


MOKELUMNE WATERSHED AVOIDED COST ANALYSIS:

# Why Sierra Fuel Treatments Make Economic Sense


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FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

# Chapter 8: Carbon Analysis

Forests can act as carbon sinks, as well as carbon sources. Through appropriate forest management practices, the forest sector can increase its carbon stocks and help reduce greenhouse gas (GHG) emissions, helping the state meet its long-term goals to address climate change. A particular area worthy of further consideration is the issue of high-severity wildfire and how management may reduce the associated risk of significant emissions and increase forest resilience in a warming climate.

This section seeks to assess the potential climate benefits of fuel treatments chosen for the Mokelumne watershed. Specifically, it explores whether such treatments would decrease the amount of carbon released under the modeled Five Fires scenario, by how much, and what the economic value of these avoided emissions might be. To help answer this question we (1) assess the total amount of carbon in the watershed, (2) assess the amount of carbon removed via treatments, (3) assess the emissions released during wildfires for both the treated and untreated scenarios, and (4) estimate the value of these avoided emissions. While the information in this section could inform efforts to address fire as part of climate policy in California, it is not intended to suggest specific criteria for how GHG reductions should be measured.

## 8.1 Carbon in the Watershed

We assessed carbon in the Mokelumne watershed using a 2005 California Department of Forestry and Fire Protection (CAL FIRE) GIS database and report called “Biomass Potentials from California’s Forests and Shrublands” (Sethi 2005). CAL FIRE uses FIA (Forest Inventory and Analysis) data stratified to CWHR (California Wildlife Habitat Relationships) habitat types and then converted to an average live tree and shrub biomass (in bone-dry metric tonnes) per hectare. CAL FIRE uses this FIA data as part of its statutory requirements under AB 32 and the US Forest Service (USFS) is also a party in this effort. The biomass weight is converted to carbon using 0.5 as the conversion factor (Penman et al. 2003).

The numbers in the CAL FIRE database do not include litter, duff, dead trees, surface fuels, or soil carbon – which collectively can compose 25-45% of the entire forest carbon pool and a significant component of carbon emissions during fires (Campbell et al. 2007; North et al. 2009). As a result we assess the additional carbon from these pools using the USFS Fuels Characteristic Classification System (FCCS) (Ottmar et al. 2007). We assign an FCCS-specified amount of woody fuels, duff, and litter based on the CWHR codes assigned to each pixel. The cross-walk is based on the dominant vegetation type for each pixel, and where applicable, the size-class of trees present. Unfortunately, the FCCS vegetation types are at a broader classification than the CWHR vegetation types, so we could not find a fuel characterization for each CWHR type, and some grouping was required. Due to limits in the vegetation data set, including its large pixel size, the survey methods for the original data set, the age of the data (some are close to 10 years old), and the use of a cross-walk with potential errors in validation, caution should be used when considering this analysis for fine-scale planning.

## 8.2 Results – Carbon in the Watershed

Carbon in the watershed is highly variable due to an elevational gradient that encompasses vegetation zones from grasslands to alpine tundra. Results include carbon from live trees, woody fuels, litter, and duff. The analysis shows that the greatest amount of carbon is in the highly productive mixed-conifer belt ranging from 3,000 to 6,000 feet in elevation, where above-ground carbon can be as high as 260 tonnes per hectare (a tonne is a metric ton, equal to approximately 2,205 pounds; 1 hectare equals approximately 2.5 acres). Even in this belt, though, the amount of carbon is variable depending on site characteristics such as vegetation type and disturbance history (including whether the site has been recently logged or had a fire).

Table 8.1 shows the results of the carbon analysis in the watershed. The much lower average carbon in the Pardee watershed is likely due to the fact that that its area is generally at a lower elevation and has lower tree biomass per acre, with more acres in chaparral and oak woodland, than the mid-elevation Tiger Creek Afterbay watershed, which has more acres with conifer forests.

