

FOREST RESOURCES  
ON STATE FOREST LANDS  
IN THE COPPER RIVER BASIN  
A PRELIMINARY ESTIMATE

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## I. EXECUTIVE SUMMARY

The inventory of timber and biomass resources on state lands classified for forestry use in the Copper River Basin has been initiated in part by the need to support potential development of biomass energy systems in this rural area of Alaska. Through funding provided by the Alaska Energy Authority, State Division of Geologic and Geophysical Surveys, and State Division of Forestry, a timber and biomass inventory has been conducted using satellite and aerial photography, ground plots and other information sources. Automated eCognition object based image classification software together with Summit Evolution stereo viewing software was used to facilitate forest typing of individual stand polygons. The inventory provides detailed stand type maps and internet mapping and querying capability. It is the first widespread stand based inventory to be performed on state lands in the area and can be used by the Division of Forestry (DOF) for general forest and fire management planning. State lands that are included have been classified for forestry use through the Copper River Basin Area Plan. The volume data primarily has been generated from timber stand data collected in September, 2009.

	<u>Acres</u>	
Inventory Area Land Classification		
Timberland	219,550	
Dwarf Forests	96,880	
Non-Forest	<u>119,227</u>	
Total Inventory Area:	435,657	
Timberland Area by Timber Type Size Class		
Sawtimber	6,756	
Mixed Sawtimber/Poletimber	11,372	
Poletimber	96,408	
Reproduction	<u>105,014</u>	
Total Timberland Area:	219,550	
Timberland Area by Timber Type Species Class		
White Spruce	6,756	
Black Spruce/White Spruce	105,014	
Aspen	11,738	
White Spruce/Aspen	33,822	
White Spruce/Balsam Poplar	<u>11,372</u>	
Total Timberland Area:	219,550	
Total Net Volume		
Cubic Feet ( $\geq 5''$ dbh)	Tons ( $\geq 5''$ dbh)	Board Feet ( $\geq 9''$ dbh)
138,373,108	2,497,118	222,449,137

Table 1. Inventory volume and acreage summary.

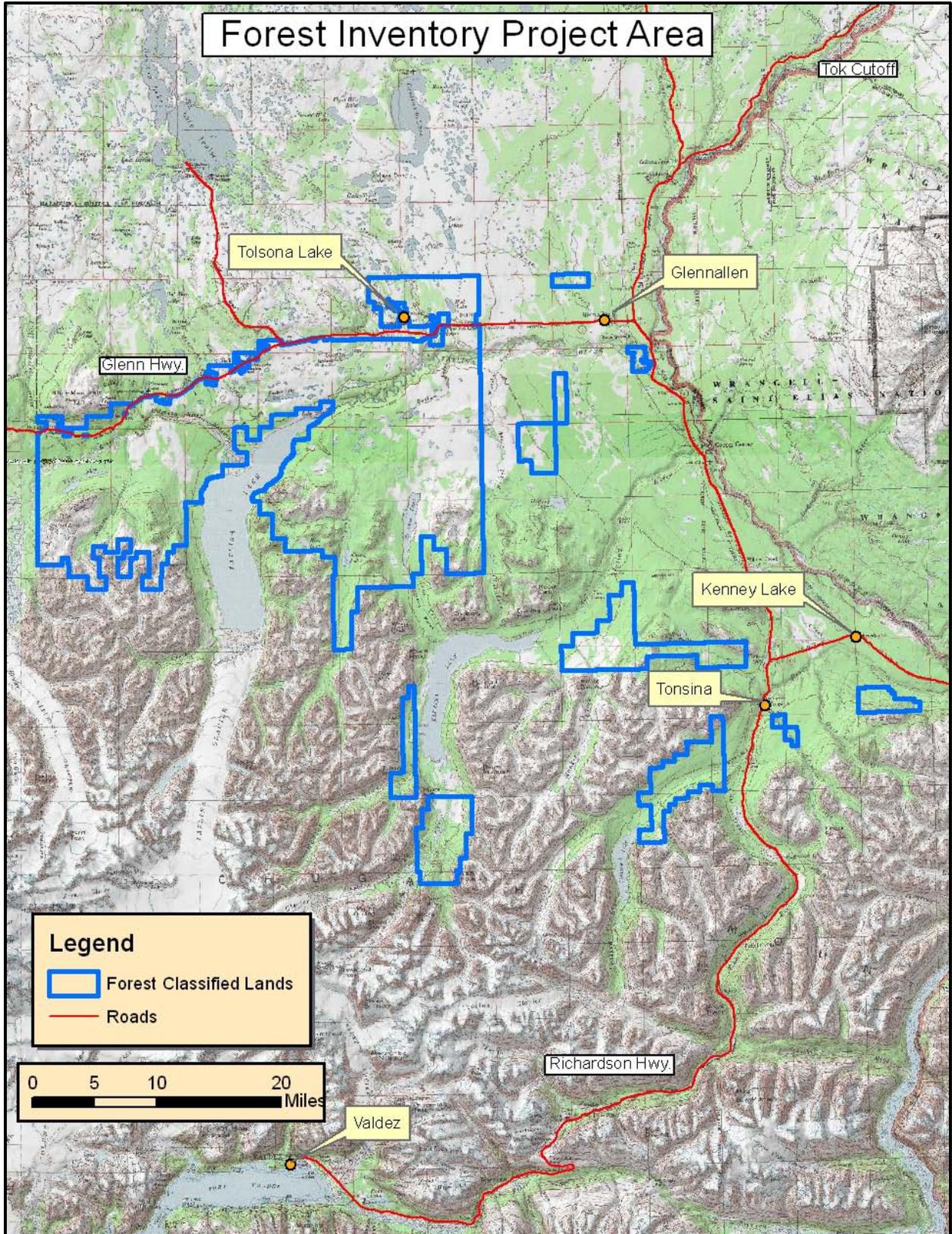


Figure 1. Project area map.

