size of the project and whether aggregating with other landowners. The reforestation projects assume a $600 per acre site preparation, planting and competing vegetation treatment cost. The verification costs were set at a fixed cost of $10,000 plus a variable cost of $0.50 per acre. The periodic inventory costs for the smaller reforestation projects were set at a fixed cost of $500 plus a variable cost of $30 per acre. The larger improved forest management periodic inventories were set at a $1,000 fixed cost and $20 per acre. The periodic inventory and verification costs are assumed to be every 6 years. Annual reporting requires third party verifier review and is estimated at $1,500 per year for the larger projects and $200 for the smaller reforestation projects.

A total initial cost estimate for the Sunset improved forest management was $20,520 assuming an inventory and management plan that included baseline and project activity characterization was needed. The McMullen Mountain improved forest management total initial cost was $35,840 with the same assumptions. The Sunset and McMullen Mountain reforestation projects initial costs were $7,120 and $12,400, respectively.

Table 26: Sunset Improved Forest Management Costs

Tract size	426	acres	Initial inventory cost	$ 9,520	per tract
Year 1 carbon sequestration rate	-	tonnes CO_2e/ac/yr	Management plan cost	$ 10,000	per tract
Sequestration rate is…	**Variable**	*Fill in rates in table below.*	Other up-front costs	$ 1,000	per tract
Carbon reserve pool factor	10%		Contract year (Year that up-front costs occur)	1	(counter year)
Initial carbon price	$ 9.00	per tonne CO_2e	Periodic verification cost	$ 10,213	per tract
Carbon price is…	**Constant**		Periodic inventory cost	$ 9,520	per tract
Aggregator's fee	0%		End of project costs	$ 1,000	per tract
Annual reporting cost	$ 1,500.00	per tonne CO_2e	Hurdle rate	5.0%	
Trading fee	$ 0.20	per tract	Finance rate	5.0%	
Other annual costs	$ 1.00	per tonne CO_2e	Count pre-contract carbon?	No	
Up-front costs sensitivity factor	0%		End-of-project year	2104	
Annual costs sensitivity factor	0%				
End-of-project costs sensitivity factor	0%		Total up-front costs	$ 20,520	per tract
Periodic costs sensitivty factor	0%		Total end-of-project costs	$ 1,000	per tract

Table 27: McMullen Mountain Improved Forest Management Costs

Tract size	1,192	acres	Initial inventory cost	$ 24,840	per tract
Year 1 carbon sequestration rate	-	tonnes CO_2e/ac/yr	Management plan cost	$ 10,000	per tract
Sequestration rate is…	**Variable**	*Fill in rates in table below.*	Other up-front costs	$ 1,000	per tract
Carbon reserve pool factor	10%		Contract year (Year that up-front costs occur)	1	(counter year)
Initial carbon price	$ 9.00	per tonne CO_2e	Periodic verification cost	$ 10,596	per tract
Carbon price is…	**Constant**		Periodic inventory cost	$ 24,840	per tract
Aggregator's fee	0%		End of project costs	$ 1,000	per tract
Annual reporting cost	$ 1,500.00	per tonne CO_2e	Hurdle rate	5.0%	
Trading fee	$ 0.20	per tract	Finance rate	5.0%	
Other annual costs	$ 1.00	per tonne CO_2e	Count pre-contract carbon?	No	
Up-front costs sensitivity factor	0%		End-of-project year	2104	
Annual costs sensitivity factor	0%				
End-of-project costs sensitivity factor	0%		Total up-front costs	$ 35,840	per tract
Periodic costs sensitivty factor	0%		Total end-of-project costs	$ 1,000	per tract

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Table 28: Sunset Reforestation Costs

Tract size		10	acres	Initial inventory cost	$ -	per tract
Year 1 carbon sequestration rate		-	tonnes CO_2e/ac/yr	Management plan cost	$ -	per tract
Sequestration rate is…		**Variable**	*Fill in rates in table below.*	Other up-front costs	$ 7,120	per tract
Carbon reserve pool factor		10%		Contract year (Year that up-front costs occur)	1	(counter year)
Initial carbon price	$	9.00	per tonne CO_2e	Periodic verification cost	$ 10,005	per tract
Carbon price is…		**Constant**		Periodic inventory cost	$ 806	per tract
Aggregator's fee		0%		End of project costs	$ 1,000	per tract
Annual reporting cost	$	200.00	per tonne CO_2e	Hurdle rate	5.0%	
Trading fee	$	0.20	per tract	Finance rate	5.0%	
Other annual costs	$	1.00	per tonne CO_2e	Count pre-contract carbon?	No	
Up-front costs sensitivity factor		0%		End-of-project year	2104	
Annual costs sensitivity factor		0%				
End-of-project costs sensitivity factor		0%		Total up-front costs	$ 7,120	per tract
Periodic costs sensitivty factor		0%		Total end-of-project costs	$ 1,000	per tract

Table 29: McMullen Mountain Reforestation Costs

Tract size		19	acres	Initial inventory cost	$ -	per tract
Year 1 carbon sequestration rate		-	tonnes CO_2e/ac/yr	Management plan cost	$ -	per tract
Sequestration rate is…		**Variable**	*Fill in rates in table below.*	Other up-front costs	$ 12,400	per tract
Carbon reserve pool factor		10%		Contract year (Year that up-front costs occur)	1	(counter year)
Initial carbon price	$	109.69	per tonne CO_2e	Periodic verification cost	$ 10,010	per tract
Carbon price is…		**Constant**		Periodic inventory cost	$ 1,070	per tract
Aggregator's fee		0%		End of project costs	$ 1,000	per tract
Annual reporting cost	$	200.00	per tonne CO_2e	Hurdle rate	5.0%	
Trading fee	$	0.20	per tract	Finance rate	5.0%	
Other annual costs	$	1.00	per tonne CO_2e	Count pre-contract carbon?	No	
Up-front costs sensitivity factor		0%		End-of-project year	2104	
Annual costs sensitivity factor		0%				
End-of-project costs sensitivity factor		0%		Total up-front costs	$ 12,400	per tract
Periodic costs sensitivty factor		0%		Total end-of-project costs	$ 1,000	per tract

7.2 Carbon and Timber Revenues

This analysis only considers the carbon revenues in the financial analysis and does not include timber revenues, which may be added in as an additional analysis. In fact, if timber revenues are forgone or delayed, there may be significant costs and therefore reductions in net present value. Two CO_2 prices were considered, the current prevailing over the counter price for voluntary market CAR project CRTs of $9.00/tonne and a realistic long-term compliance CRT price of $20.00/tonne. There is an assumed 10 percent holdback in addition to required buffer pools since this is common practice in over the counter (OTC) voluntary transactions.