**Table 8.1: Estimates of above-ground carbon in the Mokelumne watershed (tonnes)**

| | *Hectares (ha)* | *Total carbon (tonnes)* | *Average carbon (tonnes/ha)* |
|---|---|---|---|
| Pardee watershed | 56,976 | 3,955,849 | 69 |
| TCAB watershed | 38,983 | 4,517,202 | 116 |
| All upper Mokelumne | 149,805 | 14,887,693 | 99 |

## 8.3 Carbon Removed by Treatment

Table 8.2 shows the total and average carbon per acre within the treated analysis units (TAU). We show pretreatment and posttreatment amounts for the portions of the Mokelumne watershed that drain to both Tiger Creek Afterbay and Pardee Reservoir based on the biomass volume estimated to be removed during treatments. Within the TAUs, fuel treatments remove a portion of the carbon as either chips or sawlogs. The CAL FIRE biomass database and accompanying report provide estimates of biomass removed based on a rule set that describes a typical fuel treatments operation that would remove small diameter trees, resulting in removal of 4-17% of the above-ground tree biomass at a site (Sethi 2005).

We estimate the amount of biomass removed based on the treatment prescriptions described in Chapter 7 of this report and the estimates from the CAL FIRE database. Errors in the estimate of material removed could occur due to differences in treatment type between the CAL FIRE database and the modeled treatment for this study. For example, mastication leaves a portion of the biomass on-site as shredded organic material strewn over the ground. Prescribed fires can also remove a portion of the carbon through a low-intensity fire that combusts fine fuels, litter, and duff, and kills vegetation that will then decompose and emit carbon over time. The CAL FIRE database simply assumes that the treatments removed material from the site by mechanical means and therefore we could not model the carbon impact of mastication or prescribed fire.

Additionally, we did not assess the fate of the material removed, which could be used to create energy or to wood products. For simplicity, we assume that once biomass is removed it is no longer part of the carbon assessment. Using the material for energy creation could offset the carbon released by other energy sources, and thus alter the total carbon impact of fuel treatments (Winford and Gaither 2012). If the material is used for wood products, it can remain in use for 30 or more years, depending on the type of product (Earles et al. 2012). We identify this as a gap and hope that future analysis can resolve this question. We do not assume a timeframe for these treatments to occur, but present it as the total potential biomass estimated removed by the treatments. In reality, treatments will likely occur over several years to decades. Table 8.2 shows carbon in the TAUs within the Pardee Reservoir and the Tiger Creek Afterbay watershed, before and after fuel treatments.

**Table 8.2: Estimate of carbon stocks pre and post thinning (in tonnes)**

| | *Pardee Reservoir Watershed* | *Tiger Creek Afterbay Watershed* |
|---:|---:|---:|
| Treated ha | 27,988 | 10,995 |
| Carbon, pre-treatment | 1,582,670 | 1,449,725 |
| Average carbon, pre-treatment | 56.55 | 131.85 |
| Carbon post-treatment | 1,032,028 | 1,179,471 |
| Average carbon, post-treatment | 36.87 | 107.27 |
| Carbon removed | 550,643 | 270,254 |
| Average carbon removed per ha | 19.67 | 24.58 |

## 8.4 Carbon Emissions from Fires

During a fire, the combustion of foliage, bark, live wood, dead wood, duff, and soil litter emit carbon to the atmosphere. The amount of carbon emitted depends on the severity of the fire and the type of material. Direct emissions from wildfires vary by fire severity, with high-severity fires combusting more biomass and creating more emissions (Campbell et al. 2007). Duff and litter are often completely combusted and account for the majority (57%) of carbon emissions during a fire (Campbell et al. 2007). Carbon emissions from live trees, dead trees, and foliage make up the rest of the carbon emissions, but these components are often not completely consumed by fire; some will survive while others will die from damage sustained during the fire and slowly decompose. Research in the Sierra Nevada has shown that an untreated forest with a high-severity fire suffered 97% tree mortality, while a treated forest had 53% mortality (North and Hurteau 2011). The process of decay is slow, and it may take up to 30 years for these dead trees to decompose and emit the carbon they contain (Harmon 2001).

For this analysis we estimate the amount of biomass burnt by a fire by assuming that the fraction of the biomass that is immediately combusted will vary by fire severity and fuel type. We use combustion fractions for live trees, surface fuels, litter, and duff – which vary by fire severity –

from Campbell et al. (2007) for low combustion-fraction estimates. For higher estimates, we use the 0.30 combustion fraction of woodlands and forests along with the 0.90 combustion fraction for herbaceous material – which do not vary by fire severity – as reported in Wiedinmyer et al. (2006). These two combustion fractions represent a potential range for the combustion of biomass during fires – the actual percentage of vegetation combusted during a fire will depend upon the weather, fuels, and topography within the fire. None of the combustion factors used for this study came from a Sierra Nevada-specific study, although such studies are forthcoming. Recent fires in the region, including the 2013 Rim Fire, had higher fire severities than that reported by Campbell et al. (2007) and, given the expected temperature increases with climate change, we expect to see increased fire severities that could increase the combustion factors associated with fires. Fire severity in our modeled fires is based on modeled flame lengths, as described in Appendix A. We make estimates of tree mortality following a wildfire based on the fire severity and the rates reported by North and Hurteau (2011), but we do not add these estimates to this analysis due to uncertainty of the time frame of decomposition.