## II. OBJECTIVES

The objective of this report is to provide reliable inventory data to assist in the management of forest resources in the Copper River Basin. Determination of an operable land base, sustainable harvest rate and harvest scheduling all require accurate volume data and geographically referenced spatial locations of individual stands. This data, both in spatial and tabular form can be used to assess the availability of timber and biomass resources and determine economic viability of proposed harvest development activities. The inventory provides the following items useful for development and planning:

- Spatially accurate stand polygons overlaid on geographically rectified photo base.
- Accurate acreage determination of forest cover.
- Statistically valid sampling design that produces a variety of tree and stand attributes.
- Field sampling of tree and stand productivity variables useful for determining sustainable harvest rates.
- Internet GIS mapping access of spatial data with volume and acreage querying capabilities.
- Biomass sustainability data to evaluate potential project development.
- Biomass resource information to supplement statewide energy atlas data.

## III. METHODS

Forest inventory information was collected through a stratified random sampling design. The project area was divided into subpopulations (timber types) in order to account for variation in species composition, density and size class. Each timber type was then treated as a random sample population. Timber types sampled included sawtimber, poletimber and reproduction types, dwarf timber stands (mostly black spruce less than 25 feet tall at maturity) were not sampled.

Timber types to be sampled were selected randomly through the Geographic Information System (GIS). Access to stands was by foot and four-wheeler. A total of 48 stands were field sampled. Timber cruise measurements from two additional stands from a previous Tanana Chiefs Conference Native corporation inventory were also used for data compilation. The timber cruise measurements from the 50 stands provide estimates of volume, stocking, defect and growth by individual tree species. The 50 sample stands were deemed a minimum amount to determine a preliminary volume estimate. The number of sample stands was limited by project funding. Based on the calculated strata sample error values (*table 13*), it is estimated that 110 additional stands would need to be sampled to reach a desired sample error for individual strata of 5%.

### A. Imagery Sources

Scanned high altitude aerial photography at a scale of 1:60,000 and Spot 5 meter resolution satellite imagery were used for the project. The date of the aerial photography was 1978 and the date of the Spot scenes was 2003. The scanned color infrared photos were orthorectified, georeferenced to the Spot scenes, and mosaiced into a series of east-west flight lines across the project area. PCI image processing software was used for this process. Digital stereo epipolar pairs were then created from the photos for the stereo interpretation process.

## **B. Vegetation Typing**

The vegetation interpretation process as originally conceived was to use the automated object based image classification software eCognition to classify the Spot satellite scenes. Epipolar pairs were to be created from the overlapping satellite scenes using PCI allowing a forester to view the scenes in stereo and edit polygons created by eCognition in 3-D format. Polygon editing would correct errors in stand height where eCognition classification is less accurate. By correcting stand heights, the correlating size class calls of sawtimber, poletimber, reproduction or dwarf timber types would be more accurate. For this project, Spot Corporation donated six Spot 5 scenes to demonstrate this technology. A test of this new technology was conducted by DOF for the Tanana Valley in November of 2008 with good results. Unfortunately when eCognition was first run on the Glennallen Spot scenes the results were less than satisfactory. Individual polygon timber type delineation was not consistent across the scene and spruce and aspen stands were being combined with other vegetation types. Upon closer examination it was found that the scenes were acquired at a 5 meter pixel resolution versus 2.5 meter for the Tanana Valley scenes. This reduction in resolution negatively affected the ability of eCognition to consistently classify the major forest types of the Glennallen area.

Due to funding and time limitations that precluded acquiring new scenes at the desired 2.5 meter resolution, 1978 scanned high altitude aerial photography at a scale of 1:60,000 was used for the automated eCognition classification process. The best results were achieved when eCognition was used to classify open and closed aspen, spruce and mixed stands and the non-forest vegetation types. Stand size class delineation was applied to the types by viewing the photos in stereo on a computer screen with Summit Evolution stereo viewing software. Spot images were used as the base image to correct changes that occurred over time between 1978 and 2003. Using the Spot images allowed for adjusting polygon boundaries to match changes in river locations, housing development and other land use changes. The Spot images also allowed more accurate delineation of the aspen timber types. The large outbreak of spruce bark beetles and resulting spruce mortality that occurred in the region in the early 90's was not visible on the photos and was difficult to see on the Spot scenes. Ground sampling however reflected the mortality and the volume estimates include this dead material. At the time of field sampling, the bark beetle epidemic has mostly ended and there are few new trees that are infested.

Sawtimber, poletimber and reproduction stands were classified as timberland and represent the areas of greater productivity. These stands are a component of a larger class of ground cover called forestland. Forestland is defined as land that is at least 10% covered by trees. The other component of Forestland; dwarf forests, generally comprise black spruce stands that are less than 25 feet tall at maturity. These stands were identified on the imagery, but were not field sampled. It was determined that these stands currently were non-commercial even for the use of biomass. Most of the trees were significantly less than 25 feet tall. Delineation of timber types was based on tree species, size class and stand density. The most prevalent species determined the timber type. In mixed timber types, the secondary species represented at least 30% density of the type in question. Besides utilizing the stereo images to assign size class calls to the eCognition classified vegetation, physical location of the stands in question contributed to the vegetation classification process. For example, numerous spruce stands adjacent to the Tazlina and Nelchina Rivers' productive floodplain were classified sawtimber. Timber types along the

Copper River Basin itself that occurred on small rises were classified either sawtimber or poletimber because these growing sites were more productive.