7.3 Direct Benefits of the Four Scenarios

A 5 percent hurdle rate is assumed. Neither of the reforestation projects produced a positive NPV at $9.00/t or at $20.00/t. The Sunset improved forest management project, at $9.00/t, produced a positive NPV of $27,500, which was $64.55/acre ($159.45/h). At $20.00/t, the Sunset forest management project produced a NPV of $167,585 or $393.39/acre ($971.68/h). The McMullen Mountain improved forest management project had initial carbon stocks well above the FIA mean so there were immediate CRTs produced. This resulted in a NPV, at $9.00/t, of $735,235, which was $616.81/acre ($1,523.52/h). At the $20.00/t price the NPV was $1,830,926 or $1,536.01/acre ($3,793.95/h).

7.4 Sensitivity Analysis

The carbon price was varied to determine the breakeven point for the four project scenarios. The Sunset reforestation project required a price of $68.88/t CO_2 to break even. The McMullen Mountain reforestation project required a price of $109.69/t CO_2 to break even. The difference in price is due to the lower site productivity of the later unit, which results in lower and later CRTs.

The break even CRT price for the Sunset improved forest management project was $6.85/t. The McMullen Mountain forest management project had a breakeven price of $1.62/t. The improved forest management projects were much more lucrative due to not having the large upfront costs the reforestation entails and because CRTs may be realized earlier. Where timber is a competing income stream to carbon the timber values associated with the carbon project activity versus the baseline scenario could be computed to determine the optimum mix of commodities. This could be analyzed for different costs and revenue points.

CHAPTER 8: Fuels Treatment Analysis

The impact of fuels treatments on the carbon accounting of the treated and surrounding stands is an area of current research and policy debate. Version 3 of the CAR protocols acknowledges the utility of fuel treatments on the landscape by providing a risk reduction for different treatment categories of none, low, medium and high, which are not quantitatively defined. These can reduce the annual probability of the fire multiplier by 0 percent, 17.4 percent, 33.6 percent, and 50 percent respectively. For example, a return interval of 10 years would produce an annual probability of fire of 10 percent. With no treatments this would remain a 10 percent deduction. A high level of treatments would reduce it by one half so that a 5 percent risk deduction would apply. Risk is defined by the protocols (appendix D.4) as the annual probability of occurrence. This may not match other definitions of risk that multiply the probability of occurrence by the biomass lost, which is a function of burn severity.

This section simulates the planned implementation of a shaded fuel break that ties in with the treatments implemented as part of this project, Figure 4. The fire break runs along a ridge from the Sunset unit generally east to the top of McMullen Mountain and then down to treatment areas to the northeast, Figure 1. Pre and post fire simulations are performed and assumptions are made about the benefits of risk reduction for neighboring stands. The carbon benefits are then estimated. This analysis is separate from the current forestry protocols and is intended to assist the discussion around the carbon benefits of fuel treatments in forested landscapes.

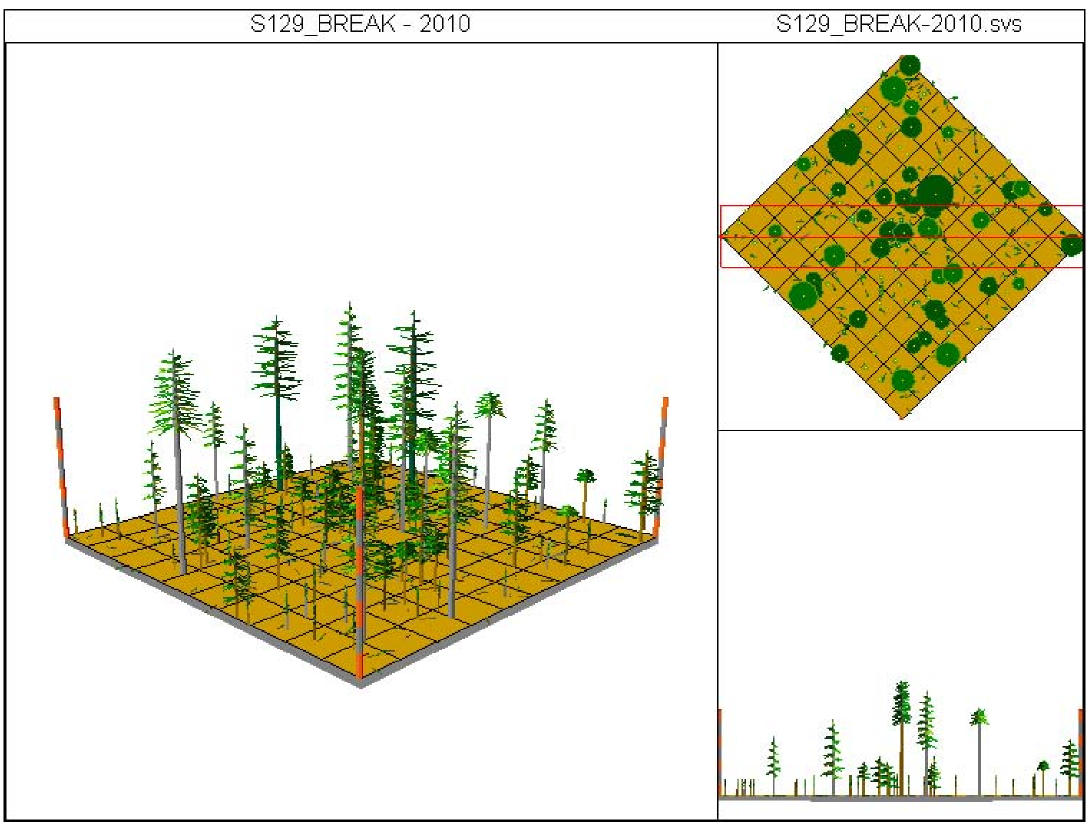
8.1 Fuel Treatments

The proposed shaded fuel break on LDSF will be 300 feet in width, retain a post-harvest basal area of 50 ft^2/acre (11.5 m^2/h), and reduce ground and ladder fuels. Table 31 shows the stands that are part of the shaded fuel break, which total 75 acres (30 hectares). Pre and post treatment conditions are shown. These are in addition to the units treated as part of the reforestation and improved forest management. An example depiction of a treatment is shown in Figure 29. This shows the thinning of the trees, but the ground fuels are also reduced by either piling and burning or chipping and hauling to a biomass plant. We are assuming here that the understory is piled and burned because current market conditions do not allow for hauling from LDSF to a biomass facility. The pre and post-harvest condition was matched to the most appropriate fuel model, Table 31, for fire behavior simulation.

