Navajo Lake Summer Homes
Fuels Treatment Analysis
Technical Fire Management 16

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Cover: Photo of Navajo Lake Summer Home
Owned By Keith & Elaine Averett Unit # 2, Lot # 27

EXECUTIVE SUMMARY

This paper analyses current vegetation and potential for damage that could result from an unplanned ignition (wildfire) in the Navajo Lake Summer Homes Area on the Cedar City Ranger District of the Dixie National Forest. This paper then presents vegetation treatment alternatives that could help minimize damage that could result from an unplanned ignition. These alternatives are based on economic analysis, probability of ignition, predicted fire behavior, percentile weather and proven silviculture practices in compliance with agency regulations and mandates.

The Navajo Lake Summer Homes are secondary residences used as vacation homes primarily in the summer months. These homes have been built in a forested area with a natural fire regime that could severely damage and/or destroy them. Despite occasional use, the area has been listed as a community at risk from wildfire and in accordance with the Dixie National Forest Fire Management Plan and the National Fire Plan, which have mandated officials to devise a fuels treatment plan to reduce this risk. This paper proposes a vegetative treatment strategy to deal with the problem that could result from an unplanned ignition in or around the Navajo Lake Summer Homes Area.

The project begins with an analysis of the vegetative components throughout the area in order to better understand the component and structural attributes. Stand inventory data was collected and RMSTAND was used to determine trees per acre, size and species. Plots were established, fuel loading inventories were collected and FUELS MANAGEMENT ANALYST was be used to determine dead and down woody loadings to determine the correct Fire Behavior Prediction System fuel model to be used. FOREST VEGETATION SIMULATOR was used to show current stand structure and possible alternative stand structure. The historical weather conditions for the area were processed using FIREFAMILY PLUS and the 50th, 90th and 97th percentile weather were used as criteria for levels of significant fire weather parameters. The BEHAVE program was used to determine fire behavior predictions for 50th, 90th and 97th weather levels. A probability analysis was conducted using PROBACRE, and historical fire occurrence data was processed to determine the chance for unplanned ignitions in the project area. An economic analysis was conducted to determine the significance of these ignitions.

The analysis determined that the 90th and 97th percentile seasonal fire behavior conditions support fire sizes greater than 0.2 acres and have flame lengths and rates of spread surpassing levels that local resources are able to direct attack and contain within the first hour of ignition. It was determined that fires of this size and duration are more likely to cause damage to the summer homes in the project area. The probability of having a fire exceeding 0.2 acres in the project area is 0.008 percent risk over the next twenty years.

The alternative of thinning, machine piling, pile burning and monitoring is recommended. This would satisfy the objective criteria, while having the lowest associated cost ($11,896) of the treatments analyzed, with a present net value of $1,813,913 for year twenty on the time horizon. This alternative will provide a better-suited fuels profile for suppression activities in and around the summer homes, resulting in safer conditions for firefighters, which will reduce the risk to life and property in the Navajo Lake Summer Homes in the event of an unplanned ignition. Although the treatment is needed Navajo Lake Summer Homes it is not likely to be the priority on the district due to the low probability of wildfire. It is suggested that comparative analysis be conducted to allow the urban interface areas with the highest risk from wildfire receive treatment first.

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Background

The district ranger and fire management officer for the Cedar City Ranger District on the Dixie National Forest have specified the need for fuels treatments to be completed around Navajo Lake Summer Homes to comply with the Dixie National Forest Fire Management Plan. The forest plan states the need to reduce hazardous fuels in and around Wildland Urban Interface areas to comply with the National Fire Plan, which has mandated federal agencies to take action to protect communities at risk from wildfire. These protective actions should reduce the risk to life and property, reduce the increasing cost of suppression activities and help firefighters safely protect these communities from wildfire.

The Cedar City Ranger District has issued special use permits, dating back to the mid-nineteen fifties, which allowed individuals to construct summer homes on federal land. There are now thirty-three lots in Navajo Lake area; all with structures having no electrical, gas, or landline phone utilities and a water system that is active May–September with no fire hydrant capabilities.

The Navajo Lake Summer Homes are secondary residences that are used as vacation homes primarily in the summer months. Despite this occasional use, the area has been listed as the second highest community at risk from wildfire, within the district. Due to this risk a fuels treatment plan to reduce this risk is needed.

Problem Statement

The line officer and fire management officials have been tasked with protecting homes that have been built in a forested area that historically supports a fire regime that could severely damage and/or destroy these homes.

Goal

Propose a vegetation treatment strategy that minimizes the damage resulting from an unplanned ignition in or around the Navajo Lake Summer Homes Area.

Objective

1. Propose treatment, based on cost efficiency, that will alter the fuel profile so existing forces can safely contain wildfires within 1 hour of ignition under severe drought seasonal fire behavior conditions based.

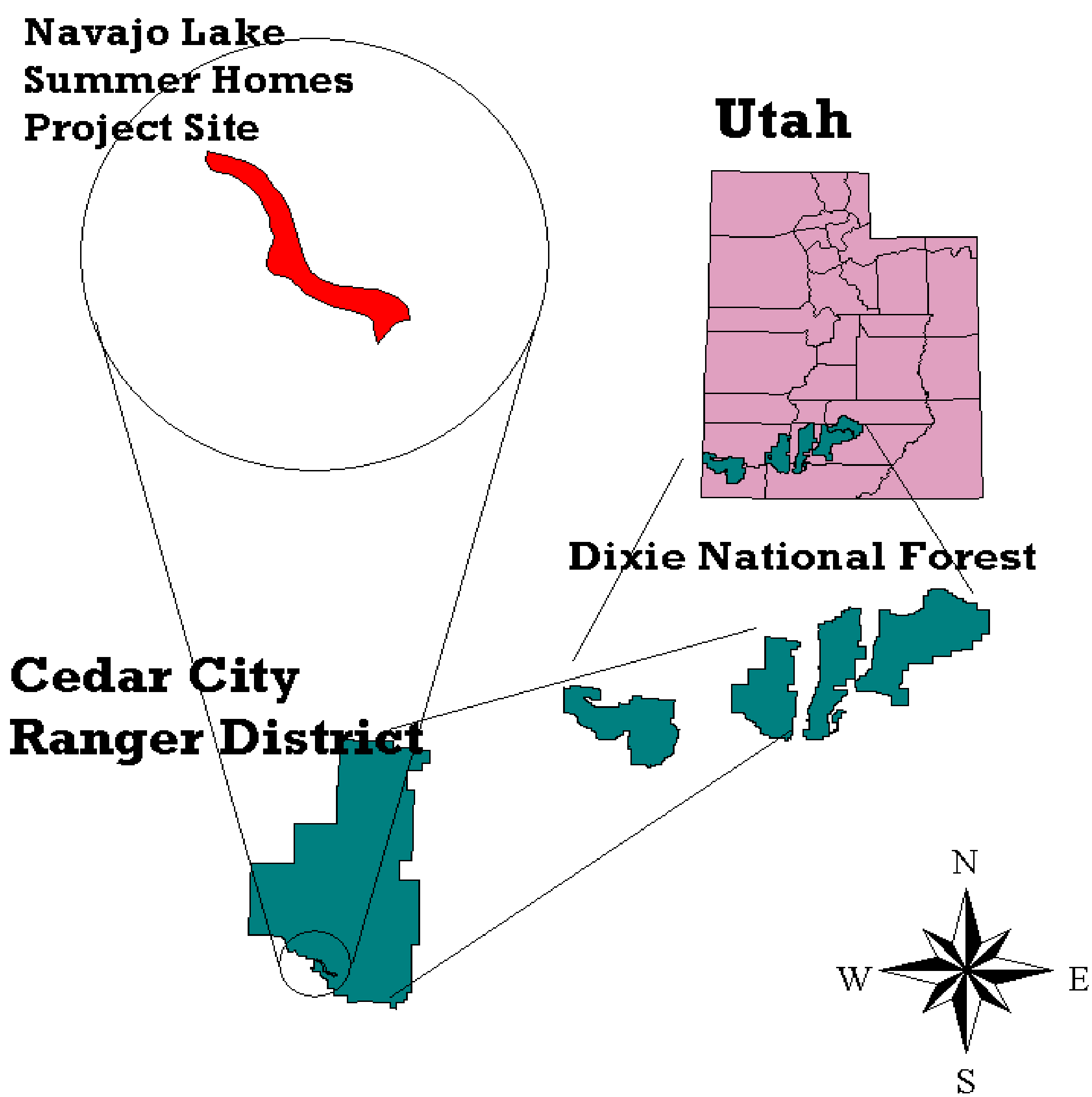
Alternatives Considered

1. Thinning and chipping that will limit flame length to < 4 feet and rate of spread to < 2 chains per hour under severe drought fire behavior conditions.
2. Thinning, hand piling and pile burning that will limit flame length to < 4 feet and rate of spread to < 2 chains per hour under severe drought fire behavior conditions.
3. Thinning, machine piling and pile burning that will limit flame length to < 4 feet and rate of spread to < 2 chains per hour levels under severe drought fire behavior conditions.
4. No Action

Alternatives Not Considered

1. Maintenance burning (under burning). Reason for non-consideration: high risk of possible escapes, small burning windows, esthetically unpleasing to some homeowners.
2. Commercial harvest. Reason for non-consideration: project area and size class of trees to small too generate enough board feet to interest commercial loggers in area.

Project
Geographic Vicinity Map



Existing Conditions

Vegetation Resources

Vegetative Composition
The forests in the Navajo Lake area are dominated by Engelmann spruce and subalpine fir (spruce-fir forest) with aspen, Douglas fir, and blue spruce, well represented. The stand in the project area is best represented by the *Abies lasiocarpa/Berberis repens* (ABLA/BERE) habitat type based on potential climax vegetation described in *Coniferous Forest Habitat Types of Central and Southern Utah* (Youngblood and Mauk 1985).