### **C. Field Inventory Design**

The variable plot radius sampling method was used for field data collection of poletimber and sawtimber size trees. The basal area factor utilized was 20 square feet. In each timber stand sampled, ten plots were spaced uniformly on a traverse located systematically through the stand. The traverse was located in such a manner as to attempt to sample the variation within a stand. To minimize travel time, plots were generally located with a maximum interval of 300 feet. Tally trees were selected or rejected with a relascope prism. On five of the ten plots, species, tree vigor, crown ratio, defect type and estimated defect percentage, were recorded and tree diameter, total tree height, bark thickness, and ten-year growth were measured (measure plots). Tree diameters were measured 4.5 feet above ground, commonly known as “diameter breast height” or dbh. Co-dominant and dominant trees were cored at dbh to determine average age and site index of the sample stand. On the other alternating five plots, only the number of trees by species and size class selected by the relascope were recorded (count plots). Count plots generally serve to lower the sample error by increasing the overall plot numbers, but economize time spent in the field collecting data. Only trees five inches dbh and greater were measured utilizing the variable plot sampling method.

The fixed plot sampling method was used for field data collection of trees less than five inches dbh. At every other plot in the ten plot traverse (measure plots) seedling and sapling size trees were measured. Species and quality were recorded and tree diameter and total tree height were measured. The fixed plot was a circular 1/250<sup>th</sup> acre plot (7.45 foot radius).

### **D. Geographic Information System Coverage**

Together with the tabular data, a GIS coverage was prepared for the inventory. A standardized vegetation key/mapping scheme was used for describing vegetation polygons (*table 2*). The acreage of individual polygons was calculated using ESRI ArcMap GIS software. Storage in the GIS will allow for queries of individual portions of the project area to be accomplished for planning purposes. Through the GIS, acreage and volume estimates as reported in this forest inventory can be recalculated to reflect a changing operable forest land base.

### **E. Data Summary**

Upon completion of the field work, sampled stand data were entered into TCruise, a timber inventory software program. The inventory software calculated volume attributes for the individual sampled stands. These stands were then grouped into strata and re-processed in TCruise. The inventory contains eight separate sample strata for which estimates of gross and net volume per acre have been calculated (Appendix A). The strata contain field data from 50 individual timber stands containing 500 plots (*table 3*). Field data from some sampled stands were similar enough to each other to allow combining of different stand timber types into like strata. Acreage of un-sampled timber types deemed similar enough was also included in the strata. Characteristics of these timber types were observed during the field work phase of the inventory. Combinations of sampled and un-sampled timber types and the corresponding strata are shown in *table 4*. Total inventory volume was calculated by multiplying the average per acre volume figures for each stratum by the number of acres each sample stratum represents. These calculations were performed in a Microsoft Access database and utilize the GIS acreage figures.

Output reports written in Access display numerous stand attributes from the associated database tables and queries.

LAND COVER KEY	
FOREST SPECIES	
1 Black Spruce	19 Birch-Aspen
2 White Spruce	31 White Spruce-Birch
3 Black Spruce-White Spruce	34 White Spruce-Aspen
16 Balsam Poplar	37 White Spruce-Birch-Aspen
17 Birch	38 White Spruce-Balsam Poplar
18 Aspen	39 White Spruce-Black Spruce- Birch-Aspen
FOREST SIZE	
S Sawtimber	≥ 9.0 inches DBH
P Poletimber	5.0 inches to 8.9 inches DBH
R Reproduction	< 5.0 inches DBH
D Dwarf	< 25 feet at maturity
FOREST DENSITY	
X	60-100% Calls are based
Y	25-59% on crown closure
Z	10-24% percent.
NON-FOREST	
63 Mixed Tall Shrub Closed	80 Lakes-Ponds
68 Mixed Tall Shrub Open	94 Bare Ground
70 Mixed Low Shrub Closed	97 Gravel pits, mines, quarries
71 Mixed Low Shrub Open	98 Roads
76 Dry Midgrass-Herb-Sedge	101 Timber Sales
79 Wet Sedge-Grass	

Table 2. Land cover key.

Stratum Number	Strata Description	Acres	Number Of Stands
1	White Spruce Sawtimber	6,756	11
2	White Spruce Poletimber Closed	20,637	9
3	White Spruce Poletimber Open	30,210	10
4	Black & White Spruce Reproduction Closed	10,220	3
5	Black & White Spruce Reproduction Open	94,794	3
6	Aspen Poletimber Closed	11,738	5
7	White Spruce-Aspen Poletimber	33,822	4
8	White Spruce-Balsam Poplar	11,372	5
	Total	219,550	50

Table 3. Acreage and number of sampled stands by strata.

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	Vegetation Type	Acres	Field Sampled?
<b>Stratum</b>	<b>1</b>	White Spruce Sawtimber	
	2SX	5,016	Yes
	3SY	5	
	2SY	1,736	Yes
<b>Sum</b>		6,756	
<b>Stratum</b>	<b>2</b>	White Spruce Poletimber Closed	
	1PX	13	
	2PX	17,954	Yes
	3PX	2,670	Yes
<b>Sum</b>		20,637	
<b>Stratum</b>	<b>3</b>	White Spruce Poletimber Open	
	1PY	2	
	3PY	8,185	Yes
	2PY	22,023	Yes
<b>Sum</b>		30,210	
<b>Stratum</b>	<b>4</b>	Black & White Spruce Reproduction Closed	
	2RX	2,852	
	1RX	354	
	3RX	7,014	Yes
<b>Sum</b>		10,220	
<b>Stratum</b>	<b>5</b>	Black & White Spruce Reproduction Open	
	2RZ	1,473	
	101	46	
	2RY	10,810	Yes
	1RY	44,950	
	1RZ	215	
	3RY	28,857	Yes
	3RZ	3,375	
	2PZ	4,152	Yes
	3PZ	916	Yes
<b>Sum</b>		94,794	

Table 4. Sampled and un-sampled timber types by strata.