Table 30: Summary of Stands in the Proposed Shaded Fuel Break

			Pre-Treatment						Post-Treatment				
Stand	Acres	WHR Class	Trees per Acre	Basal Area (sq. ft./ac.)	Quadratic Mean Diameter (inches)	Fuel model (Photo series)	Fuel model (FB-Model 2005)	Fuel Load, Biomass (tons/ac)	Trees per Acre	Basal Area (sq. ft./ac.)	Fuel model (Photo series)	Fuel model (FB-Model 2005)	Fuel Load, Biomass (tonnes/ac)
STAND_105_BREAK	13.9	WFR4D	117.7	236	19.2	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	36.1	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_106	2.2	WFR4D	179.5	177	14.7	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	43.2	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_118_BREAK	2.7	WFR4D	108	216	19.2	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	22.7	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_123_BREAK	1.8	WFR4M	44.7	65	16.4	PNW-95/1-TF-4-PC True Fir, size class 4, partial cut	TL01	17.6	28.2	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_155	5.5	WFR4D	117.7	236.01	19.2	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	22.9	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_156	14.1	KMC4M	141.1	127.2	12.9	PNW-95/3-MC-4-PC Mixed Conifer, size class 4, partial cut	TL01	28.6	47.9	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_158	5.9	KMC4M	67.4	94.2	16	PNW-95/3-MC-4-PC Mixed Conifer, size class 4, partial cut	TL01	28.6	32.2	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_164_BREAK	1.8	KMC4D	159.9	271.7	17.7	PNW-95/4-MC-4-PC Mixed Conifer, size class 4, partial cut	TL07	38.2	26.7	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_390_BREAK	7.8	KMC4D	111.7	186.6	17.5	PNW-95/4-MC-4-PC Mixed Conifer, size class 4, partial cut	TL07	38.2	27.3	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
S129_BREAK	19.1	KMC2P	314.57	50.62	5.4	PNW-105/1-PP-1 Ponderosa pine, size class 1, natural	TL-08	10	116.66	50	PNW-52/4-PP-1-TH Ponderosa pine, size class 1, thinned, assume pile and burn slash	TL07	2.7

Figure 29: Stand 129 Shaded Fuel Break in 2010 Showing Removal of Small Trees



8.2 Fire Simulations in Treated Stands

Fire behavior was simulated using Fuels Management Analyst Plus version 3 (FMA 2009). The FVS tree list files for each of the stands were input directly into FMA. Weather conditions for the categories of moderate, high and extreme were derived from local RAWS stations using Fire Family Plus version 4 (Bradshaw and Brittain 2008) from the ten year period 1999-2008. The fire weather categories for LDSF are shown in Table 32. Burning index was used as the parameter to determine the fire weather categories. Moderate weather has a 75 percent climatological probability, high severity weather a 7 percent probability and extreme a 3 percent probability. This probability covers the fire season, which is defined as May 1 to October 31.

Table 31: Fire Weather for LDSF

		Condition Category		
		Moderate	High	Extreme
Fuel Moisture (percent)	1-hour dead	4.86	3.31	2.86
	10-hour dead	6.12	4.31	3.81
	100-hour dead	10.08	7.56	7.45
	1000-hour dead	12.11	9.31	8.85
	Herbaceous live	11.56	3.49	2.86
	Woody live	81.77	72.19	70.41
Wind (mph)	20-foot wind speed	4	5.84	6.83

Figure 30: Profile of the Crown Density of a Stand

		Condition Category		
		Moderate	High	Extreme
Fuel Moisture (percent)	1-hour dead	4.86	3.31	2.86
	10-hour dead	6.12	4.31	3.81
	100-hour dead	10.08	7.56	7.45
	1000-hour dead	12.11	9.31	8.85
	Herbaceous live	11.56	3.49	2.86
	Woody live	81.77	72.19	70.41
Wind (mph)	20-foot wind speed	4	5.84	6.83

Figure 30 shows a profile of the crown density of a stand. FMA is sensitive to ground and canopy fuel interactions, which I ideal for analyzing the effects of fuel treatments. Table33 through Table 35 show the results of the modeling for the moderate, high and extreme weather conditions. In general, both treated and untreated stands were surface fires with little or no crown scorching or tree mortality, with the exception being the small tree stand 129. The primary benefit of the treatments was to decrease the rate of spread in many of the stands. Given that the 300 foot width is 4.5 chains (one chain is 66 feet) and the maximum fire spread is reduced from 3.2 to 1.7 chains per hour under extreme weather conditions, this allows more than two hours for resources to respond or hold the line at the fuel break. In all cases the flame lengths are below 4 feet, which is a rule of thumb for where hand crews must transition to dozers due to heat intensity. Therefore, all resources may be brought to bear at this location under all the weather scenarios.

The weather scenarios are likely conservative in that the winds may be higher than modeled because of the ridge-top location. The weather station that supplied the fire weather data was not in such an exposed location. Based on this modeling a shaded fuel break would not be necessary as it would not be beneficial to separate tree crowns because the ground fire would not reach the crowns even under extreme weather conditions. If this could be reliably determined, then an understory biomass harvest would be beneficial, which would retain most of the carbon on site. Since a shaded fuel break can allow more light and wind to the ground, creating hotter and drier understory conditions, all of these factors should be considered in total.