Vegetative Processes

Insects and Diseases
The lack of a mosaic in the spruce forest structure within the Navajo Lake Summer Homes project area has led to outbreak populations of spruce beetle, which began in 2000. In 2001, monitoring of the area indicates that over 50 percent of the Engelmann spruce greater than six inches in diameter have now been infested by the spruce beetle and killed. Spruce beetle populations within the project area are now considered to be at epidemic levels (Navajo Lake EA, 2001).

In infested areas in the northern portion of the spruce-fir forest on the Markagunt Plateau, mortality exceeds 90 percent in areas infested at epidemic levels. This level of mortality is expected to occur in the Navajo Lake basin. This event is not desired from the perspective of meeting Forest Plan management objectives within the area, but it does appear to be a natural, cyclic occurrence common to old-growth spruce-fir forests (Agenbroad et. al. 1993).

Fire Processes and Regime
The project site is listed as Fire Group Six, which consists of non-riparian white fir climax habitat types and three upland sites where blue spruce is the dominant potential climax. Historical fuel loadings in the mixed conifer type were probably no more than one fourth to one third of present day loading or 12.14 to 18.20 tons per acre (Bradley et al, 1992). There is no current data for the forests in Utah, but it has been reported in the mixed conifer stands in the White Mountains of Arizona that the average fire interval is 22 years (Dieterich, 1983). This average was based on stands with no suppression activities, which favored fire tolerable species such as ponderosa pine. The fire suppression activities practiced over the last century have altered the historic composition of these mixed conifer stands and leaned them towards a white fir stand. As the stand age increases the chance of a crown or stand replacing fire increases (Bradley et al, 1992).

Recreation Resources

Recreation is a primary use of the lands within the spruce zone of the Markagunt Plateau, which encompasses the project area. Recreation sites such as Brian Head Town and Ski Resort, Cedar Breaks National Monument, the Ashdown Gorge Wilderness, the Yankee Meadows Reservoir area, the Navajo Lake area, Duck Creek area, and Panguitch Lake area attract many recreation visitors. The National Parks and Monuments also attract national and international visitation to the Cedar City Ranger District.

Recreation activities include: viewing scenery, watching wildlife, motorcycle and ATV riding, mountain biking, horseback riding, camping, hunting, snowmobile use, cross country and down hill skiing, hiking, fishing and boating. Recreation use on the Cedar City Ranger District has steadily increased, especially from residents of Las Vegas, Nevada; St. George, Utah; Phoenix, Arizona; and southern California (A & A 1994).

Trail Use

Trails adjacent to the analysis area receive heavy to moderate use throughout the summer and fall season by hikers, mountain bikers, and horseback riders. Trail counters on the Virgin River Rim trail recorded 2,130 users in August 1995(Navajo Lake EA, 2001).

Primary use trails in the analysis area include: Virgin River Rim trail, Navajo Lake Loop trail, and the Lodge trail. Secondary use trails in the analysis area include: Dike, Spruce, and Navajo trails.

Hunting And Fishing

Hunting and fishing are popular recreation activities and the area receives use during the general season deer and elk hunts. Blue grouse are hunted along the rim areas. Fishing occurs from the Navajo Lake shore and from small watercraft serviced by permitted boat launch facilities.

Soil, Hydrology, And Fisheries Resources

Geology/Geomorphology/Soils

The Project Area is located near the southwest edge on the Markagunt Plateau, in the Claron Formation. The prominent geology consists of both limestone and lava from volcanic basalt flows. The limestone has numerous fractures, cavities, and solution channels, and the basalt contains many tubes and pockets, all of which influence groundwater flow in the area.

The project area is located on Soil Unit #204, the Buffmeyer-Amesmont families' complex. It is located along the south side of Navajo Lake and consists of deep soils on limestone side slopes (Bayer, 1999).

Hydrology
The Navajo Lake area receives 30 to 40 inches of precipitation annually, mostly in the form of snow. Peak flows in the Duck Creek Watershed occur around May from snowmelt. Navajo Lake was formed when a basalt flow blocked off the surface drainage of Duck Creek. The lake receives a large portion of its inflow from snowmelt and runoff, however it is also fed by subterranean flow through limestone solution channels and tubes and fractures in basalt layers. Several intermittent solution-channel springs on the north shore flow into the lake during snowmelt or from storm runoff, and are often submerged by the lake. Three perennial springs feed the lake, Navajo Lake Spring to the west, and Elderberry and Larson Springs to the southwest, though the flows normally decrease significantly by late summer (Merritt et al, 1996).

Wildlife Resource

The project area is approximately ½ mile from goshawk nesting areas. The territory in which the nesting areas are located was found active in 1995 and produced two fledglings. Two nests were located in large Douglas fir trees (only one was active). In 1996, the territory was occupied (adult male and female birds were seen in the area) but and active nest was not located. The territory was also occupied in 1997 with only the female observed. No goshawk activity was detected from 1998 to 2001. The Virgin River Rim Trail, which was constructed in 1995, passes within 200 yards of both nests (Navajo Lake EA, 2001).

Bald eagles use the Dixie National Forest in fall and early winter (Rodriguez 1998). Habitat around the lake is suitable for bald eagle fall roosting; bald eagles were documented in fall of 1996. There are no nest sites on the Dixie National Forest.

Habitat for mule deer is fair to good, due to presence of cover, water, and the grass/forbs present. Although Rocky Mountain elk are present, they tend to use the higher elevation areas surrounding the lake where more grasses are present, such as Deer Valley. They are not often observed in the campgrounds or along Navajo Lake Road.

Cultural Resources

Human beings have used the project area for at least 8000 years. Cultural Resource surveys have been conducted within the Dixie for over the past 20 years. Within and adjacent to the project analysis area numerous archaeological surveys have been conducted in the past 5 years. Over 1750 sites have been found across the forest, some of these within the project area, and of the 1750, numerous ones have been identified as being Historic Properties. Some types of prehistoric sites identified include, but are not limited to, campsites, stone quarries, tool manufacturing areas, kill sites, and long-term seasonal encampments. Historic period sites include such features as fences, water troughs, corrals, cabins, tin dumps, sheep camps, and sawmill sites are known to exist within the forest.

Quantification of Existing Conditions

Stand Inventory

A 71-acre site, established by the district silviculturalist, which is based on like vegetation, slope, aspect, and encompasses all of the summer homes, has been identified as the project area. The analysis begins by determining the stand composition of the project area by conducting a stand exam. The exam was conducted using Standard Specifications Stand Exam Region Four (USDA Forest Service, 1993). The data was collected on six plots using a centerline azimuth with a fixed distance between plots. The six plots established in the project area result in a coefficient variation percentage of sixty eight, which was desired to be eighty percent or above. After discussing it with the deciding officials and it was determined that the delay to gather more data was more prove to be to costly to the project so the confidence interval of sixty eight percent would be statistically satisfactory for this project. The results from the stand exam data are summarized in Table 1 with the stand exam reports included in Appendix A. The formula to compute percent standard error is shown in figure 1.

Table 1. Stand Density (Trees/Acre)

	Mean	Coefficient of Variation %	Standard Error of the Mean	%Standard Error
Trees/ Acre	**2434**	**68%**	**512**	**19%**

Figure 1. Percent Standard Error Formula

$$\frac{t(CV)}{\sqrt{(n)}} = \%\ \text{Standard Error}$$

Where:

t = critical value of t based on number of plots

CV = coefficient of variation

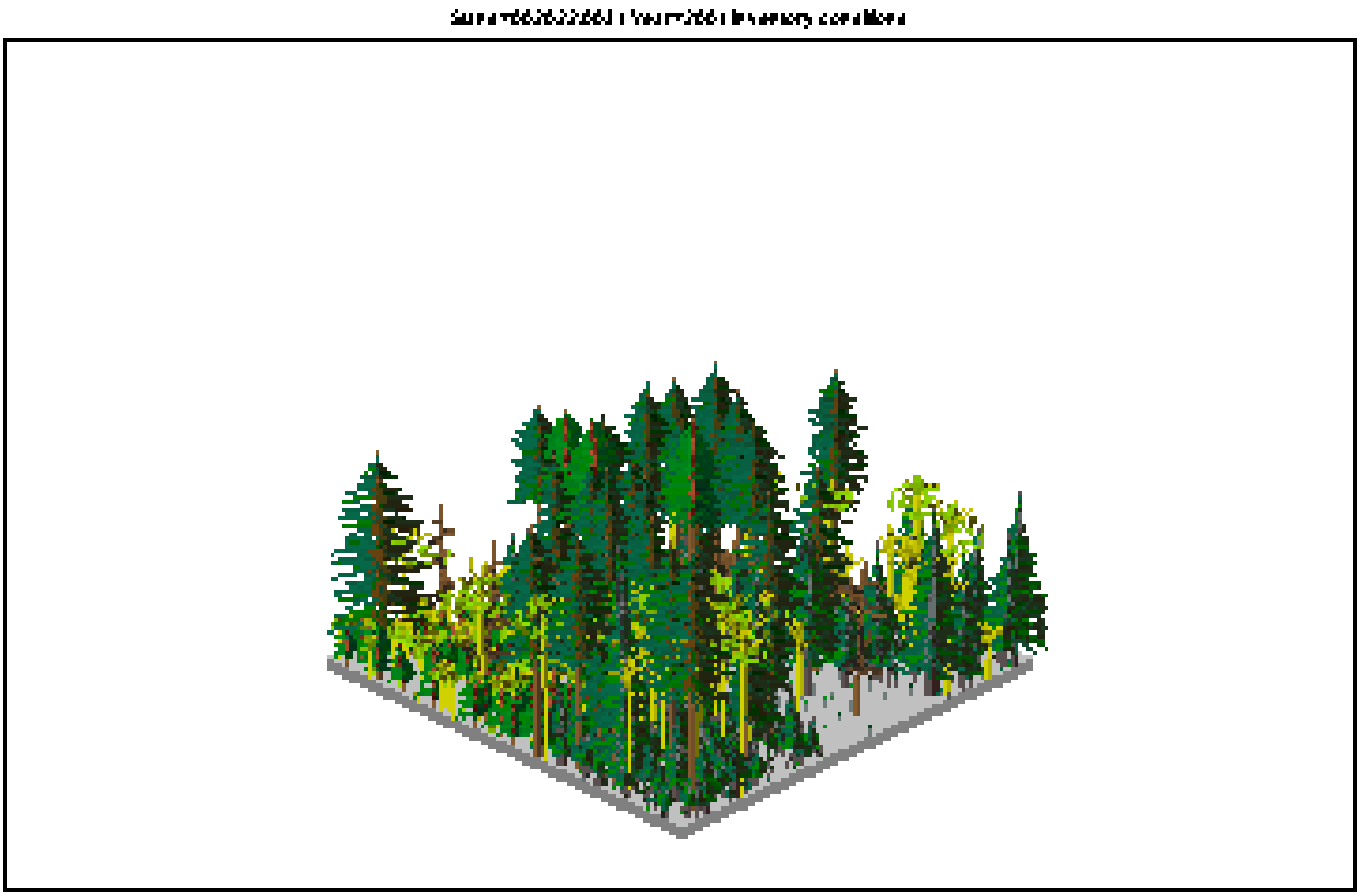
√ = Square root

n = sample size

The stand condition was determined to be functioning non-properly due to overstocking of young immature trees. The stand exam conducted determined the stand density index at (45%) which is a reference index to a stand that is considered to have the desired density to maximize growth, and basal area (152 square ft per acre) which is tree stump base, to be above the recommended levels (50 % SDI and 150 BA) for a properly functioning condition based on an Engelmann Spruce-Sub-alpine Fir stand (Properly Functioning Condition, USDA Forest Service, 1996,).

This stand data was entered into Forest Vegetation Simulator and a model of the existing stand was generated which is displayed in Figure 2.

Figure 2. Current stand profile



Fuel Inventory

An inventory was taken to determine the amount of naturally fallen dead and down woody debris that was present in the stand. Six plots were established on two transect azimuths. A 35' linear transect line was used and fuels were tallied;0-.24" from 0-7', .25"-.9" from 0-7', 1"-2.9" from 0-35', 3"+ from 0-35' (Brown, et. al 1982). The fuel loadings recorded from these plots showed a significant difference in the materials greater than 4 inches in diameter and duff depth. The area itself explains the lack of materials greater than four inches. Summer homes in the area are heated by wood burning stoves or fireplaces and it is determined that most dead and down larger than 4 inches in diameter has been consumed as firewood. The field data was processed using Dead and Down Woody Inventory (Fire Program Solutions, 2001) and the six plots did not capture a statistically sound inventory (more than or equal to a coefficient variation percentage of sixty eight) of the dead and down woody fuels in the project area. Management made the decision to proceed with the project based on the fact that the larger fuel classes and increased duff depth increased fire severity and duration but had a minimal effect on fire intensity, flame length, and fire growth rates. Chart 1 summarizes fuel loading by size class and gives the tons per acre for each class. The fuel loading reports associated with this chart are included in Appendix B.

Chart 1. Dead And Down Fuel Loading

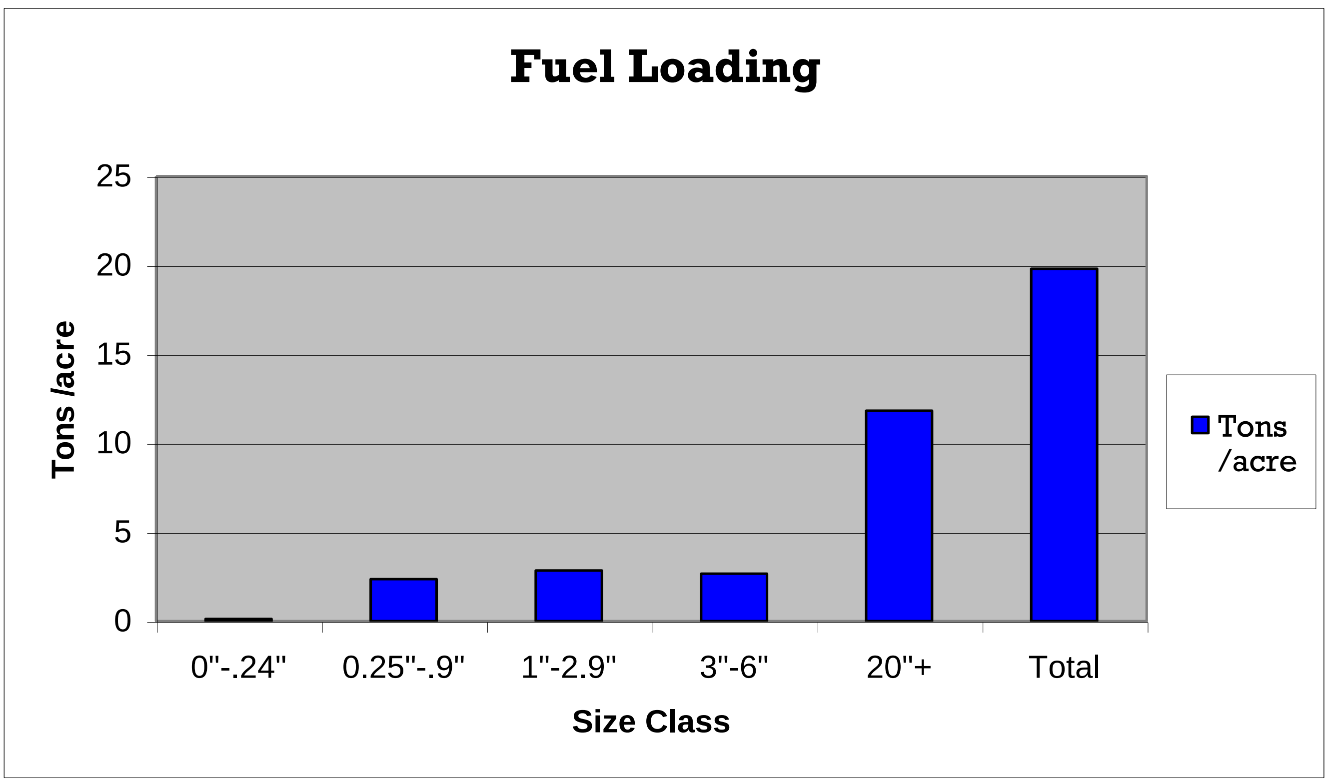


Chart 2 displays the percent standard error associated with each size class. It shows with 68% or greater confidence that they represent the actual loadings except for the 20" plus size class. Using standard error percent we are able to determine that the fuel samples do not reflect the actual loadings for the 20"+ size class. It would be possible to correct this with more sampling but was deemed non-critical due to the time delay and it would be fiscally non-productive for the project so more sampling was not completed. The fuel loading reports associated with this chart are included in Appendix B

Chart 2. Percent standard error for fuel loading

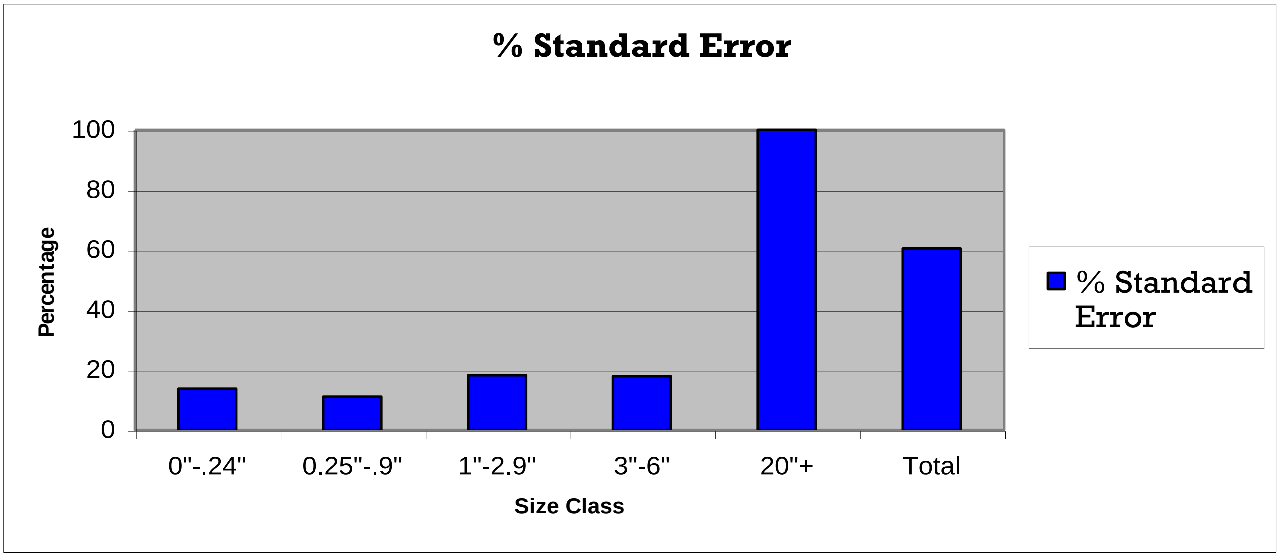


Table 2 shows the average duff and fuel bed depth. The standard error allows us to calculate the coefficient variation, which determines that the fuel bed depth is accurately estimated, but the duff depth generated by the sampling does not meet the 68% degree of confidence desired. This is determined not to be significant and the rationale behind this determination was explained above. The fuel loading reports associated with this chart are included in Appendix B