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Vegetation Type			Acres	Field Sampled?
<i>Stratum</i>	6	Aspen Poletimber		
		19PX	1	
		18SX	7	
		18RX	3,615	
		18PY	5,020	Yes
		18PX	3,092	Yes
		17PY	3	
<b>Sum</b>			<i>11,738</i>	
<i>Stratum</i>	7	White Spruce Aspen Poletimber		
		18RZ	1,024	
		18PZ	119	
		18RY	9,948	Yes
		34SY	5	
		39PX	141	Yes
		31PX	2	
		39PY	400	Yes
		39PZ	57	
		39RX	624	
		39RY	3,860	
		39RZ	267	
		34PX	1,185	Yes
		37PX	5	
		34SX	54	
		34RZ	1,367	
		34RY	9,376	
		34RX	1,927	
		34PZ	263	
		34PY	3,127	
		31RX	30	
		31PY	34	
		37RY	6	
<b>Sum</b>			<i>33,822</i>	

Table 4 Continued. Sampled and un-sampled timber types by strata.

Vegetation Type	Acres	Field Sampled?
<i>Stratum</i> 8 White Spruce Balsam Poplar		
16PX	1,160	Yes
16RZ	30	
16RY	1,958	
16RX	2,155	
16SX	198	Yes
16PY	760	
38RZ	58	
16PZ	10	
16SY	19	
16SZ	1	
38SX	216	
38RY	1,682	
38RX	476	
38PZ	221	
38PY	1,629	
38PX	649	
38SY	149	
<b>Sum</b>	<b>11,372</b>	
<b>Grand Total Timberland</b>	<b>219,550</b>	

Table 4 Continued. Sampled and un-sampled timber types by strata.

## F. Description of Strata

The eight strata are described below. Pictures are shown for selected strata where available.

### 1. *Stratum 1 White Spruce Sawtimber*

This stratum is found in limited amounts across the project area. It occurs on the most productive sites (Vioreck et al. 1992. *The Alaska Vegetation Classification*) and had the highest volume per acre within the project. The sites generally were well drained to moderately well drained with silt and silt loam soil types. Stands with the highest volumes per acre were found along the Tazlina and Nelchina Rivers. Stands found on upland sites generally were on high ground with a southerly aspect. Average age of the stratum was 143 years. Bark beetle mortality is severe in the stratum and most trees greater than 13 inches dbh have been killed. Fortunately many of the dead trees are standing and merchantability for fuelwood and biomass is still good. Stands on the more productive sites, i.e. river bottoms, had somewhat less mortality than on the upland sites. Stands located in the south edge of the project area in the vicinity of the Edgerton Highway had greater amounts of blow down, which probably reflects that the bark beetle epidemic began in this area and the trees have been dead for 3-4 years longer than in the

north portion of the project area. Increased wind speeds in this area may also be contributing to blow down. The stratum contains 4,879 board feet per acre, but 22% of the board foot volume was in dead trees. The stratum averages 29 tons per acre and has a net annual yield of 0.21 tons per acre per year (12.4 cubic feet per acre per year).

2. *Stratum 2 White Spruce Poletimber Closed*

This stratum is found across the project area on sites that are of poor to medium productivity. Permafrost is probably present on numerous sites. In some stands black spruce is mixed in, but with generally minor amounts compared to white spruce. Occasionally some aspen is also present. Average age of the stratum was 144 years, which is similar to the white spruce sawtimber stratum and indicates relatively low productivity. Although old, the stem count is fairly high and averaged 259 trees per acre. The stratum contains 1,243 cubic feet per acre, with 17% of this volume in dead trees. The stratum contains 21 tons per acre and has a net annual yield of 0.17 tons per acre per year (10 cubic feet per acre per year).

3. *Stratum 3 White Spruce Poletimber Open*

This stratum is found across the project area on sites that are of poor productivity. On higher elevations of the project area such as near the Little Nelchina River, the stands appear to have a high percentage of black spruce trees. During field measurements however, these trees were indeed white spruce which reflects the species' ability to out compete black spruce at higher elevations. Unfortunately however, these trees exhibit the slow growth characteristic of black spruce. The stem count is 169 trees per acre with 20% of the trees of sawtimber size. Many of the sawtimber sized trees have succumbed to the bark beetle infestation. Average age of the stratum was 184 years, the highest of all eight strata. These stands contain an average of 955 cubic feet per acre, with 21% of this volume in dead trees. The stratum contains 16 tons per acre. The combination of slow growth and beetle mortality resulted in the slowest growth rate of all the strata. Annual yield was .04 tons per acre per year (2.1 cubic feet per acre per year).

4. *Stratum 4 Black and White Spruce Reproduction Closed*

This stratum is found across the project area on sites that are of poor productivity. Although these stands contain a majority of trees less than five inches dbh, they are not true reproduction stands, but stands of very slow growing trees. They are however more productive than the common black spruce dwarf stands that occur widespread across the project area. These stands have measurable cubic foot volume and contain useable biomass. Average age was 162 years and the stands that were sampled have put on very little growth in the past 50 years. It is likely that productivity can be improved by opening these sites and increasing soil warming. The stem count averaged 179 trees per acre, but a substantial number of trees less than five inches dbh were present that totaled 2,017 trees per acre. The majority of the trees greater than five inches dbh were white spruce and the majority of trees less than five inches dbh were black spruce. Within the reproduction size class, 450 trees per acre were between three and five inches dbh. The stratum contains 330 cubic feet per acre, and 6 tons per acre. The average net annual yield is 0.05 tons per acre per year (3.2 cubic feet per acre per year).