The probabilities of the modeled fires and the selected fire perimeters are discussed more in Chapter 3 and Appendix A. For this analysis, we simply assume that a fire occurs within the lifespan of the treatment – typically 10-20 years for mixed-conifer forests, depending on treatment type, treatment intensity, topography, and site productivity (Stephens et al. 2012; Chino et al. 2012; Collins et al. 2013). Refer to Chapter 6.5 for specific probabilities of these fires and the likelihood that a fire does happen in the project timeframe.

Estimates of carbon emissions shown in Table 8.3 are for pretreatment conditions. We combine surface fuels, litter, and duff into one category for ease of reading. Fire A is within the Tiger Creek Afterbay watershed and Fires B through E are in the Pardee Reservoir watershed. The carbon emissions using the combustion factors from Campbell et al. (2007) (denoted as C*) range from 17-30% of the total carbon on site pre fire, while those from Wiedinmyer et al. (2006) range from 29-49% of total carbon on site pre fire. Potential carbon emissions from tree decay show the estimated emissions from decay over the expected 30-year decay period for mixed-conifer species (Harmon et al. 2001). While we report this result, we do not add it to resulting calculations, given uncertainty in the magnitude and timing of emissions from decay.

Table 8.4 describes the carbon emissions from fires A-E after treatment. Table 8.5 compares the emissions from the low and high estimates pre and post treatment. Fuel treatments that alter the size and intensity of wildfires reduce the amount of carbon emitted by fires from 36-85%, depending on the fire. The fuel treatments also reduce the expected emissions from decaying trees, because of the modeled reduction in fire severity and fire size.

**Table 8.3: Analysis of carbon emissions from fires – pretreatment**

| | *Hectares - pre treatment* | *% at high severity* | *Tree carbon* | *Ground fuels carbon* | *C emissions-Campbell* | *C emissions-Wiedinmyer* | *Potential C emissions from tree decay* |
|---|---|---|---|---|---|---|---|
| Fire A | 7,712 | 22 | 628,598 | 300,134 | 277,905 | 458,700 | 120,339 |
| Fire B | 7,618 | 39 | 446,721 | 198,801 | 196,919 | 312,937 | 156,761 |
| Fire C | 2,242 | 16 | 91,958 | 26,220 | 25,909 | 51,185 | 13,502 |
| Fire D | 1,758 | 18 | 36,986 | 7,565 | 8,106 | 17,904 | 6,061 |
| Fire E | 1,224 | 26 | 35,533 | 6,597 | 7,457 | 16,597 | 8,246 |

**Table 8.4: Analysis of carbon emissions from fires – posttreatment**

| | *Hectares - post treatment* | *% at high severity* | *Tree carbon* | *Ground fuels carbon* | *C emissions-Campbell* | *C Emissions-Wiedinmyer* | *Potential C emissions from tree decay* |
|---|---|---|---|---|---|---|---|
| Fire A | 5,395 | 6 | 316,433 | 209,641 | 177,930 | 283,607 | 17,725 |
| Fire B | 4,778 | 19 | 181,633 | 122,827 | 108,679 | 165,034 | 31,217 |
| Fire C | 545 | 1 | 10,487 | 4,913 | 4,246 | 7,567 | 76 |
| Fire D | 1,006 | 9 | 7,624 | 3,342 | 2,997 | 5,295 | 598 |
| Fire E | 453 | 17 | 5,338 | 2,511 | 2,295 | 3,861 | 815 |

**Table 8.5: Reduction in carbon emissions from fuel treatments**

| | *Reduction in emissions – C** | *Reduction in emissions – W** | *Mid-point between the two estimates* |
|---|---|---|---|
| Fire A | 99,974 | 175,094 | 140,000 |
| Fire B | 88,240 | 147,903 | 120,000 |
| Fire C | 21,663 | 43,618 | 33,000 |
| Fire D | 5,110 | 12,609 | 8,900 |
| Fire E | 5,161 | 12,736 | 8,900 |

Note: C* denotes the use of combustion fractions from Campbell et al. (2007); W* uses combustion fractions from Wiedinmyer et al. (2006). Calculated by subtracting the "C emissions" columns in Table 8.4 from the corresponding columns in Table 8.3.