Figure 31: Canopy Density for Stand 105, Used for Fire Modeling

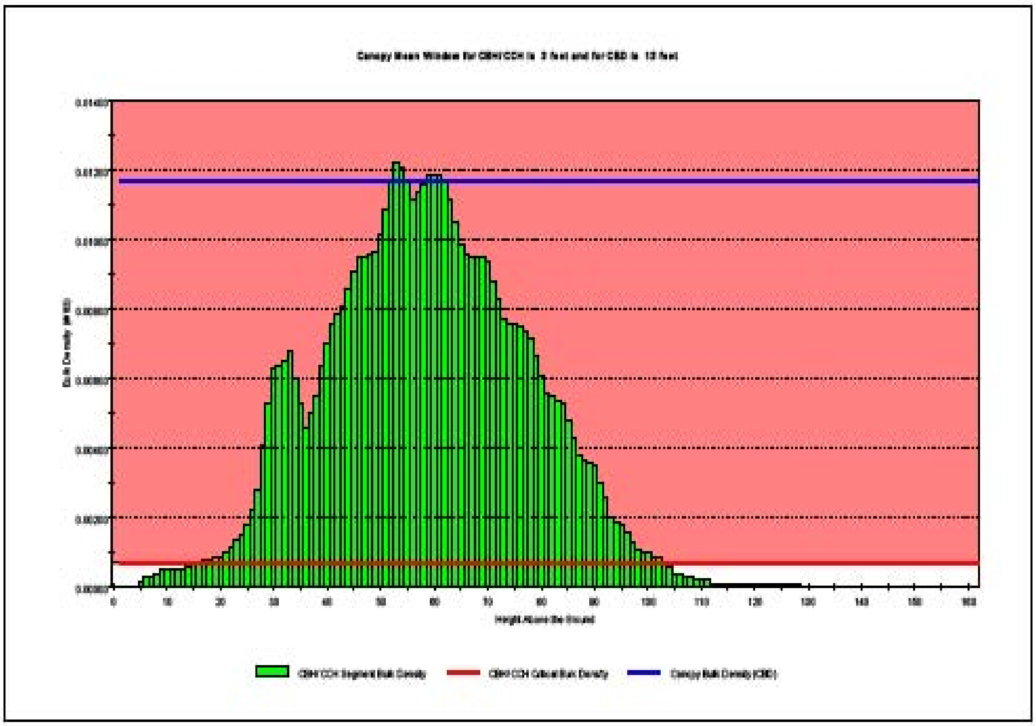


Table 32: Fire Modeling Results for Moderate Weather Conditions

Stand	Fire Type		Flame Length (feet)		Rate of Spread (ch/hr)		Probability of Ignition (%)		Spotting Distance from Torching Tree (mi)		Percent Mortality		Average Crown Scorch (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
STAND_105_BREAK	Surface	Surface	0.8	0.3	0.7	0.3	65	68	0.10	0.10	16.1	16.1	0.0	0.0
STAND_106	Surface	Surface	0.8	0.3	0.7	0.3	67	67	0.10	0.10	17.9	17.9	0.0	0.0
STAND_118_BREAK	Surface	Surface	0.8	0.3	0.7	0.3	67	67	0.11	0.11	11.0	11.0	0.0	0.0
STAND_123_BREAK	Surface	Surface	0.3	0.3	0.3	0.3	67	67	0.10	0.10	11.2	11.2	0.0	0.0
STAND_155	Surface	Surface	0.8	0.3	0.7	0.3	67	67	0.11	0.12	12.5	12.5	0.0	0.0
STAND_156	Surface	Surface	0.3	0.3	0.3	0.3	67	67	0.10	0.10	18.1	18.1	0.0	0.0
STAND_158	Surface	Surface	0.3	0.3	0.3	0.3	67	67	0.10	0.10	16.7	16.7	0.0	0.0
STAND_164_BREAK	Surface	Surface	1.2	0.3	0.9	0.3	67	67	0.11	0.10	10.8	10.8	0.0	0.0
STAND_390_BREAK	Surface	Surface	1.2	0.3	0.9	0.3	67	67	0.10	0.10	11.7	11.7	0.0	0.0
S129_BREAK	Surface	Surface	1.9	1.2	1.7	0.9	67	67	0.10	0.08	29.8	25.5	25.5	0.1

Table 33: Fire Modeling Results for High Weather Conditions

Stand	Fire Type		Flame Length (feet)		Rate of Spread (ch/hr)		Probability of Ignition (%)		Spotting Distance from Torching Tree (mi)		Percent Mortality		Average Crown Scorch (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
STAND_105_BREAK	Surface	Surface	1.0	0.4	1.1	0.4	81	84	0.15	0.15	16.1	16.1	0.0	0.0
STAND_106	Surface	Surface	1.0	0.4	1.1	0.4	82	82	0.15	0.15	17.9	17.9	0.0	0.0
STAND_118_BREAK	Surface	Surface	1.0	0.4	1.1	0.4	82	82	0.16	0.16	11.0	11.0	0.0	0.0
STAND_123_BREAK	Surface	Surface	0.4	0.4	0.4	0.4	82	82	0.15	0.15	11.2	11.2	0.0	0.0
STAND_155	Surface	Surface	1.0	0.4	1.1	0.4	82	82	0.16	0.16	12.5	12.5	0.0	0.0
STAND_156	Surface	Surface	0.4	0.4	0.4	0.4	82	82	0.14	0.14	18.1	18.1	0.0	0.0
STAND_158	Surface	Surface	0.4	0.4	0.4	0.4	82	82	0.15	0.15	16.7	16.7	0.0	0.0
STAND_164_BREAK	Surface	Surface	1.6	0.4	1.5	0.4	82	82	0.16	0.16	10.8	10.8	0.0	0.0
STAND_390_BREAK	Surface	Surface	1.6	0.4	1.5	0.4	82	82	0.16	0.16	11.7	11.7	0.0	0.0
S129_BREAK	Surface	Surface	2.5	1.6	2.7	1.5	82	82	0.14	0.12	32.9	35.2	39.5	29.7

Table 34: Fire Modeling Results for Extreme Weather Conditions

Stand	Fire Type		Flame Length (feet)		Rate of Spread (ch/hr)		Probability of Ignition (%)		Spotting Distance from Torching Tree (mi)		Percent Mortality		Average Crown Scorch (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
STAND_105_BREAK	Surface	Surface	1.1	0.5	1.3	0.5	86	89	0.18	0.17	16.1	16.1	0.0	0.0
STAND_106	Surface	Surface	1.1	0.5	1.3	0.5	88	88	0.17	0.17	17.9	17.9	0.0	0.0
STAND_118_BREAK	Surface	Surface	1.1	0.5	1.3	0.5	88	88	0.19	0.19	11.0	11.0	0.0	0.0
STAND_123_BREAK	Surface	Surface	0.5	0.5	0.5	0.5	88	88	0.18	0.18	11.2	11.2	0.0	0.0
STAND_155	Surface	Surface	1.1	0.5	1.3	0.5	88	88	0.19	0.19	12.5	12.5	0.0	0.0
STAND_156	Surface	Surface	0.5	0.5	0.5	0.5	88	88	0.17	0.17	18.1	18.1	0.0	0.0
STAND_158	Surface	Surface	0.5	0.5	0.5	0.5	88	88	0.18	0.18	16.7	16.7	0.0	0.0
STAND_164_BREAK	Surface	Surface	1.7	0.5	1.7	0.5	88	88	0.18	0.18	10.8	10.8	0.1	0.0
STAND_390_BREAK	Surface	Surface	1.7	0.5	1.7	0.5	88	88	0.18	0.18	10.8	10.8	0.0	0.0
S129_BREAK	Surface	Surface	2.7	1.7	3.2	1.7	88	88	0.17	0.14	36.0	36.2	43.6	31.9

8.3 Carbon and Fire Risk Tradeoff Analysis

The carbon reduction from the shaded fuel break treatments reduces stocks from approximately 48.6 tonnes of live (above and below ground) carbon per acre (120.0 t/h) to 20.4 t/a (49.4 t/h) for a reduction of 28.2 t/a (69.7 t/h) total. In five years this recovers to 24.7 t/a (61.0 t/h). Considering just the treated acres and based on the fire modeling, there was not a net benefit to the thinning from a carbon standpoint. Significant carbon was removed and the site occupancy will be maintained over time at this lower level. Some of this will be recovered in long-term wood products storage and if prices for biomass improve, over time there will be higher utilization of the understory thinning material. The pre versus post treatment fire behavior modeling does not change significantly in this case.