Figure 2. Stratum 2, white spruce poletimber closed, south of Tazlina lodge.

##### *5. Stratum 5 Black and White Spruce Reproduction Open*

This is the largest stratum by acreage comprising over 43% of the total timberland acreage. This stratum is found across the project area on sites that are of poor productivity. Plots from similar stands on adjacent Native lands were used in addition to the single sampled stand to calculate volume. It is similar to stratum 4 where the productivity is greater than dwarf timber types. This stratum has been determined to have useable biomass. The stem count of trees five inches dbh and greater totals 41 trees per acre. The stem count of trees less than five inches dbh totals 1,000 trees per acre. Within this size class, 266 trees per acre are between three and five inches dbh. The stratum contains 98 cubic feet per acre, and 2 tons per acre. The average net annual yield is 0.03 tons per acre per year (1.8 cubic feet per acre per year).



Figure 3. Stratum 3, white spruce poletimber open, north of Little Nelchina River.

#### *6. Stratum 6 Aspen Poletimber Closed*

Stands comprising this stratum occur on the warmest of sites with a southerly aspect. The sites generally are well drained with silt and silt loam soil types. Average age of the stratum was 84 years and some stands have vigorous white spruce regeneration growing under the aspen. The stem count averages 334 trees per acre. The stratum contains 1,236 cubic feet per acre. It contains 25 tons per acre and has a net annual yield of 0.8 tons per acre per year (48.7 cubic feet per acre per year). This stratum has lower volume per acre than stratum 1, but has the highest annual yield of all the strata.

#### *7. Stratum 7 White Spruce-Aspen Poletimber*

This stratum by occurs across the project area on variable sites. Average age of the stratum is 91. Stands in the stratum are quite variable. The aspen component varies in density with the older stands containing fewer stems. The stratum contains 1,020 cubic feet per acre. It contains 19 tons per acre and has a net annual yield of 0.5 tons per acre per year (27.2 cubic feet per acre per year).



Figure 4. Stratum 4, black spruce-white spruce reproduction, west of Tolsona Creek.

#### 8. *Stratum 8 White Spruce-Balsam Poplar*

This is the smallest stratum by acreage comprising less than 4% of total timberland acreage. It occurs along the active floodplains of the larger river systems within the project area. These drainages include the Tazlina, Nelchina, Little Nelchina and Tonsina Rivers and Bernard Creek. Average age of the stratum is 103. Stands in the stratum are quite variable. Some stands are mostly balsam poplar where others are a mix of white spruce and balsam poplar. The stem count averages 185 trees per acre. The stratum contains 956 cubic feet per acre. It contains about 19 tons per acre and has a net annual yield of 0.5 tons per acre per year (30 cubic feet per acre per year).

#### 9. *Non-Forest*

*Figure 6* illustrates non-forest dwarf shrub with scattered black spruce dwarf trees. The picture is looking south near the Little Nelchina River. Shrub species include low bush cranberry, low bush blueberry, Labrador tea and dwarf birch. Vegetation pictured here also includes sedge tussock tundra.



Figure 5. Stratum 7, white spruce-aspen poletimber, west of Tolsona Creek.



Figure 6. Non-forest dwarf shrub, north of Little Nelchina River.

## IV. RESULTS

### A. Forest Volume Definitions

Estimates of timber volume on forested lands have been calculated with three different measurements; cubic foot volume, board foot volume and green tons. The cubic foot measurement includes all timber greater than or equal to five inches dbh and is divided among the live and dead poletimber and sawtimber components of the forest. The board foot measurement is commonly used to determine the amount of lumber that can be sawn from a log. Because the measurement is based on actual boards that can be sawn from a log, it disregards all material wasted in the process such as slabs and sawdust. The board foot measurement only includes timber equal to or greater than 9 inches dbh.

Volume calculations for both cubic and board foot measurements are based on volume equations produced for Interior Alaska; U.S. Forest Service research notes NOR-5, NOR-6 and PNW-59. Board foot volume is reported in Scribner Decimal C scale and is based on 16-foot log segments (short log scale). For spruce it is reported to a 6-inch top (PNW-59) and for hardwoods to an 8-inch top (NOR-5). Cubic volume is reported in Smalian's rule and for spruce and hardwoods includes volume to a 4-inch top (NOR-6). Both live and dead volume is reported. Dead volume includes recently dead trees estimated to have died within the last 16 years. This time period coincides with the spruce bark beetle outbreak.

Volume Formula Name	Volume Unit	Species	Formula
NOR-6	Cubic Foot 4-inch Top	White and Black Spruce	$(-2.055)+0.2982*(dbh)+0.00181*(dbh)^2*ht$
NOR-6	Cubic 4-inch Top	Birch	$(-2.5767)+0.9524*(dbh)-0.10446*(dbh)^2-0.03303*(ht)+0.00282*(dbh)^2*(ht)$
NOR-6	Cubic 4-inch Top	Aspen	$(-0.5553)-0.02216*dbh^2+0.00246*dbh^2*ht$
NOR-6	Cubic 4-inch Top	Balsam Poplar	$(-3.2187)+0.8281*(dbh)-0.05908*(dbh)^2-0.01985*(ht)+0.00199*(dbh)^2*(ht)$
PNW-59	Board Foot Scribner 6-inch Top	White and Black Spruce	$39.71+4.2659*dbh-0.55865*dbh^2-1.1184*ht+0.016113*dbh^2*ht-437.92/dbh^2$
NOR-5	Board Foot Scribner 8-inch Top	Birch and Aspen	$(-27.263)+0.00995*dbh^2*ht$
NOR-5	Board Foot Scribner 8-inch Top	Balsam Poplar	$(-46.7415)+0.00956*dbh^2*ht$

Table 5. Volume formulas by species for poletimber and sawtimber size classes.