Table 2. Fuel Bed and Duff Depth

	Duff	Fuel Bed
Average Depth Inches	**0.66**	**0.94**
% Standard Error	**58.54**	**10.9**

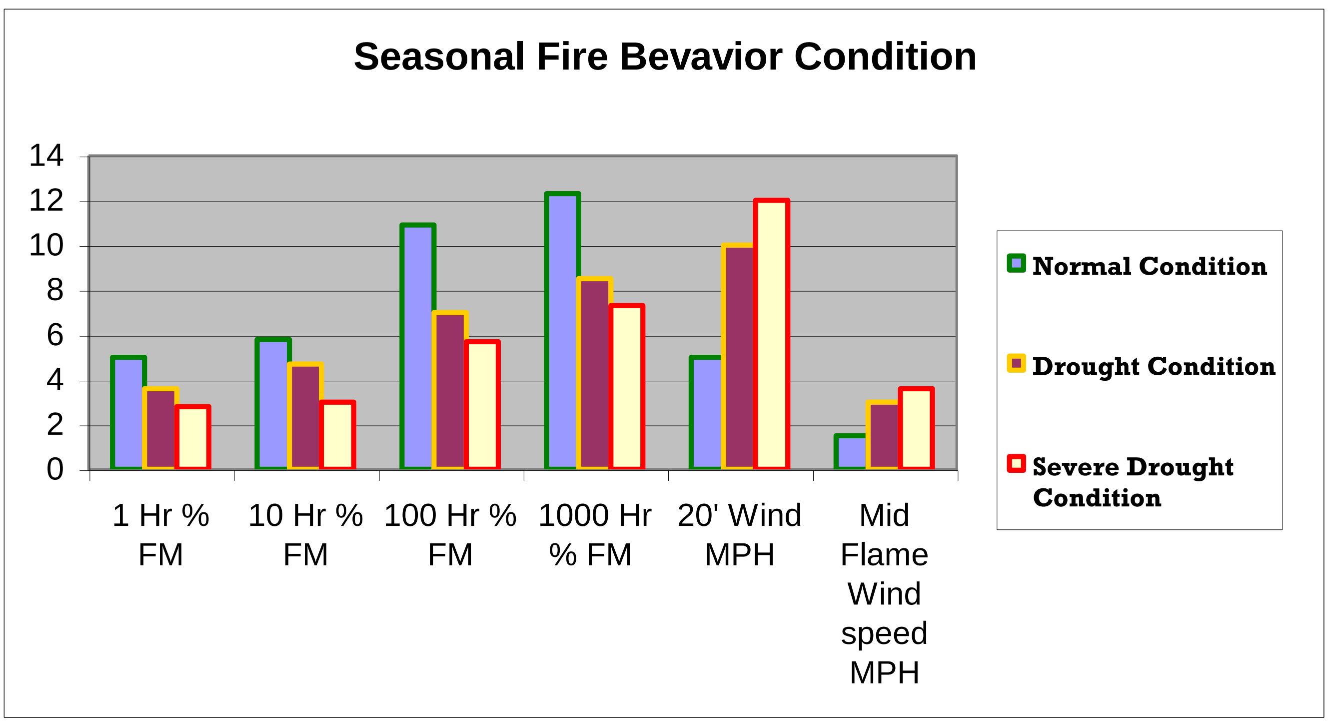
Assumptions:
1. Fuel bed depth entered as 1 inch if between .1 and 1.
2. Aspen was recorded as mixed under species delegation.

Weather Analysis

Historic weather data recorded from the Lava Point Weather Station (422801) was collected from the Kansas City Data Base. Records were received from 1993 to 2001 (9 years). This station is 10 air miles from the project site and is at a similar elevation. This station best represents the weather conditions at the project site.

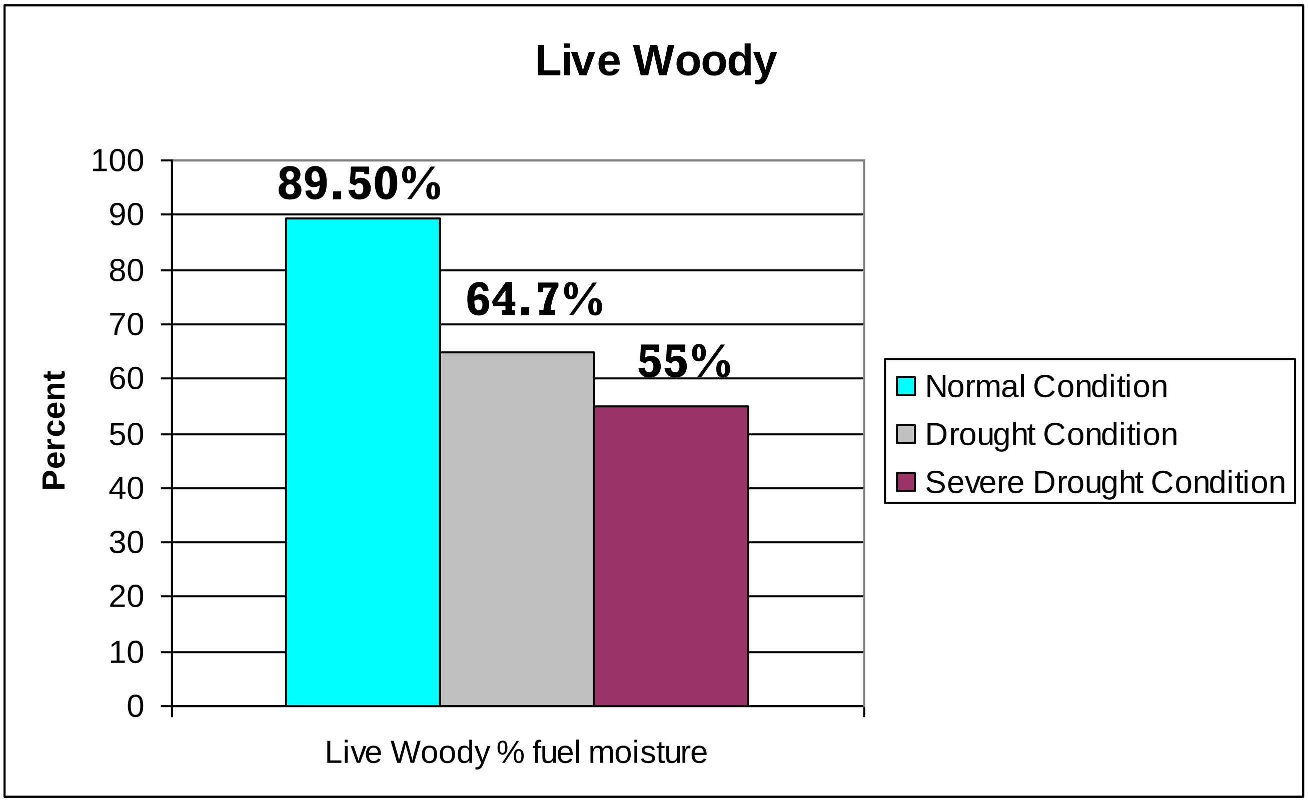
The data collected from Kansas City was processed using the *Firefamily Plus* program (USDA Forest Service, 1999). The average fire season on the Cedar City Ranger District is projected from June 1 thru September 30. Runs were conducted to produce the 50th, 90th, and 97th percentile weather day observations. These percentiles can be approximated to seasonal fire behavior observations where 50th percentile equals "normal conditions," 90th percentile equals "drought condition," and 97th percentile equals "severe drought condition." These comparisons will be used throughout the remainder of the paper. Chart 3 labeled "Seasonal Fire Behavior Condition" summarizes the percentile weather output from *FireFamily Plus* and displays the differences between each of these percentiles. The data supporting these runs are included in Appendix C.

Chart 3. Seasonal Fire Behavior Condition



The live woody fuel moisture percentages are displayed in Chart 4 and the data supporting these runs are included in Appendix C.

Chart 4. Live Woody Fuel Moisture



Fire Behavior Modeling

Current Condition

To calculate the predicted fire behavior for the project area the *Fire Behavior Prediction System, (FBPS*) fuel-modeling system will be used. It is necessary to determine the correct FBS fuel model that represents the fuel type this is based on loading, spacing, profile, and species among other factors. This was determined by using Aids to Determining Fuel Models for Estimating Fire Behavior (Anderson, 1982).

It has been determined that currently the project area is best represented by Fuel Model 10. The basis for this determination is stand inventory and fuel-loading data collected on the site along with local knowledge of the fire behavior previously observed near the site. Fire behavior observed in 2001 showed that the live fuel component was a contributing factor to flame length and fire spread (Orton Fire 2001). This fuel model (FM10) was also run through *Crown Mass* (Fire Program Solutions, 2001) and the critical level for crown fire initiation was not met under severe drought fire behavior conditions, knowing this the rest of the analysis will deal with ground fire and the descriptions and assumptions will be based on ground fire. Given the fire behavior condition stated in the previous section three modeling runs were conducted with each different seasonal fire behavior condition input into *Behave 4.4* (USDA Forest Service). Table 3 displays the outputs from the *Direct* module in *Behave 4.4,* and is included in Appendix D.