Since the proposed fuel break divides the two project areas in half approximately, consider the fuel break as protecting one half of the total carbon stocks over a 100 year project period. Such an assumption may be optimistic on average, but given the topographic layout and good access this is not an unreasonable assumption. What would the expected average value be given these assumptions? Equation 1 provides a way to quantify the estimate of the value of the shaded fuel break where it is assumed to protect one half of the project carbon. Growth is not included in (1) because we are assuming that the fuel break will be maintained over time and only replacement trees will be allowed to grow to maturity.

$$CVS = LTL + \sum_{t} (PF_t \times PC_t) \times FREQ_t \times (EL_t \times EP_t + HL_t \times HP_t + ML_t \times MP_t) + RECAP \quad (1)$$

Where

CVS = carbon value saved by implementing project,

*LT*L = long-term loss from fuel break treatment,

PF = protection factor (what proportion of project is protected),

PC = project carbon on site,

*FRE*Q = average long-term fire frequency as an annual probability, *EL = extreme weather loss of carbon as a proportion,*

EP = extreme weather probability (annual),

*H*L = high severity weather loss of carbon as a proportion,

*H*P = high severity weather probability (annual),

*M*L = moderate weather loss of carbon as a proportion,

*M*P = moderate weather probability (annual),

RECAP = recapture of site given incident (in carbon), and

t = time, which is 100 years in this case but may be in 5 or 10-year increments.

The following is an example of using equation (1). Several examples are shown in Table 36 that illustrate that CVS may be positive or negative depending on the parameters and assumptions. RECAP may be complex in that reforestation or natural succession would have to be modeled. Alternatively, a persistent brush field may occur, especially on nonindustrial private lands where there is no legal requirement and it is often common not to reforest after a catastrophic fire. In this example we assume that is the case and RECAP=0.

Table 35: Example Calculations of Carbon Tonnes Protected by Shaded Fuel Break under Different Assumptions

Example More Severe Fire outside Parameter	Expected	Fuel Break	Increased Frequency	Less Protection
LTL	-2,109.4	-2,109.4	-2,109.4	-2,109.4
PF	0.50	0.50	0.50	0.20
PC	98,616.9	98,616.9	98,616.9	98,616.9
FREQ	0.03	0.03	0.10	0.03
EL	0.30	0.60	0.30	0.30
EP	0.03	0.03	0.03	0.03
HL	0.20	0.40	0.20	0.20
HP	0.07	0.07	0.07	0.07
ML	0.10	0.20	0.10	0.10
MP	0.75	0.75	0.75	0.75
RECAP	0.0	0.0	0.0	0.0
CVS	12,387.3	26,884.0	46,212.9	3,689.3

The frequency of fire (*FREQ*), or the return interval, and the weather category characteristics may change over the 100 year period due to fuel changes in the fire-shed, climate change, fire prevention and protection measures. They are held constant in this example. We have made a simple assumption regarding loss of carbon outside the fuel break but in the project area, which is 30 percent loss for an extreme fire event, 20 percent loss for a high severity fire, and 10 percent loss for a moderate event. These are low figures for areas with steeper slopes or lower in elevation where weather is more severe on average.

In all cases examine, Table 36, the fuel break provided a positive carbon benefit. Holding other things constant it would take a fire frequency of .435 percent a year to reach a breakeven point between the carbon lost in the fuel break treatment and that theoretically saved. These are conservative estimates because the carbon saved used the beginning period carbon stocks, which increases over time.

CHAPTER 9: Discussion and Conclusions

Harvest scheduling for the improved forest management project type can be complex, even for smaller properties. This is due to trying to optimize reductions by simulating the baseline close to the FIA mean or starting inventory, depending on starting point. If you are conducting an economic analysis, such as maximizing NPV, then a flexible optimizing harvest schedule is even more desirable. Therefore, we recommend using an optimizing harvest schedule for improved forest management project types, such as a linear or dynamic program.

The inclusion of harvested wood products in the baseline accounted for reductions in harvest over the 100 year projection period. The secondary effects calculation applied an additional penalty of 20 percent of the reduced harvest to account for market leakage. The risk assessment analysis produced what appear to be reasonable results, but will have to be monitored over time to match long-term results by geographic region.

The contribution of wood products was relatively small or even negative for the scenarios presented. This might have been different if there was more harvesting, especially over a larger area with a mix of age classes where harvests could be offset with on-site growth and not cause a reduction in CRTs. Improvements in stand growth could also change the contribution of the harvested wood products pool. Both the baseline and project activity were projected using growth calibrations from the native lightly managed stands. Where group selections or clearcuts occur that create rapidly growing thrifty stands, wood products contributions could increase. This would be captured over time with inventories and would ultimately be reflected in CRTs. Therefore, the CRT projections for these scenarios are conservative.

The application of the reforestation project type was found to be appropriate for both private and public lands, but not economically viable without subsidy. The improved forest management project type was not found to be appropriate for these projects on public lands, as the baseline could not be shown to differ from the project activity. Improved forest management project types on private lands had economic returns (NPV) of $65 and $617 per acre ($159 and $1,524 per hectare) for the two demonstration project areas assuming a price of $9.00 a tonne CO_2. At $20.00 a tonne CO2e the NPVs were $393 and $1,536 per acre ($972 and $3,794 per hectare). The higher value resulted from the starting inventory being substantially above the common practice for the assessment area, which resulted in CRTs being immediately created.

The use of CVal (Bilek et al. 2009) rapidly produces an economic analysis of a project based on carbon income and project costs. This software provides an excellent example of the type of analytic tools needed to build rational ecosystem services markets.

The analysis of the effects of a fuel reduction project showed that the project appeared beneficial to carbon management when carbon benefits from avoided fire to adjacent acres was included in the calculation. More work is needed in this area as it is the application of stochastic landscape disturbances to project specific areas. Quantification necessarily involves estimates of disturbance and weather probabilities from historical records and local knowledge, along with estimates of fire severity for both treated and untreated conditions.

GLOSSARY

BAF	Basal Area Factor
CAL FIRE	California Department of Forestry and Fire Protection
CAR	Climate Action Reserve
CARB	California Air Resources Board
CCX	Chicago Climate Exchange
CFI	Continuous Forest Inventory
CRT	Certified Reserve Tonnes
CVTS	Cubic Volume Total Stem
dbh	Diameter at breast Height
FIA	Forest Inventory and Analysis
FMA	Fuels Management Analyst
GHG	Greenhouse Gas
LDSF	LaTour Demonstration State Forest
MBF	Thousand Board Feet
MCF	Thousand Cubic Feet
MSP	Maximum Sustained Production
OTC	Over the Counter
RGGI	Regional Greenhouse Gas Initiative
SE	Secondary Effects
TAI	Timber Atlas Inventory
THT	Total Height
VCS	Voluntary Carbon Standard Association
VCU	Voluntary Carbon Unit
WCI	Western Climate Initiative

REFERENCES

Bilek, E.M., P. Becker and T. McAbee 2009. CVal: A spreadsheet tool to evaluate the direct benefits and costs of carbon sequestration contracts for managed forests. *I*n General Technical Report. USDA Forest Service, Forest Products Laboratory. FPL-GTR-180., p. 27.