**Table 8.6: Carbon impact of fuel treatments compared with emissions from fires**

| | *Carbon removed by treatment* | *Total carbon removal - C** | *Pre-treatment – fire emissions - C** | *Carbon impact - C** | *Total carbon removal - W** | *Pre-treatment – fire emissions - W** | *Carbon impact - W** |
|---|---|---|---|---|---|---|---|
| Fire A | 115,517 | 293,447 | 277,905 | (15,542) | 399,123 | 458,700 | 59,577 |
| Fire B | 105,309 | 213,988 | 196,919 | (17,069) | 270,343 | 312,937 | 42,594 |
| Fire C | 12,116 | 16,362 | 25,909 | 9,547 | 19,684 | 51,185 | 31,501 |
| Fire D | 10,415 | 13,411 | 8,106 | (5,305) | 15,710 | 17,904 | 2,195 |
| Fire E | 5,374 | 7,670 | 7,457 | (213) | 9,235 | 16,597 | 7,362 |

Note: *C removed by treatment* = carbon removed by fuel treatment. *Total carbon removal* = carbon removed by treatment plus the carbon emissions from the fire (post treatment). *Carbon impact* = the carbon released by a wildfire pre treatment minus the carbon removed by treatments and posttreatment wildfire emissions. Negative values are shown in parentheses and red text and indicate where treatments did not have a net carbon benefit post fire.

To answer the question of whether fuel treatments had a net positive carbon impact, we also need to consider the carbon impact of removing biomass during fuel treatments. Table 8.6 shows the total carbon impact of fuel treatments compared to the pretreatment scenario. In this table we added the carbon removed by fuel treatments ("C removed by treatment") to the carbon emissions post treatment and compare it to the carbon emitted by fire from the pretreatment fires. We use "Total carbon removed" to show the carbon removed by treatment and the estimated carbon emissions from wildfires (post treatment) for each fire. Because we have two different estimates of emissions, we use "– C*" to denote estimates of emissions based on Campbell et al. (2007)'s equations and "– W*" to denote estimates of emissions based on Wiedinmyer et al. (2006)'s equations. We then compare this amount to the carbon released by a wildfire prior to treatment ("Carbon impact" in the table).

This shows the impact of using various combustion factors on the question of whether fuel treatments have a net positive or negative carbon impact. For the modeled fires, the lower combustion factors (from Campbell et al. 2007) generally do not show a net carbon benefit from fuel treatments, but the high combustion factors (from Wiedinmyer et al. 2006) do. Where the carbon impact value is positive, estimates of the carbon left on site post treatment and post fire in trees that will continue to grow and sequester more carbon is greater than no-treatment postfire estimates. Because of the uncertainty of the combustion factors for a hypothetical fire in the Mokelumne watershed, we will use the midpoint of these emissions in the next section, which estimates the economical benefits to society.

## 8.5 Value of Avoided Carbon Emissions

Economists use the social cost of carbon to estimate the value of changes in greenhouse gas emissions. The social cost of carbon represents "the full global cost today of emitting an incremental unit of carbon at some point of time in the future, and it includes the sum of the global cost of the damage it imposes on the entire time it is in the atmosphere" (Shaw 2009). There are currently over 200 different estimates of the social cost of carbon. One review of the literature found values ranging from about $7 to over $100 per tonne of $CO_2$e ($CO_2$ equivalent) (Shaw 2009).