Computation of green tons was derived from weight ratios produced for Alaska wood species (Sturgeon 1979. *Wood As A Fuel*). *Wood As A Fuel* lists the weight of green cord wood which can be converted into pounds per cubic foot. The inventory cubic foot values are converted to green tons using these ratios (*table 6*). A cord of wood is assumed to contain 90 cubic feet of solid wood.

Species	Pounds per Cubic Foot
White Spruce	34
Black Spruce	34
Birch	50
Aspen	43
Balsam Poplar	43

Table 6. Inventory species and weight for poletimber and sawtimber.

### B. Inventory Volume by Species

Inventory volume is reported below in *table 7* by tree species across all timber types. When the entire volume by species is summed, a grand total of 1,383,731 net cunits (1 cunit=100 cubic feet=1 CCF) is present. If this total is divided by the timberland area of 219,550 acres, then overall there is 630 net cubic feet per acre. Similarly, overall there are 11.37 net tons per acre and 1,013 net board feet per acre. The values for cubic feet and tons are reported for trees equal to or greater than five inches dbh. Board foot values are reported for trees equal to or greater than nine inches dbh (MBF=1,000 board feet). *Table 8* reports inventory volume by species and size class across all timber types. The sawtimber size class comprises 40% of the total net cubic volume or about 556,000 cunits. The poletimber size class comprises 60% of the total net cubic volume or about 827,000 cunits. Dead sawtimber trees mostly killed from bark beetles comprise 15% of the total sawtimber net cubic volume.

Species	Net CUFT Per Acre	Total Net CUNITS	Net Tons Per Acre	Total Net Tons	Net BDFT Per Acre	Total Net MBF
<i>Aspen</i>	106	233,416	2.29	501,844	35	7,736
<i>Balsam Poplar</i>	36	78,435	0.77	168,635	71	15,506
<i>Birch</i>	3	5,553	0.06	13,882	2	441
<i>Black Spruce</i>	39	85,175	0.66	144,797	1	225
<i>White Spruce</i>	447	981,153	7.60	1,667,960	904	198,542
Total	630	1,383,731	11.37	2,497,118	1,013	222,449

Table 7. Total net volume across all strata.

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		Gross Cunits	Net Cunits	Gross Tons	Net Tons	Gross MBF	Net MBF
<i>Saw Live</i>	<i>Aspen</i>	41,850	39,313	89,977	84,524	8,279	7,736
	<i>Balsam</i>						
	<i>Poplar</i>	59,600	54,190	128,140	116,509	17,343	15,506
	<i>Birch</i>	3,485	2,788	8,712	6,969	551	441
	<i>Black Spruce</i>	579	417	985	709	281	225
	<i>White Spruce</i>	403,353	373,776	685,701	635,420	175,239	161,956
	Total	508,867	470,485	913,515	844,131	201,694	185,863
<i>Saw Dead</i>	<i>White Spruce</i>	105,775	85,886	179,818	146,006	45,558	36,586
	Total	105,775	85,886	179,818	146,006	45,558	36,586
<i>Pole Live</i>	<i>Aspen</i>	197,146	194,102	423,863	417,320		
	<i>Balsam</i>						
	<i>Poplar</i>	25,884	24,245	55,651	52,127		
	<i>Birch</i>	3,456	2,765	8,641	6,913		
	<i>Black Spruce</i>	80,420	74,932	136,715	127,385		
	<i>White Spruce</i>	490,316	482,475	833,537	820,207		
	Total	797,223	778,519	1,458,407	1,423,952		
<i>Pole Dead</i>	<i>Black Spruce</i>	10,779	9,825	18,324	16,703		
	<i>White Spruce</i>	42,858	39,016	72,859	66,328		
	Total	53,637	48,841	91,183	83,031		
Grand Total							
		1,465,502	1,383,731	2,642,923	2,497,118	247,252	222,449

Table 8. Volume summary by size class and species across strata.

**C. Defect Estimates by Species**

Defect renders portions of individual trees unusable or of very limited use as forest products due to insect damage, rot and physical damage such as broken stems, sweep and crook. The net volumes shown however do not take into account all defects because hidden defect has not been estimated. Visible defect is the difference between gross and net volume. Visible defect percentage by species is shown in *Table 9*.

Species	Gross Cubic Feet/Acre	Net Cubic Feet/Acre	Percent Defect
<i>Aspen</i>	109	106	2.3
<i>Balsam Poplar</i>	39	36	8.2
<i>Birch</i>	3	3	20.0
<i>Black Spruce</i>	42	39	7.2
<i>White Spruce</i>	475	447	5.9
<b>Totals</b>	<b>668</b>	<b>630</b>	<b>5.6</b>

Table 9. Cubic foot defect estimates by species.

#### D. Inventory Volume by Strata

Timber inventory results by stratum and species are shown in *figure 7* and *table 10*. Detailed results by stratum are contained in Appendices A and B.