Blonski, K.S. and J.L. Schramel 1981. Photo series for quantifying natural forest residue: southern Cascades, northern Sierra Nevada. USDA Forest Service, General Technical Report. GTR-PSW-56:145.

Bradshaw, L. and S. Brittain 2008. Fire Family Plus. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Lab, Missoula, Montana, USA.

Cairns, M.A., J.K. Winjum, D.L. Phillips, T.P. Kolchugina and T.S. Vinson 1997. Terrestrial carbon dynamics: case studies in the former Soviet Union, the conterminous United States, Mexico and Brazil. Mitigation and Adaptation Strategies for Global Change. 1:363-383.

CAR 2009. Forest Project Protocol, Version 3.1. Climate Action Reserve, Los Angeles, p. 109. Dixon, G.E. 1999. ICASCA Variant (Inland California / Southern Cascades) Forest Vegetation Simulator. USDA Forest Service, Fort Collins, p. 41.

FMA 2009. Fuels Management Analyst 3. Fire Program Solutions/Acacia.

Harmon, M.E. and J. Sexton 1996. Guidelines for measurements of woody detritus in forest ecosystems, p. 42.

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

Jenkins, J.C., D.C. Chojnacky, L.S. Heath and R.A. Birdsey 2003. National-scale biomass estimators for United States tree species. Forest Science. 49:12-35.

Martin, R.E., D.W. Frewing and J.L. McClanahan 1981. Average biomass of four Northwest shrubs by fuel size class and crown cover. USDA Forest Service, Research Note. PNW-374:6.

PRISM 2009. PRISM Group. Oregon State University.

Robards, T. and E. Smith 2006. Carbon sequestration planning using the Landscape Management System. *I*n Society of American Foresters National Convention, Pittsburg, PA.

Robards, T.A. 2009. California Forest Carbon Processor. California Department of Forestry and Fire Protection, Sacramento.

APPENDIX A:
LDSF Inventory, Biomass Calculations and Growth Projections

Inventory and projection methods will be discussed below with results provided in the appropriate sections in the main body of the report. A description of the inventory, biomass calculations, carbon conversions and growth projection methodologies will be provided here since they apply uniformly to both project areas and the private as well as the public scenarios.

Inventory

LDSF maintains two inventories across the entire Forest. The first is a continuous forest inventory (CFI) that consists of 221 permanent plots or approximately one plot per 40 acres. These plots were established in 1964/5 and have been measured, with one exception, every five years. The second inventory consists of temporary plots and is called the timber atlas inventory (TAI). These two data sets provide a level of information and intensity that is not typical for most forestlands, but provide useful data for a demonstration and research forest such as this.

CFI Overview

The CFI is based on 221 permanent plots on a systematic grid across the forest. The plots are probability proportional to size (the larger the tree the larger the probability of inclusion on the plot, at a given distance from plot center) and use a basal area factor (BAF) of 15 ft^2/acre (3.44 m^2/hectare). Tree species, diameter at breast height (dbh) to the nearest 0.1 inch (0.25 cm), crown ratio, and condition are recorded for each measured tree. A subsample of total tree height is collected. The data is stored in a Microsoft Access database.

TAI Overview

The TAI inventory is a multi-resource inventory that evolved over time from an inventory originally designed for timber and tax purposes in the 1960s. There are approximately 3,600 current plots across the forest, on a 16-plot systematic grid within 40-acre (16.2 h) units called lots. The plots are probability proportional to size and use a basal area factor (BAF) of 20 ft^2/acre (4.59 m^2/hectare). Tree species, dbh to the nearest 2.0 inches (5.08 cm), and crown ratio were recorded for each measured tree. A subsample of total tree height, breast height age, and crown radius was collected. A small tree subplot was sampled. Shrub species, height and cover; standing dead and lying dead wood was estimated with dimensions and decay class variables. An estimate of canopy cover was made by taking a sighting tube shot at each plot center and between each plot, recording the tree canopy intersections. Shrub information was also collected at each intermediate plot. Other wildlife habitat information was collected for each plot. The data was stored in a Microsoft Access database.

Inventory Workup

The TAI inventory was used in conjunction with a type map to provide the carbon estimates and growth projections for both projects. For the above-ground live carbon pool, each tree record's data was input into the FIA standard biomass functions. Only trees 5 inches (12.7 cm) dbh and above were included in the analysis. The steps and appropriate functions for the most common species present are shown below.

Step 1, calculate the bole volume: The bole volume calculation is shown for each species using a 20-inch (50.80 cm) dbh tree and a total height (THT) of 80 feet (24.4 m). The volume assumes a ground to tip bole, no stump or tip deduction. These equations, cubic volume total stem (CVTS), are from the document *Volume estimation for the PNWFIA Integrated Database* (dated 13 May 2009).

Ponderosa pine (Equation #5): CVTS(DBH=20 in.,THT=80 ft.) = 64.5787 ft^3.

White fir (Equation #23): CVTS(DBH=20 in.,THT=80 ft.) = 60.5337 ft^3.

Incense-cedar (Equation #19): CVTS(DBH=20 in.,THT=80 ft.) = 50.8788 ft^3.

Douglas-fir (Equation #3): CVTS(DBH=20 in.,THT=80 ft.) = 60.0552 ft^3.

Black oak (Equation #41): CVTS(DBH=20 in.,THT=80 ft.) = 115.4407 ft^3.

Step 2, calculate the biomass of the bole: The bole, or stem or trunk, biomass is the volume of the wood multiplied by the wood density. Wood density is variable and average densities are reported by species or species groups. The wood densities below are from *the Regional biomass equations used by FIA to estimate bole, bark and branches* (dated 13 May 2009).

Ponderosa pine: 64.5787 ft^3 X 23.71 lbs/ft^3 X (1 lb./2.204622 kg) = 694.5237 kg

White fir: 60.5337 ft^3 X 23.09 lbs/ft^3 X (1 lb./2.204622 kg) = 633.9972 kg

Incense-cedar: 50.8788 ft^3 X 21.84 lbs/ft^3 X (1 lb./2.204622 kg) = 504.0288 kg

Douglas-fir: 60.0552 ft^3 X 28.7 lbs/ft^3 X (1 lb./2.204622 kg) = 781.8048 kg

Black oak: 115.4407 ft^3 X 34.94 lbs/ft^3 X (1 lb./2.204622 kg) = 1,829.5637 kg

Step 3, calculate the biomass of the bark: The bark biomass is estimated directly from the tree DBH, THT and wood density although some species equations only use DBH. These functions may be found in the *Regional biomass equations used by FIA to estimate bole, bark and branches* (dated 13 May 2009).