Table 3. Predicted Fire Behavior Outputs From Behave 4.4 Fuel Model 10

	Normal Condition	Drought Condition	Severe Drought Condition
Rate of Spread (CH/HR)	2.6	6.9	9.8
Heat per Unit Area (BTU/SQFT)	1338	1475	1562
Fire-line Intensity (BTU/FT/S)	64	187	282
Flame Length (FT)	3	5	6
Reaction Intensity (BTU/SQFT/M)	6146	6781	7176
Mid-flame Wind speed (MI/H)	1.5	3	3.6
Area after 1 Hour (acres)	0.5	2.4	4.4
Perimeter After 1 hour (Chains)	8	18	25

Assumptions:

1) A 0.3 wind adjustment factor was used to model partially sheltered fuels (Rothermel, 1983)
2) Weather analysis was based on observations from June 1- September 30 which is the determined fire season on the Cedar City Ranger District.
3) Weather input was determined by using the 50th, 90th, 97th, percentiles derived by FireFamily Plus and historical weather observations recorded by the Lava Point Weather Station (422801).
4) Behave outputs express conditions at the flaming front of fire.
5) The fire behavior predictions are based on a static fuel bed and weather.
6) The fire behavior predictions are based on a point source ignition.
7) The predictions are based on 0% slope.

After determining the predicted fire behavior with the existing representative fuel model (Fuel Model 10) it was concluded that under drought or severe drought fire behavior conditions, district initial attack resources will not be able direct attack fires (Fire Line Handbook).

Desired Condition

Knowledge of the fuel type and previous treatments of fuel model 10 suggests that treatments resulting in a fuel model 8 could result in fire behavior which would allow initial attack forces to directly attack fires under all seasonal fire behavior conditions.
Fire behavior runs were then calculated for Fuel Model 8 for all seasonal fire behavior conditions. The fire behavior runs indicate that under all seasonal fire behavior conditions the initial attack resources currently staffed on the district would be able to direct attack and contain the fire within 1 hour of ignition. Table 4 displays the outputs for fuel model 8 from the *Direct* module in *Behave 4.4,* and is included in Appendix D.

Table 4. Predicted Fire Behavior Outputs From Behave 4.4 Fuel Model 8

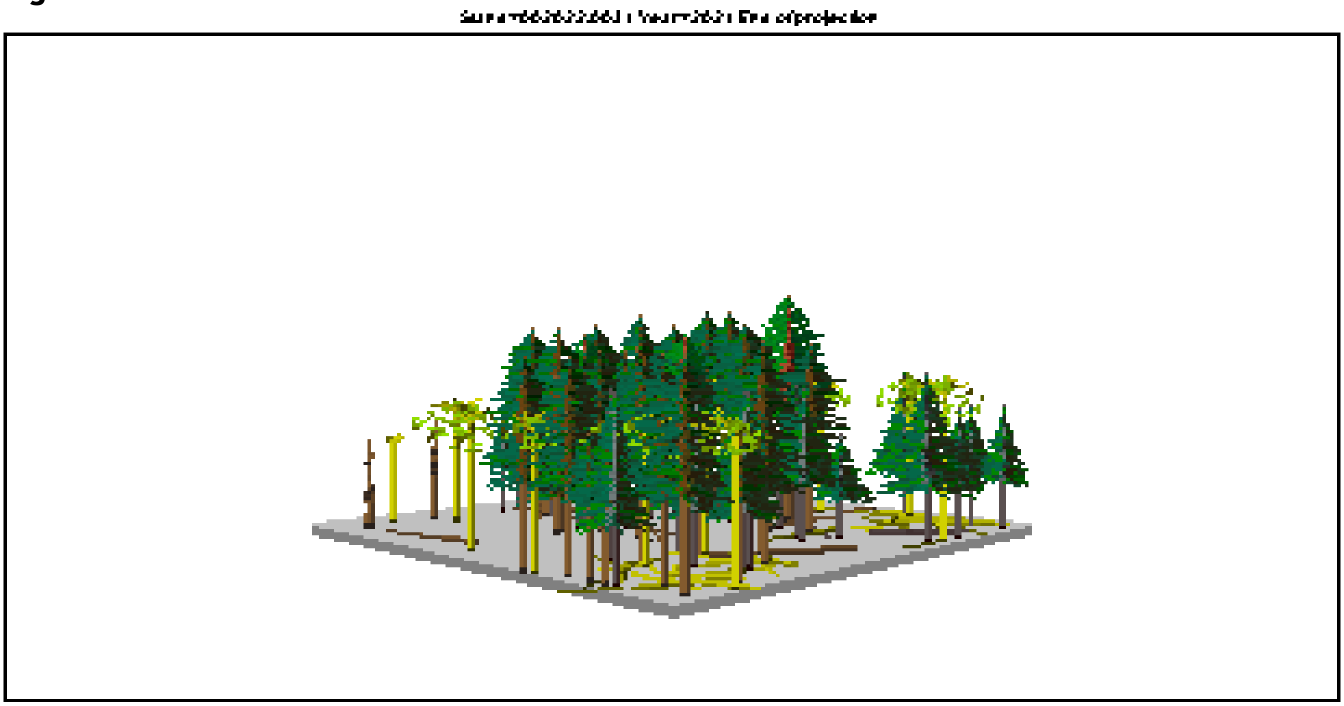
	Normal Condition	Drought Condition	Severe Drought Condition
Rate of Spread (CH/HR)	0.6	1.3	1.8
Heat per Unit Area (BTU/SQFT)	198	216	229
Fire-line Intensity (BTU/FT/S)	2	5	8
Flame Length (FT)	0.6	1	1.1
Reaction Intensity (BTU/SQFT/M)	973	1062	1125
Mid-flame Wind speed (MI/H)	1.5	3	3.6
Area after 1 Hour (acres)	< 0.1	0.1	0.2
Perimeter After 1 hour (Chains)	2	4	5

Assumptions:

1) A 0.3 wind adjustment factor was used to model partially sheltered fuels (Rothermel, 1983)
2) Weather analysis was based on observations from June 1- September 30 which is the determined fire season on the Cedar City Ranger District.
3) Weather input was determined by using the 50^{th}, 90^{th}, 97^{th}, percentiles derived by FireFamily Plus and historical weather observations recorded by the Lava Point Weather Station (422801).
4) Behave outputs express conditions at the flaming front of fire.
5) The fire behavior predictions are based on a static fuel bed and weather.
6) The fire behavior predictions are based on a point source ignition.
7) The predictions are based on 0% slope.

Forest Vegetation Simulator (USDA Forest Service) was used with the stand exam data to create a model of the current stand, which is displayed in Figure 1. That stand was processed also using *Forest Vegetation Simulator* to create a model representing fuel model 8. The desired fuel model 8 is demonstrated in Figure 3.

Figure 3. Desired Stand Profile: Fuel Model 8



Probability Of Fire

The probability of an unplanned ignition that would likely cause damage to the summer homes is determined in this section. The assumptions and criteria that the probability is based on is also explained and presented in this section.

It has been determined that fires having flame lengths greater than 4 feet and rates of spread greater than 6.9 chains per hour are be more likely to allude control efforts of initial attack resources staffed on district (Fire Line Hand Book, 2001). Current stand conditions produce fires with flame lengths and rates of spread that permit to exceed 0.2 acres within 1 hour of ignition. These fires have been determined to be more likely to cause damage to the summer homes and therefore the critical threshold for fire size was set at fires greater than 0.2 acres, 1 hour after ignition.

The computer program *Probarce* (Wiitala, M.R., 1992) was used to determine the probability of an unplanned ignition in the analysis area. *Probarce* assesses risk based on historical fire occurrence data and makes probability estimates based on the Poisson probability model (Figure 4) to generate output.

Figure 4. Poisson Probability Model

$f(x) = \lambda^x * e^{-\lambda} / x!$

Where:

λ = Mean # of occurrences in a given time interval (i.e. annual fire frequency)

X = random variable with possible values 0,1,2….

e = 0.1653 (Modern Elementary Statistics, Table XI)

To analyze the historical fire occurrence, the Duck Creek Watershed was determined to be an accurate representation for the project area. The watershed is 22,611 acres with 13,099 acres of vegetation, which is predominantly a Sub-alpine fir/spruce mix. This was determined using GIS soils data for the watershed.

Historical fire records dating back to 1972 are available and are primarily location and size. There were fifty-two fires recorded in the watershed from 1972-2001, seven of these were larger than .2 acres. The probability was predicted for a twenty-year time horizon. This data was the entered into *Probacre* and output data displayed in Chart 5, shows the probability of having multiple fires greater than 0.2 acres in the given years of the time horizon. The *Probacre* output data is included along with historical fire record information in Appendix E.

Table 4. Probability For # Of Fires > .2 Acres

Time years	Number of Fires > .2 Acres					
	0 Fires	**1 Fire**	**2 Fires**	**3 Fires**	**4 Fires**	**>4 Fires**
5	0.993	0.006	0.000	0.000	0.000	0.000
10	0.988	0.012	0.000	0.000	0.000	0.000
15	0.981	0.018	0.000	0.000	0.000	0.000
20	0.97	0.024	0.000	0.000	0.000	0.000

Assumptions:

1. This analyzes all reported ignitions natural and human caused.
2. Ignitions historically occurred at given rate and are expected to continue at that rate.
3. Ignitions are based on 13,099 acres of vegetated area in the watershed, which were derived by soil type data in GIS.

The Duck Creek Watershed Analysis Area is 22,611 acres with 13,099 acres of vegetated acres and encompasses the smaller 71- acre project site. In an effort understand relative risk to the project site based on historic occurrence within the greater fire frequency analysis area, the area was divided into parcels for further analysis and the probability was projected for a twenty-year time horizon.

Dividing the watershed into equal vegetated areas the size of the project area (71 Acres) produces 184 parcels of equal size, which will be used to narrow the analysis. The probability associated with any time horizon free of fires greater than 0.2 acres can be calculated for an unplanned ignition in any one parcel.