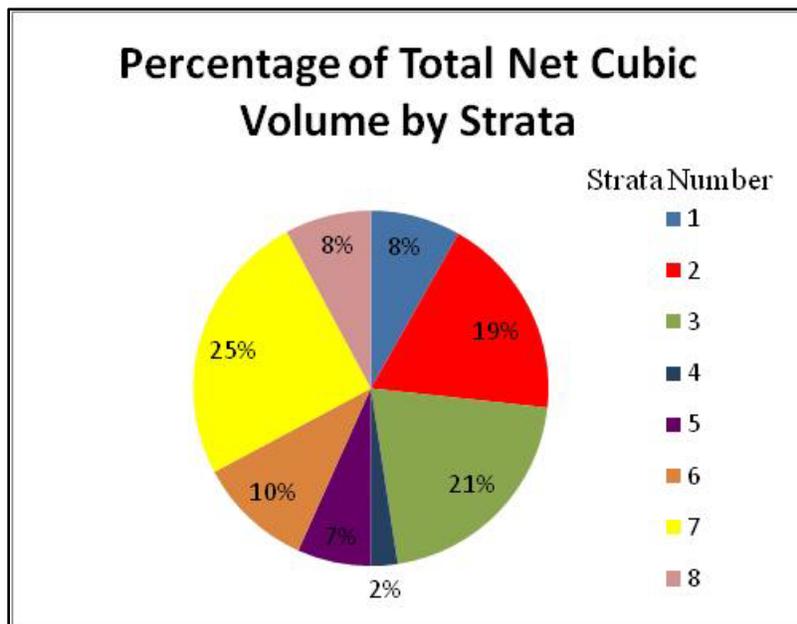


Figure 7. Percent of total net cubic foot volume by strata.

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	Net CUFT Per Acre	Total Net CUNITS	Net Tons Per Ac.	Total Net Tons	Net BDFT Per Acre	Total Net MBF
<b>Stratum 1 White Spruce Sawtimber = 6,756 Acres</b>						
<i>Aspen</i>	0	0	0	0	2	14
<i>Balsam Poplar</i>	10	687	0	1,476	21	140
<i>Black Spruce</i>	9	594	0	1,009		
<i>White Spruce</i>	1,661	112,223	28	190,778	4,856	32,811
<b>Totals</b>	<b>1,680</b>	<b>113,504</b>	<b>29</b>	<b>193,263</b>	<b>4,879</b>	<b>32,965</b>
<b>Stratum 2 White Spruce Poletimber Closed = 20,637 Acres</b>						
<i>Balsam Poplar</i>	29	5,996	1	12,892	116	2,401
<i>Black Spruce</i>	94	19,349	2	32,893	11	225
<i>White Spruce</i>	1,120	231,180	19	393,006	2,334	48,157
<b>Totals</b>	<b>1,243</b>	<b>256,525</b>	<b>21</b>	<b>438,791</b>	<b>2,461</b>	<b>50,783</b>
<b>Stratum 3 White Spruce Poletimber Open = 30,210 Acres</b>						
<i>Black Spruce</i>	51	15,382	1	26,149		
<i>White Spruce</i>	904	273,011	15	464,118	2,197	66,364
<b>Totals</b>	<b>955</b>	<b>288,393</b>	<b>16</b>	<b>490,267</b>	<b>2,197</b>	<b>66,364</b>
<b>Stratum 4 Black &amp; White Spruce Reproduction Closed = 10,220 Acres</b>						
<i>Black Spruce</i>	224	22,911	4	38,948		
<i>White Spruce</i>	106	10,843	2	18,433	78	798
<b>Totals</b>	<b>330</b>	<b>33,754</b>	<b>6</b>	<b>57,381</b>	<b>78</b>	<b>798</b>
<b>Stratum 5 Black &amp; White Spruce Reproduction Open = 94,794 Acres</b>						
<i>Black Spruce</i>	12	11,306	0	19,220		
<i>White Spruce</i>	86	81,259	1	138,140	119	11,298
<b>Totals</b>	<b>98</b>	<b>92,565</b>	<b>2</b>	<b>157,360</b>	<b>119</b>	<b>11,298</b>
<b>Stratum 6 Aspen Poletimber = 11,738 Acres</b>						
<i>Aspen</i>	976	114,586	21	246,360	383	4,501
<i>Balsam Poplar</i>	0	9	0	20		
<i>White Spruce</i>	260	30,521	4	51,885	463	5,431
<b>Totals</b>	<b>1,236</b>	<b>145,116</b>	<b>25</b>	<b>298,265</b>	<b>846</b>	<b>9,932</b>
<b>Stratum 7 White Spruce Aspen Poletimber = 33,822 Acres</b>						
<i>Aspen</i>	344	116,230	7	249,894	95	3,221
<i>Birch</i>	16	5,553	0	13,882	13	441
<i>Black Spruce</i>	46	15,633	1	26,577		
<i>White Spruce</i>	614	207,694	10	353,079	899	30,413
<b>Totals</b>	<b>1,020</b>	<b>345,110</b>	<b>19</b>	<b>643,432</b>	<b>1,007</b>	<b>34,075</b>
<b>Stratum 8 White Spruce Balsam Poplar = 11,372 Acres</b>						
<i>Aspen</i>	23	2,600	0	5,590		
<i>Balsam Poplar</i>	631	71,743	14	154,247	1,140	12,965
<i>White Spruce</i>	303	34,423	5	58,519	288	3,270
<b>Totals</b>	<b>957</b>	<b>108,766</b>	<b>19</b>	<b>218,356</b>	<b>1,428</b>	<b>16,235</b>
<b>Grand Total</b>		<b>1,383,731</b>		<b>2,497,118</b>		<b>222,449</b>

Table 10. Volume by stratum and species.