Ponderosa pine (Equation #9): BB(DBH=50.80 cm, THT=24.4m) = 79.5466 kg

White fir (Equation #1): BB(DBH=50.80 cm) = 369.0422 kg

Incense-cedar (Equation #12): BB(DBH=50.80 cm) = 124.5344 kg

Douglas-fir (Equation #8): BB(DBH=50.80 cm) = 187.6330 kg

Black oak (Equation #30): BB(DBH=50.80 cm, THT=24.4m, Density) = 167.7698 kg

Step 4, **calculate the biomass of the live crown branches**: The live crown branches are computed from tree DBH and THT although some species equations only use DBH. These functions may be found in the *Regional biomass equations used by FIA to estimate bole, bark and branches* (dated 13 May 2009).

Ponderosa pine (Equation #7): BB(DBH=50.80 cm, THT=24.4m) = 178.3803 kg

White fir (Equation #1): BB(DBH=50.80 cm, THT=24.4m) = 91.0286 kg

Incense-cedar (Equation #10): BB(DBH=50.80 cm, THT=24.4m) = 239.9483 kg

Douglas-fir (Equation #6): BB(DBH=50.80 cm) = 110.4461 kg

Black oak (Equation #16): BB(DBH=50.80 cm) = 289.3839 kg

Step 5, **sum the aboveground live tree biomass**: The bole, bark and live branches are summed. The leaves or needles are not estimated here. Technically, much of the bole and bark is dead as much of the live portions are at the intersection of the two, but we lump these pools into the live component as the organism is alive.

Ponderosa pine: (694.5237 kg + 79.5466 kg + 178.3803 kg)/1,000 kg/tonne = 0.95 tonne

White fir: (633.9972 kg + 369.0422 kg + 91.0286 kg)/1,000 kg/tonne = 1.09 tonne

Incense-cedar: (504.0288 kg + 124.5344 kg + 239.9483 kg)/1,000 kg/tonne = 0.87 tonne

Douglas-fir: (781.8048 kg + 187.6330 kg + 110.4461 kg)/1,000 kg/tonne = 1.08 tonne

Black oak: (1,829.5637 kg + 167.7698 kg + 289.3839 kg)/1,000 kg/tonne = 2.29 tonne

Step 6, **convert biomass to carbon estimate**: The carbon content of biomass is approximately ½ or 50 percent.

Ponderosa pine: 0.95 tonnes biomass X 0.5 = 0.476 tonnes C

White fir: 1.09 tonnes biomass X 0.5 = 0.547 tonnes C

Incense-cedar: 0.87 tonnes biomass X 0.5 = 0.434 tonnes C

Douglas-fir: 1.08 tonnes biomass X 0.5 = 0.540 tonnes C

Black oak: 2.29 tonnes biomass X 0.5 = 1.143 tonnes C

Step 7, estimate below-ground carbon: The below-ground carbon was estimated using the protocol suggested reference by Cairns et al. (1997). The function is:

$$BBD = e^{-0.7747 + 0.8836 * \ln(ABD)}$$

where

ABD = above-ground biomass density in tonnes per hectare,

BBD = below-ground biomass density in tonnes per hectare.

This estimate is made for each plot so that it may be incorporated into the plot-level standard error estimates. The carbon is estimated by multiplying BBD by 0.5.

Step 8, estimate standing and lying dead wood for both project types: The TAI inventory provides estimates for both of these carbon pools. The specifications of the inventory are as follows.

- Minimum size of 10 inches (25.4 cm) diameter for snags, 8 inches (20.3 cm) diameter for down wood
- Species coded for snags where identifiable
- Decay classes of sound and rotten for both snag and down wood, down wood also has an intermediate class
- Length, small diameter and large diameter for down wood, dbh for snags.

The volume of the above ground wood was estimated and then multiplied by a density factor that varied by species and decay class. The frustum of a parabaloid formula (1.2) was used to calculate volume for down wood (Husch et al. 1993). A neiloid formula (1.3) was used for snags, since only one measurement was taken (dbh) and that was near the base.

$$V = \frac{h}{2}(A_b + A_u) \qquad (0.2)$$

$$V = \frac{1}{4}(A_b h) \qquad (0.3)$$

where,

Ab = cross-sectional area at the base,

Au = cross-sectional area at the top, and

H = height or length.

The wood density used for snags was the same as that for the standing live trees, where the wood was sound. Where species was not identified for snags, white fir density was used as it was the most common species on LDSF. Rotten snags received a density of 0.202 g/cm^3, which was the decay class 3 for down white fir in the Sierra Nevada, according to Harmon and Sexton (1996). Since snag height was not measured the height was estimated using the LDSF height-diameter functions used for live trees.

No estimates for bark biomass were made. The wood density for down wood used the white fir estimates for the Sierra Nevada from Harmon and Sexton (1996, see table 4). This was translated to be 0.340 g/cm^3 for sound logs, 0.333 g/cm^3 for intermediate logs, and 0.185 g/cm^3 for rotten logs. Biomass estimates from dead wood was converted to carbon tonnes as in previous steps.

Step 9, **calculate the standard error and sampling error of the carbon estimate**: The standard error is a common statistical parameter used to express the variability of an estimate. The protocols require an estimate of the confidence bound using a 90 percent level of confidence. This is calculated by multiplying the standard error by the t-value of 1.645. The standard error formula will be a function of the sampling design, which could be systematic with random start (treated as random), stratified, multi-stage, double, combinations of the above or other design. In this case we have a systematic grid of plots that have been overlaid on a type map yielding a stratified random sample. Each stand was treated as a separate stratum. The total and standard error formula are as follows (Husch et al. 1993).

Mean (live and dead tree carbon per acre) per stand or stratum: $\bar{x}_j = \frac{\sum_{i=1}^{n_j} x_{ij}}{n_j}$, where x_{ij} is the above-and below-ground live tree and above-ground standing and lying tree carbon from the ith tree on the jth plot and n_j are the number of plots in the jth stratum.

Mean (live and dead tree carbon) per project: $\bar{x} = \frac{\sum_{j=1}^{M} N_j \bar{x}_j}{N} = \sum_{j=1}^{M} P_j \bar{x}_j$,

where M is the number of strata (or stands), N_j is the number of sampling units in the jth stratum, N is total number of sampling units in the population, and P_j is the proportion of the total forest area in the jth stratum (N_j/N).

Total (live and dead tree carbon) per project: $\hat{X} = N\bar{x}$

Each stand or stratum stand variance (standard deviation squared) is calculated using the simple random sampling formula.