This was accomplished by using data from Table 4, which uses *Probacre* output to generate an expected value, where E. V. equals the summation of all products of probabilities and number of fires greater than.2 acres occurring in the analysis area for any year in the planning horizon.

Figure 5. Expected Value per Time Span

E.V.= sum {X*f(x)}

Where:

E.V. = Expected value
X= number of fires
f(x)= probability

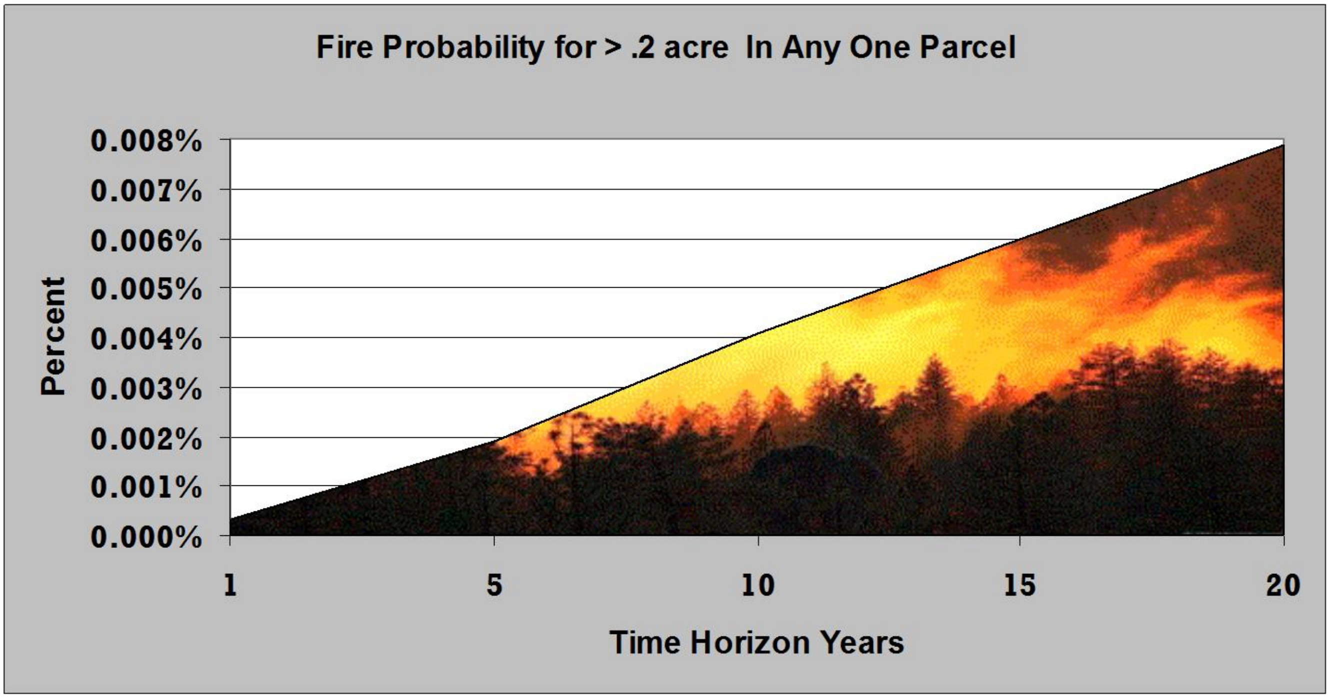
The probability of an unplanned ignition greater than 0.2 acres in any 71-acre parcel, including the project site, can be calculated by dividing the expected value of the random variable by the number of 71-acre parcels in the area (184). The probability associated with a fire in the Duck Creek Water Shed and the project area for the 5th, 10th, 15th and 20th year of the twenty-year time horizon is summarized in Table 5 and the *Probacre* output table is found in Appendix E.

Table 5. Probability Of a Fire Greater Than .2 acre In Any One Parcel

Time Horizon Years	Expected # of Fires > .2 acres in Duck Creek Water Shed	Probability of Fire > .2 acres in Project Area
5	0.006	0.00002
10	0.013	0.00004
15	0.019	0.00006
20	0.025	0.00008

Chart 5 shows the probability of an unplanned ignition in any of the 71-acre vegetated parcels within the Duck Creek Water Shed including the 71- acre project area. The *Probacre* output table supporting this data is found in Appendix E.

Chart 5. Fire Probability for > .2 acre in any One Parcel over 20 years



If unplanned ignitions resulting in fires greater than 0.2 acres remain constant for the next twenty years throughout the project area, there is a 0.008% chance of an unplanned ignition greater than 0.2 acres in the next 20 years. This probability is based on a 71-acre parcel size.

Assumptions:

1. Fuels are constant and ignitions occur randomly across the project area analysis area.
2. Seasonal weather is assumed to be constant: past, present and future.

Economic Analysis

Economic analysis was conducted to determine the value(s) at risk and the risk associated with a variety of mechanical treatments proposed in the following alternatives.

Alternatives Considered

1. Mechanical treatment and monitoring that will limit maximum flame lengths to 1 Feet under severe drought condition with fuel loadings less than 5 tons per acre with re-entry every 20 years. (Thinning and Chipping)
2. Mechanical treatment, pile burning and monitoring that will limit maximum flame lengths to 1 Feet under severe drought condition with fuel loadings less than 5 tons per acre with re-entry every 20 years. (Thinning, Hand Piling and Burning.
3. Mechanical treatment, pile burning and monitoring that will limit maximum flame lengths to 1 Feet under severe drought condition with fuel loadings less than 5 tons per acre with re-entry every 20 years. (Thinning, Machine Piling and Burning)
4. No action.

Valuation Of The Summer Homes

Although the land the summer homes are built on is federally owned, the homeowners still have equity in the structures themselves and are taxed on these properties. The total market value (taxable value) for the 33 summer homes is $827,846(Kane County Tax Commission, 2002) and information regarding these values is included in Appendix F.

An assumption was made that fires greater than 0.2 acres in the project area were more likely to damage or destroy the summer homes. It was also determined that treatment objectives would result in conditions that meet fire behavior and fuel loading objectives for a 20 year period with a planning horizon of twenty years.

The present market value of the summer homes is $827,846, and a planning horizon of 20 years, gives an expected value of the homes to be $1,813,913 (current discount rate = .04) at the end of the planning period (twenty years). To accomplish this, the compounding formula shown in Figure 5 was applied using a discount rate of 4% and present value of $827,846, which generated an expected value for the summer homes twenty years into the future.

Figure 6. Compounding

$$V_n = V_0 (1+i)^n$$

Where:

V_0 = present value (time is now = 0)

V_n = value in year n

i = discount rate (annual)

Treatment Costs

Treatment costs were calculated using a variety of treatment alternatives derived from current practices currently used throughout the forest. Costs per acre were derived from discussion with the District silviculturist and current planning costs on the Dixie National Forest. Table 6 displays the costs associated with each individual treatment.

Table 6. Treatment Cost Per Acre

Treatment	Cost / Acre
Thinning	$100
Chipping	$300
Hand Piling	$250
Machine Piling	$40
Pile Burning	$15
Monitoring	$5

The cost of monitoring remained constant for alternatives1, 2 and 3. To generate cost per acre multiply $ figure from Table 6 by 71 (project size in acres). Monitoring was conducted at year 0, 5, 10, 15, and 20 over a 20 year planning horizon and a terminable periodic annuity/cost formula shown in Figure 4, was applied. The formula calculates the cost of the monitoring by projecting the cost in each year using a discount rate of 4 percent.

Figure 7. Terminable Periodic Series

$$V_0 = a\{1-(1+i)^{-n}\}/\{(1+i)^t-1\}$$

Where:

V^0= present value
a = periodic payment
i = Discount rate = .04
n = number of years from the beginning of the period to the end
t = the period (number of years) that a repeats

The number of acres in the project area (71) was multiplied by estimated treatment costs from Table 6, and total estimated costs for each treatment were generated, and are displayed in Table 7.

Table 7. Total Cost For Each Treatment

Treatment	Cost per Acre	Acres	Total Estimated Cost for Project Area
Thinning	$100	71	$7,100
Chipping	$300	71	$21,300
Hand piling	$250	71	$17,750
Machine piling	$40	71	$2,840
Pile Burning	$15	71	$1,065
Monitoring*	$5	71	$891

*Monitoring takes place at year 0, 5, 10, 15, and 20. Discounted present net cost equals $891 over the 20 year planning horizon.

Total Cost For Each Alternative

Alternative 1) Mechanical Treatment A: Thinning, chipping and monitoring.
Thinning, chipping and planning takes place at year 0 and monitoring takes place at year 0, 5, 10, 15, and 20. Discount present net cost equals: **$29,291**

Alternative 2) Mechanical Treatment B: Thinning, hand piling, pile burning and monitoring.
Thinning, hand piling and planning takes place at year 0 and monitoring takes place at year 0, 5, 10, 15, and 20. Discount present net cost equals: **$26,806.**

Alternative 3) Mechanical Treatment C: Thinning, machine piling, pile burning and monitoring.
Thinning, machine piling and planning takes place at year 0 and monitoring takes place at year 0, 5, 10, 15, and 20. Discount present net cost equals: $11,896

Alternative 4) No Action

Assumptions:

1) Slope of project area is conducive to use of mechanized equipment.
2) Costs are projected estimates and are assumed to remain constant throughout completion of project.
3) Pile burning takes place after sufficient amount of snow has reduced the risk of fire spread.

Expected Value Of The Risk

To complete the analysis expected value of the risk of the risk must be determined. This is accomplished by multiplying the probability of the event and the present net value.