Over the past decade, several voluntary and regulatory carbon markets have emerged around the world along with several attempts at taxing carbon. Table 8.7 summarizes the total volume, total value, and per unit value of carbon traded in voluntary and regulatory carbon markets around the world in 2011. The average carbon price across these markets was about $21 per tonne of $CO_2$e. In addition to these carbon markets, many public agencies around the world have proposed or implemented carbon tax schemes (e.g., South Africa, India, Japan, South Korea, Australia, New Zealand, Denmark, Finland, and France). In 2008, British Columbia passed the Carbon Tax Act, which consumers pay when they purchase fossil fuels in the Province. The carbon tax rate has creased each year and in July 2012 it was set at $27 per tonne of $CO_2e$ (Ministry of Finance 2013).[1]

**Table 8.7: Voluntary and regulatory carbon markets (2011 summary)**

| *Carbon Market* | *Tonnes of $CO_2e$ (millions)* | *Total market value (millions)* | *Average value per tonne ($/tonne of $CO_2e$)* |
|---|---|---|---|
| Voluntary carbon markets | 78 | $576 | $7.38 |
| European union emission trading scheme | 6,463 | $147,848 | $22.88 |
| Primary clean development mechanism | 239 | $3,320 | $13.86 |
| Secondary clean development mechanism | 1,500 | $23,250 | $15.50 |
| Kyoto protocol | 39 | $318 | $8.15 |
| Regional greenhouse gas initiative | 99 | $249 | $2.52 |
| Annex 1 market (Kyoto protocol) | 4 | $12 | $3.31 |
| New Zealand carbon market | 22 | $351 | $16.12 |
| California carbon allowance | 4 | $63 | $17.36 |
| Others | 22 | $40 | $1.84 |
| *Total* | *8,468* | *$176,027* | *$20.79* |

Source: Ecosystem Marketplace. 2012. *Developing Dimension: State of the Voluntary Carbon Markets 2012*. May 31.

A recent publication from the U.S. Interagency Working Group on Social Cost of Carbon recommends using even higher values than those described above (U.S. Interagency 2013). The group's estimate is based on the value of potential damages associated with incremental increases in carbon emissions, including agricultural productivity, human health, property damages, and ecosystem services. The group's estimates range from about $13 to $64 (in 2012 dollars) per tonne of $CO_2$ in 2013, depending on the discount rate (5.0%-2.5%). The group also suggests that at the high end of the 95% confidence interval, the social cost of carbon could be as high as about $110 per tonne of $CO_2$ in 2013.

To account for carbon values in existing markets, particularly California, government taxes, and the Interagency Working Group on Social Cost of Carbon estimates, in Table 8.8 we consider a range of $17 (Total Market Value) to $63 (Total Social Value) per tonne of $CO_2e$.

The difference in carbon emissions from the fires with and without fuel treatments totals $5 million to $19 million for the five fires. The effect of treatments on the difference in emissions pre and post fire for the Tiger Creek Afterbay and Pardee Reservoir watersheds is worth $14 million to $52 million dollars (Table 8.8). The specific timing of the avoided emissions, in terms of when the fires would occur, would determine the present value, as more distant future avoided emissions are less valuable. For example, if these avoided emissions did not occur for 20 years, the carbon value at a 3% discount rate would be between $3 million and $11 million. While there are good reasons to use low discount rates when considering benefits and costs of carbon mitigation and adaptation

[1] $30 Canadian at exchange rate of 1.1 Canadian to U.S. British Columbia.

(e.g., Weitzman 2007), the presence of current opportunities to mitigate carbon emissions does dictate that society would likely be better off with current mitigation rather than delayed mitigation.

**Table 8.8: Value of avoided carbon emissions**

| *Carbon source* | *Tonnes of $CO_2e$* | *Total market value ($17/tonne)* | *Total social value ($63/tonne)* |
|---|---|---|---|
| Tiger Creek Afterbay Watershed pre- and post-T difference | 550,000 | $9,400,000 | $35,000,000 |
| Pardee Reservoir Watershed pre- and post-T difference | 270,000 | $4,600,000 | $17,000,000 |
| *Treatment total* | *820,000* | *$14,000,000* | *$52,000,000* |
| Fire A | 140,000 | $2,300,000 | $8,700,000 |
| Fire B | 120,000 | $2,000,000 | $7,400,000 |
| Fire C | 33,000 | $550,000 | $2,100,000 |
| Fire D | 8,900 | $150,000 | $560,000 |
| Fire E | 8,900 | $150,000 | $560,000 |
| *Fire emissions total* | *310,000* | *$5,200,000* | *$19,000,000* |
| *Treatment and emissions total* | *1,100,000* | *$19,000,000* | *$71,000,000* |

Note: Fire-specific estimates are based on the midpoint column in Table 8.5 above.