Variance of the mean per acre estimate for a stratum: $s_j^2 = \frac{\sum_{i=1}^{n_j}(X_{ij} - \bar{x}_j)^2}{n_j - 1}$

The variance estimate for the mean of the project, or population, assumes that the sample is small relative to the population so that the finite population correction may be ignored (a more conservative estimate).

Variance of the mean per acre estimate for project: $s_{\bar{x}}^2 = \sum_{j=1}^{M} P_j^2 \frac{s_j^2}{n_j}$

Variance of the carbon estimate for project: $s_X^2 = N^2 s_{\bar{x}}^2$

The standard error of the total is the square root of s_X^2.

Step 10, estimate shrub carbon for reforestation units: The carbon contained in the vegetation removed from a site when conducting a reforestation project type must be estimated. This was done by using shrub biomass estimates from Martin et al. (1981) for live and dead aboveground material. Two species were available from this paper, greenleaf manzanita (*Arctostaphylos patula*) and snowbrush (*Ceanothus velutinus*). To be conservative, other species used the manzanita estimates since they were the larger of the two. The biomass estimates were provided by percent cover in 10 percent classes. Cover estimates from field plots that were installed pre-treatment were used to estimate the biomass.

Herbaceous cover is also required but is rare, in a carbon inventory sense, in these brush fields. Indirect estimations of emissions from mobile combustion preparing and planting the site are taken from the protocols (FPP table 6.1). The reforestation in the McMullen Mountain project was in heavy brush using mastication to clear it; therefore a heavy emission is appropriate, given as 0.429 tonnes per acre CO_2. This equates to 0.117 tonnes per acre C. The reforestation unit in the Sunset project was sprayed, brush raked, and piled. Since the brush was also dense and large the heavy emission amount of 0.117 tonnes per acre C will also apply. No emissions from shifting from croplands occurred.

The results of this analysis are shown in Table 4 and Table 16 for the Sunset and McMullen Mountain projects respectively. The reforestation components did not have any aboveground live tree components; therefore the tree calculations were not performed for that project type. Shrub carbon removed was estimated for the reforestation types only. The biomass functions used for the projections of both baseline and project activity were the same as the FIA functions.

Growth Projections

The growth projections used the same modeling methods as for the LDSF option-A plan (CCR 933.13), which is a state-approved long-term (100 years) harvest schedule to demonstrate sustained yield. The project activity projections are the same as that presented in the option-A plan; for both the private and public lands scenarios.

Growth data from the CFI plots was used to calibrate the diameter growth component of the Forest Vegetation System (FVS) variant ICASCA (Dixon 1999), by species. This growth simulator was used within the Landscape Management System (LMS) version 2.0.46 (Robards and Smith 2006). LMS provided an integrated system for growth projections, harvest simulation, statistical reports, stand visualization and carbon yield reporting. Figure A-1 shows the key file that was used with every simulation in this report. The BFVOLUME keyword sets the merchantable volume at a minimum 10-inch dbh, 6 inch top and 1 foot stump. At least 3,000 board feet per acre must be available to harvest economically. The BAIMULT keyword is the LDSF growth calibration factors. The BFVOLUME keyword sets hardwood species to zero board foot volume.

Figure A-1: FVS Key File Used in the Simulations

```
File: C:\PROJ\Carbon\LaTourDemo\CMAIAnalysis\LDSF.KEY  4/15/2007, 6:53:32PM

COMMENT
DEFAULT KEY FILE FOR LATOUR HARVEST SCHEDULE 2006. TA ROBARDS.
KEYWORD    111111111 222222222 333333333 444444444 555555555 666666666 777777777
END
BFVOLUME                               10.0       6.0       1.0
MINHARV                              3000.0
BAIMULT             0         DF       2.52
BAIMULT             0         PP       2.26
BAIMULT             0         SP       1.45
BAIMULT             0         WP       1.62
BAIMULT             0         LP       6.07
BAIMULT             0         WF       1.40
BAIMULT             0         RF       1.23
BAIMULT             0         IC       2.83
BAIMULT             0         BO       6.15
BFVOLUME            0         BO        999
BFVOLUME            0         TO        999
BFVOLUME            0         MH        999
BFVOLUME            0         PY        999
BFVOLUME            0         WO        999
BFVOLUME            0         BM        999
BFVOLUME            0         RA        999
BFVOLUME            0         MA        999
BFVOLUME            0         GC        999
BFVOLUME            0         CL        999
BFVOLUME            0         OH        999

                                                                      Page: 1
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While carbon pool estimates were available from within LMS, based primarily on Jenkins et al. (2003), we used the FIA biomass functions for both baseline and project activity projections. This was done by post-processing the inventory data files by 5-year periods using the custom-made California Forest Carbon Processor program (Robards 2009). This accounted for both above-ground and below-ground carbon. Dead wood was simulated using the LMS defaults for dead wood decay over time, but were found to estimate very little down or standing dead wood over time. Since this would cause an underestimation in the baseline and therefore an overestimation in additionality over time, an average down wood component was estimated from published fuel loading for down dead wood that was 3.1 inches (7.9 cm) or larger (Blonski and Schramel 1981; FMA 2009). Table 37 shows the default values that were used by forest type and size class. The ratio of long-term average projected snag to down wood biomass was assumed to be 1:1.

Table A-1: Default Down Wood Density by Forest Type and Size Class
(class 2: 5-11” (12.728.0 cm) dbh, class 3: 12-20” (30.5-50.8 cm) dbh, 4: >20” (50.8 cm) dbh)

Forest Type	Size Class	DDW 3.1”+ (tons biomass per acre)	DDW 3.1”+ (tonnes C per acre)
Ponderosa pine	2	4.9	2.2
Ponderosa pine	3	3.2	1.4
Ponderosa pine	4	6.5	2.9
White fir	2	2.2	1.0
White fir	3	6.7	3.0
White fir	4	7.8	3.5
Red fir	3, 4	1.8	0.8
Lodgepole pine	2	2.2	1.0
Lodgepole pine	3	6.1	2.8
Mixed Conifer, Fir	4	6.6	3.0
Mixed Conifer, Pine	4	5.2	2.4

The wood products estimates for the baseline require that a volume estimate be obtained from the simulations, which was taken from LMS. Then the merchantable cubic foot volumes were multiplied by the density factor of 24.59 lbs/ft^3 and then converted to tonnes of C by multiplying by ½ and dividing by 2,204.6 pounds. The wood product class was estimated to be 70 percent softwood plywood and 30 percent softwood lumber based on the last two timber sales from the Forest (Ben Rowe, CAL FIRE, personal communication). Therefore, a .470 factor for softwood lumber and a 0.490 factor for softwood plywood were applied for in-use. A 0.294 and a 0.283 factor were applied for landfills, respectively.