In determining the expected value risk, it was assumed that if any of the treatments were completed, the fuel profile of the stand would change from the existing fuel model 10 to a fuel model 8 *(FBPS)*. With this assumption, any unplanned ignition in project area could be contained at .2 acres or less within one hour of ignition during severe drought seasonal fire behavior conditions. The following table displays the present value for the summer homes in the year indicated. This value is then multiplied by the associated probability of having a fire greater than 0.2 acres in the project area, which gives us the expected value at risk for the each year listed in Table 7. The present net value is the present value for that year minus expected value risk and treatment cost. This is summarized in Table 7.

Table 7. Present Net Value And Expected Value Risk

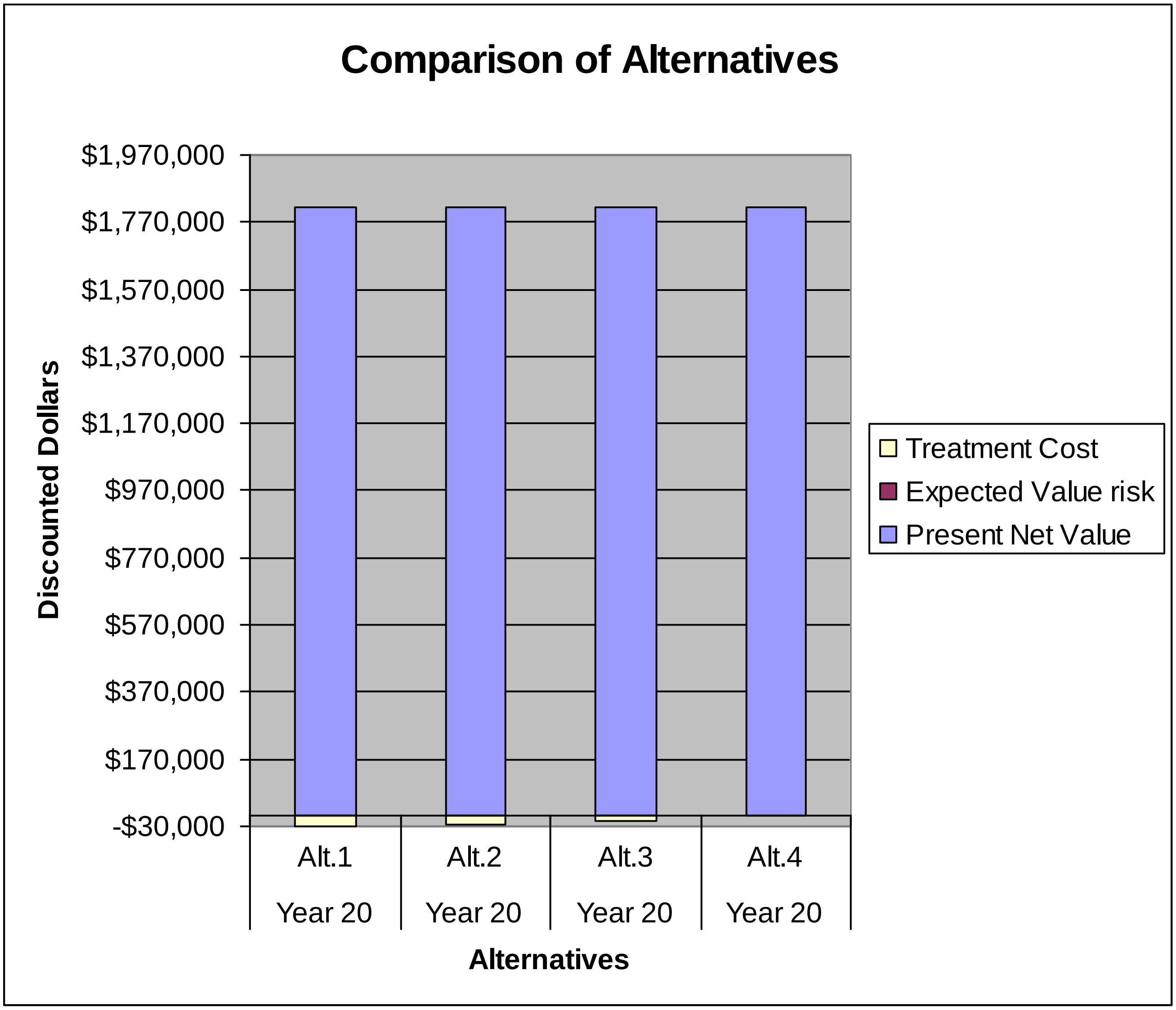
Alternative	Year	Present Value	Associated Probability Fire Size > .2 Acres within 1 Hour Of Ignition	Expected Value risk	Treatment Cost	Present Net Value
1	20	$1,813,913	0	$0	-$29,291	$1,784,622
2	20	$1,813,913	0	$0	-$26,806	$1,787,107
3	20	$1,813,913	0	$0	-$11,896	$1,802,017
4	5	$1,007,201	0.00002	-$19	$0	$1,007,182
	10	$1,225,414	0.00004	-$50	$0	$1,225,364
	15	$1,490,904	0.00006	-$89	$0	$1,490,815
	20	$1,813,913	0.00008	-$143	$0	$1,813,770

Alternatives

1. Thinning, chipping and monitoring.
2. Thinning, hand piling, pile burning, and monitoring.
3. Thinning, machine piling, pile burning and monitoring.
4. No action.

The present net value for year twenty, cost of alternatives and expected value at risk for each alternative in year twenty is displayed in Chart 7. The expected value risk is not visible due to the small value that it represents.

Chart 7. Comparison Of Alternatives



Assumptions:

1. Monitoring costs will stay constant over the 20-year analysis.
2. Economic analysis is derived using seasonal fire behavior, probability analysis and fire behavior modeling.
3. Unplanned ignitions in treated areas (fuel model 8) will be contained within one hour.
4. Project area slope is not that to exceed use of mechanized equipment.

Possible Silvicultural Prescription for Thinning

Cut all trees except aspen less than 5 inches DBH (Diameter Breast Height) when in a 30' proximity to trees over 8" DBH and with thirty-foot spacing when < 5" diameter trees are exclusive. Spruce and aspen would be the favored species. Stand exam info data lists 2233 trees per acre with DBH < 5" if 90% of these trees are removed the current stands will be altered from a fuel model 10 to the preferred fuel model 8. This will hold true for alternatives 1, 2, and 3.

Consideration of Alternatives as Related to Objectives

Alternative 1) Mechanical Treatment A: Thinning, Chipping, Monitoring

This alternative would change the fuel profile in a way that unplanned ignitions, burning under severe drought seasonal fire behavior conditions, would have flame lengths and rates of spread modeled by *Behave,* which would allow local initial attack forces to direct attack and contain a fire within one hour of ignition (Fire Line Hand Book). This alternative would reduce stand density and fuel loadings to a level, that if an unplanned ignition resulted in a fire that burned into the project area, fire behavior would be reduced to a level that suppression forces could safely perform structure defense procedures.

This alternative has the lowest expected value risk, equal to that of alternatives 2 and 3, and the lowest present net value for the twenty-year planning horizon of the four alternatives proposed.

Alternative 2) Mechanical Treatment A: Thinning, Hand piling, Pile Burning, Monitoring

This alternative would also change the fuel profile in a way that unplanned ignitions, burning under severe drought seasonal fire behavior conditions, would have flame lengths and rates of spread modeled by *Behave,* which would allow local initial attack forces to direct attack and contain a fire within one hour of ignition (Fire Line Hand Book). This alternative would reduce stand density and fuel loadings to a level, that if an unplanned ignition resulted in a fire that burned into the project area, fire behavior would be reduced to a level that suppression forces could safely perform structure defense procedures.

This alternative has the lowest expected value risk, equal to that of alternatives 1 and 3, and the second lowest present net value for the twenty-year planning horizon of the four alternatives proposed.

Alternative 3) Mechanical Treatment A: Thinning, Machine piling, Pile Burning, Monitoring

This alternative would also change the fuel profile in a way that unplanned ignitions, burning under severe drought seasonal fire behavior conditions, would have flame lengths and rates of spread modeled by *Behave,* which would allow local initial attack forces to direct attack and contain a fire within one hour of ignition (Fire Line Hand Book). This alternative would reduce stand density and fuel loadings to a level, that if an unplanned ignition resulted in a fire that burned into the project area, fire behavior would be reduced to a level that suppression forces could safely perform structure defense procedures.

This alternative has the lowest expected value risk, equal to that of alternatives 1 and 2, and the second highest present net value for the twenty-year planning horizon of the four alternatives proposed.

Alternative 4) No Action

Potential damage to the homes from fire exists based on historic fire data and predicted seasonal fire behavior conditions. The probability of a fire causing damage and the expected loss over a twenty-year planning period is lower than the costs associated with doing the mechanical treatments suggested in alternatives 1,2,and 3.
This alternative has the highest expected value risk and the highest present net value for the twenty-year planning horizon of the four alternatives proposed.

Recommended Alternative and Rationale

The recommended alternative is Alternative 3) Mechanical Treatment C: Thinning, machine piling, pile burning and monitoring.

This alternative meets the goal as measured by the criteria in all of the objectives. It complies with National Fire Plan and in the event of an unplanned ignition, predicted fire behavior is limited to acceptable levels and fire containment is probable within the first hour of ignition at a size of .2 acres or less. The area is also more defendable if a larger fire were to burn into the project area.

Economic efficiency was taken into consideration when analyzing the alternatives, but was not a factor that contributed to meeting the objectives. Alternative 3 has the lowest expected value at risk, equal to alternative 1 and 2, and has the present net value of $1,802,017 second only to the no action alternative.

If the only basis used to select an alternative were economics then Alternative 4 would have been the obvious choice for the preferred alternative. Despite the need to better manage federal dollars, it has been proven time and again that a small amount of prevention and treatment prior to an event can be invaluable. Although the probability of wild fire in the project area has been shown to be small, there is still some risk. This risk cannot be totally eliminated while maintaining desired conditions of the forest and adhering to current policy, but it can be reduced by a significant amount.