## 8.6 Discussion of Results

This analysis shows that fuel treatments reduce carbon emissions from the modeled fires by 38-77%. These avoided carbon emissions are almost entirely due to the smaller size and lower severity levels of the fires post-treatment. As shown in Table 8.6, using the higher combustion factors from Wiedinmyer et al. (2006), avoided carbon emissions from fires in the untreated areas are greater than the carbon that fuel treatments remove plus emissions from a fire. This suggests that fuel treatments can actually help increase carbon stocks by reducing the size and severity of fires (Hurteau and North 2009). Using the lower combustion fractions from Campbell et al. (2007), only Fire C has more avoided carbon emissions from fires in untreated areas than the carbon removed by fuel treatments plus fire emissions in the treated areas. This could be explained because Fire C had a 95% reduction in modeled fire severity. All other modeled fires using the Campbell et al. (2007) combustion factors have less avoided emissions from wildfires in the untreated areas than the treated areas. This would suggest that fire severity, and the resulting combustion factors, has a determining role in whether fuel treatments help increase carbon stocks in the forest given a wildfire or not.

From an economic perspective, the value of the carbon volumes at stake is potentially in the millions to tens of millions of dollars. If biomass removed in treatment can be sequestered or offset other emissions (e.g., bioenergy facility offsetting coal power emissions), the additional value can likely reach into the millions. We realize that, in practice, fuel treatments will not likely cover as many acres as in our simulation treatment scenario and therefore the actual volumes would likely be less, as would the costs. For reduced emissions due to smaller fires attributable to treatment, the value of carbon that remains sequestered also reaches into the millions of dollars.

Overall, carbon volumes and avoided emissions for our scenarios are likely in the tens of millions of dollars in overall social value, and would be in the millions for market opportunities in California, if such market participation is allowed. Regardless, market rates demonstrate the cost to Californians to achieve these equivalent avoided emissions as the least costly option.

An important point to note is that this analysis only looks at the impact of one fire and one treatment upon any particular pixel over the 30-year planning period. Whether any particular fuel treatment provides for greater carbon stocks post fire depends on the fire return interval (FRI), or the number of fires that occur in the area in a given span of time, and the type of treatment (Winford and Gaither 2012). If the vegetation type experiences frequent fires, such as the 11-year mean FRI of ponderosa pine (van de Water and Safford 2011), then fuel treatments may provide for greater carbon stocks post fire. However, vegetation in longer fire-return intervals, such as the 40-year mean FRI of red fir, may not show greater carbon stocks post fire after a fuel treatment.

A more refined analysis could incorporate a life-cycle approach by monitoring carbon that is removed from the forest, the carbon that is emitted by machinery used to treat the forest and employed during fire suppression, the emissions from prescribed fire, the fate of the woody products removed from the forest, or the emissions from dead trees killed by the fire (Earles et al. 2012; Kashian et al. 2006; Winford and Gaither 2012). It could also integrate this information with more comprehensive efforts to develop GHG accounting frameworks to sequester carbon and reduce emissions from forests. Additional research into the decomposition rates of the vegetation types in the Mokelumne watershed could provide some insight into how fast fire-killed trees decompose, thereby increasing the carbon benefits of fuel reduction due to the reduced fire severity and reduced tree mortality (North and Hurteau 2011). Additionally, tracking the biomass removed from treatment, its end uses and longevity, as well as the carbon that could be sequestered by the sites post fire, would allow for a full life-cycle analysis of the carbon impact of fuel treatments. This sort of life-cycle analysis is possible, though it is difficult to accomplish at the scale of the entire Mokelumne watershed without more specific data on the current vegetation. Site-specific assessments that record fire probability and fire severity along with pre- and posttreatment biomass quantities, and that follow the fate of the removed material, would be more feasible and would help refine the answers given in this report.

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# Mokelumne Watershed Avoided Cost Analysis: Why Sierra Fuel Treatments Make Economic Sense

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## Disclaimer

This report is rich in data and analyses and may help support planning processes in the watershed. The data and analyses were primarily funded with public resources and are therefore available for others to use with appropriate referencing of the sources. This analysis is not intended to be a planning document.

The report includes a section on cultural heritage to acknowledge the inherent value of these resources, while also recognizing the difficulty of placing a monetary value on them. This work honors the value of Native American cultural or sacred sites, or disassociated collected or archived artifacts. This work does not intend to cause direct or indirect disturbance to any cultural resources.

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