Beyond the reduction of damage caused to a summer home by wildfire, the rationale behind selecting Alternative 3 is to ensure the public that federal land managers are concerned with safety of life, and property as well as the health of the ecosystem. There are values indirectly related to the summer homes that cannot be measured by expected values at risk, yet are still real values that are to subjective too be captured by dollar figures.

It is probable that fire data dating back further than records kept in federal archives, would show that the stand would eventually burn with a stand replacing fire if there is no intervention. We are also finding out that suppression efforts used to combat these stand replacing fires is getting more expensive each fire season. The exclusion of fire burning in its natural regime has created an abundance of fuels that historical fire data may not be able to accurately model even using the best science and technology.

The National Fire Plan has mandated that federal agencies work with communities at risk to reduce the threat of a wildfire. This has to be managed in a way that is beneficial to the taxpayers as well the ecosystem. Alternative 3 addresses the mandate, keeps economic efficiency in mind, and maintains the ecosystem, thus using the art of compromise to attain goals and mitigate problems.

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Appendix List

Appendix A
Stand Exam Reports

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Summer Home Market Values 2002

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Appendix A
Stand Exam Reports

Appendix B
Fuel Loading Reports

Dead and Down Woody Inventory - Planar Intercept Loading

Site: **Navajo Lake Summer Homes**
Organization: **Dixie National Forest, Cedar City Ranger District**
Acres: **71**
Taken By: **Clint Coates, Nan Coates, Steve Barker, Andrea Howard**
Date Taken: **06/27/2001**

Inventory Parameters:

Age Class: **Natural** Percent Foliage Retained(%): **0**

Transect Lengths(ft):		3"+ Class Breaks	0-3" Fuel Composition:	
0"-.24":	**7**	**3" - 6"**	**0**%	**0** Avg DBH (in.)
.25"- .9":	**7**	**6" - 9"**	**0**%	**0** Avg DBH (in.)
1"-2.9":	**35**	**9" - 20"**	**0**%	**0** Avg DBH (in.)
3"+:	**35**	**20" +**		

Fuel Loading and Depth Results:

Plot	0"-.24"	.25"-.9"	1"-2.9"	Total 0"-2.9"	3"-6"	6"-9"	9"-20"	20"+	3"+	Plot Total	Avg. Duff Depth Inches	Avg. Fuelbed Depth Inches
	<--	Tons Per Acre							-->			
1	**0.11**	**2.34**	**2.90**	**5.36**	**1.11**	**0.00**	**0.00**	**0.00**	**1.11**	**6.46**	**2.55**	**1.33**
2	**0.07**	**1.83**	**1.66**	**3.56**	**3.94**	**0.00**	**0.00**	**0.00**	**3.94**	**7.50**	**0.38**	**1.00**
3	**0.14**	**1.56**	**1.66**	**3.36**	**3.08**	**0.00**	**0.00**	**0.00**	**3.08**	**6.44**	**0.00**	**0.67**
4	**0.16**	**2.61**	**4.56**	**7.33**	**1.97**	**0.00**	**0.00**	**0.00**	**1.97**	**9.30**	**0.15**	**1.00**
5	**0.19**	**2.35**	**4.15**	**6.68**	**1.97**	**0.00**	**0.00**	**70.89**	**72.86**	**79.55**	**0.50**	**1.00**
6	**0.11**	**3.39**	**2.08**	**5.57**	**3.94**	**0.00**	**0.00**	**0.00**	**3.94**	**9.51**	**0.38**	**0.67**
Mean:	**0.13**	**2.35**	**2.84**	**5.31**	**2.67**	**0.00**	**0.00**	**11.82**	**14.48**	**19.79**	**0.66**	**0.94**
S.D.:	**0.04**	**0.64**	**1.27**	**1.61**	**1.17**	**0.00**	**0.00**	**28.94**	**28.62**	**29.30**	**0.94**	**0.25**
S.E.:	**0.02**	**0.26**	**0.52**	**0.66**	**0.48**	**0.00**	**0.00**	**11.82**	**11.68**	**11.96**	**0.39**	**0.10**
%Err:	**13.78**	**11.11**	**18.28**	**12.37**	**17.88**	**0.00**	**0.00**	**100.00**	**59.03**	**60.44**	**58.54**	**10.85**

Needle Loading (Tons Per Acre): **0.00**
Total Needle and Dead Down Loading (Tons Per Acre): **19.79**

Species Delineation:

Tons Per Acre

	3"- 6"	6"- 9"	9"- 20"	20"+	Total
Alpine Fir	**1.68**	**0.00**	**0.00**	**0.00**	**1.68**
Engl. Spruce	**0.00**	**0.00**	**0.00**	**11.82**	**11.82**
Mixed	**0.66**	**0.00**	**0.00**	**0.00**	**0.66**
Rotten	**0.33**	**0.00**	**0.00**	**0.00**	**0.33**
Total:	**2.67**	**0.00**	**0.00**	**11.82**	**14.48**

Dead and Down Woody Inventory - Planar Intercept Input Data

Site: **Navajo Lake Summer Homes**
Organization: **Dixie National Forest, Cedar City Ranger District**
Acres: **71**
Taken By: **Clint Coates, Nan Coates, Steve Barker, Andrea Howard**
Date Taken: **06/27/2001**

Inventory Parameters:

Age Class: **Natural** Percent Foliage Retained(%): **0**

Transect Lengths(ft):		3"+ Class Breaks	0-3" Fuel Compostion:		
0"-.24":	**7**	**3" - 6"**	**0**%	**0**	Avg DBH (in.)
.25"- .9":	**7**	**6" - 9"**	**0**%	**0**	Avg DBH (in.)
1"-2.9":	**35**	**9" - 20"**	**0**%	**0**	Avg DBH (in.)
3"+:	**35**	**20" +**			

Plot Data:

Plot	Slope	Fuel Bed Depth (in.) 1	2	3	Duff Depth (in.) 1	2	<------Particle Count-----> 0-.24"	.25"-.9"	1"-2.9"
1	**0**	**2**	**1**	**1**	**3**	**3**	**8**	**9**	**7**
2	**5**	**1**	**1**	**1**	**0**	**1**	**5**	**7**	**4**
3	**3**	**0**	**1**	**1**	**0**	**0**	**10**	**6**	**4**
4	**2**	**1**	**1**	**1**	**0**	**0**	**12**	**10**	**11**
5	**2**	**1**	**1**	**1**	**1**	**1**	**14**	**9**	**10**
6	**3**	**0**	**1**	**1**	**1**	**0**	**8**	**13**	**5**

3"+ Material:

Plot	Species	Diameters																		
1	**Alpine Fir**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2	**Alpine Fir**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2	**Rotten**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
3	**Alpine Fir**	**5**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
4	**Alpine Fir**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
5	**Alpine Fir**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
5	**Engl. Spruce**	**24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
6	**Mixed**	**4**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Appendix C
Weather Data and FireFamily Plus Reports

Appendix D
Fire Behavior Run Data

Appendix E
Probacre Run Data
Historical Fire Occurrence Data

Historical Fire Occurrence 1972-2001

	REF_NUM	FIRE_NAME	YEAR	MONTH	DAY	STAT_CAUSE	ACRES
1	33	DUCK CREEK RIDGE	1998	10	9	4	0.10
2	64	Ice Cave	1995	9	11	1	0.10
3	85	ASPEN MIRROR	1996	5	6	4	0.10
4	91	MOVIE RANCH	1996	6	6	1	0.10
5	154	A-SEVEN	1996	7	26	1	0.50
6	250	DUCK CREEK	1997	7	4	9	0.10
7	251	DUCK POND	1997	7	5	3	0.10
8	0		1970	6	7	4	0.10
9	0		1970	6	28	4	0.10
10	0		1970	8	14	1	0.10
11	0		1971	6	24	3	0.10
12	0		1971	6	27	4	0.10
13	0		1971	8	5	1	0.10
14	0		1972	7	31	1	0.10
15	0		1973	9	3	3	0.10
16	0		1973	9	3	3	0.10
17	0		1974	7	6	4	0.10
18	0		1974	8	1	1	0.10
19	0		1976	6	20	3	1.00
20	0	DEER HOLLOW	1977	7	13	1	0.10
21	0		1977	8	8	1	2.00
22	0		1978	8	6	1	0.10
23	0		1978	8	20	3	0.10
24	0		1978	9	7	1	0.10
25	0		1978	9	9	4	0.10
26	0		1979	8	10	2	0.10
27	0		1979	8	11	1	0.10
28	0		1980	8	18	3	0.10
29	0		1981	8	1	3	0.10
30	0		1981	8	10	1	0.10
31	0		1981	8	18	1	0.10
32	0		1982	6	1	3	0.10
33	0		1983	7	9	1	0.10
34	0		1984	8	17	1	0.10
35	0		1988	7	30	3	0.10
36	0		1989	6	14	3	0.10
37	0		1989	7	3	4	4.00
38	0		1990	6	23	3	0.50
39	0		1990	8	9	1	0.10
40	0		1990	10	16	5	0.10
41	0		1991	7	1	3	0.20
42	0		1991	10	14	3	5.00
43	0		1992	8	11	1	0.10
44	0		1992	10	10	9	0.20
45	0		1994	6	26	3	0.10
46	0		1994	7	6	4	0.10
47	0		1994	7	6	3	0.50
48	0		1994	7	8	4	0.10
49	0		1994	7	9	3	0.10
50	0		1994	7	26	1	0.10
51	0		1994	7	28	4	0.10
52	0		1994	8	13	1	0.10

Appendix F

Summer Home Market Values 2002

Appendix G
Maps