### A. Inventory Volume of Sapling Size Trees

Inventory volume results have been calculated for the sapling component to determine the tonnage of this material that may be available as a biomass resource. These values represent the total above ground portion of the tree including branches and needles and use equations published for Interior Alaska tree species. The regression equations (Yarie 2007. *Aboveground Biomass Equations for the Trees of Interior Alaska.*) relate the weight of individual tree components by species to physical measurements that are easy to obtain in the field. White spruce and black spruce equations (table 11) were applied to regeneration diameter and height data to get an estimate of available tons. These equations were compared to wood chip weight recovery data conducted in Tok by the Division of Forestry, Tok Area Office for similar species and size classes. The equations with the closest fit to the actual Tok cut out data were used. Due to inaccuracies in projecting weight of very small trees, the equations were only applied to trees with diameters between two and 4.9 inches dbh.

Species	Sapling Aboveground Weight in Pounds
White Spruce, Birch, Aspen Balsam Poplar	$((8628.215*(dbh*2.54))+525.26667*(dbh*2.54)^2+6320.94097*(Ht*0.3048))/453.59237$
Black Spruce	$((2454.230*(Ht*0.3048))/453.59237)$

Table 11. Inventory sapling species and weight regression equations.

As can be expected, the highest tons per acre values are in the reproduction strata. Both strata 4 and 5 contain a significantly higher amount of tonnage in trees less than 5 inches dbh than in trees greater than 5 inches. Depending on accessibility, these stands could be a source of biomass material. If tonnage of sapling, poletimber and sawtimber tree sizes is combined stratum 4 contains 17 tons per acre and stratum 5 contains 7 tons per acre.

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	Trees/Acre	Tons/Acre
<b>Stratum 1 White Spruce Sawtimber</b>		
<i>Black Spruce</i>	18	0
<i>White Spruce</i>	95	1
Total Trees Per Acre	114	1
<b>Stratum 2 White Spruce Poletimber Closed</b>		
<i>Black Spruce</i>	78	1
<i>White Spruce</i>	189	3
Total Trees Per Acre	267	4
<b>Stratum 3 White Spruce Poletimber Open</b>		
<i>Balsam Poplar</i>	5	0
<i>Black Spruce</i>	40	0
<i>White Spruce</i>	155	1
Total Trees Per Acre	200	1
<b>Stratum 4 Black &amp; White Spruce Reproduction Closed</b>		
<i>Black Spruce</i>	617	10
<i>White Spruce</i>	50	1
Total Trees Per Acre	667	11
<b>Stratum 5 Black &amp; White Spruce Reproduction Open</b>		
<i>Black Spruce</i>	267	4
<i>White Spruce</i>	167	2
Total Trees Per Acre	433	6
<b>Stratum 6 Aspen Poletimber</b>		
<i>Aspen</i>	130	3
<i>White Spruce</i>	50	1
Total Trees Per Acre	180	4
<b>Stratum 7 White Spruce Aspen Poletimber</b>		
<i>Aspen</i>	38	0
<i>Black Spruce</i>	75	2
<i>White Spruce</i>	138	2
Total Trees Per Acre	250	4
<b>Stratum 8 White Spruce Balsam Poplar</b>		
<i>Aspen</i>	20	0
<i>Balsam Poplar</i>	100	1
<i>White Spruce</i>	180	2
Total Trees Per Acre	300	2

Table 12. Volume summary by stratum and sapling species 2" - 4.9" dbh.

**B. Sampling Error by Volume**

Sample error was calculated for the live gross cubic foot estimate by strata and size class (*table 13*). The sample error percent is given within one standard deviation of the mean. This means that there is a 68% chance (one standard deviation) that the volume of the individual live size class components are within plus or minus the error percentage indicated. Sample error is

relatively high for the reproduction strata 4 and 5. This is indicative of the variation of the sawtimber and poletimber component within mostly sapling sized dominated stands.

Stratum	Number of Plots	Live Poletimber		Live Sawtimber		Combined	
		Gross CF/Ac	% Sampling Error	Gross CF/Ac	% Sampling Error	Gross CF/Ac	% Sampling Error
1	110	440	8.3	943	9.4	1,383	6.9
2	90	605	10.9	456	15.3	1,061	9.0
3	100	396	10.0	393	10.8	789	7.4
4	30	325	21.4	18	55.5	343	20.5
5	30	72	33.5	43	44.7	115	26.8
6	50	985	8.3	293	10.4	1,278	6.8
7	40	747	14.1	283	22.5	1,030	11.9
8	50	481	14.9	524	15.7	1,005	10.9
Total	500	515	4.2	476	5.6	991	3.5

Table 13. Gross live cubic foot percent sampling error.

### C. Log Grade

Log grade estimates were made during field sampling. Log grade was only tallied for the live sawtimber sized trees ( $\geq 9$  inches dbh). A grade was given for each of the first two 16-foot log segments. Log grades use Puget Sound grading rules, which contain specifications for various species. White spruce and black spruce were applied to the Puget Sound western white pine rules. Aspen and birch were applied to red alder rules and balsam poplar to the cottonwood rules. The summary for white spruce trees in stratum 1 is shown in *table 14*. Appendix C shows the Puget Sound grading rules and detailed results for each stratum. Log grade results were not computed by volume but do provide grade estimates in straight percentage terms of trees measured in the field. This gives a reference point for the grade distribution in each stratum. For the white spruce sawtimber component in stratum 1, over one half of the measurements coded each of the first two log segments as a number 4 log grade.

First 16-Foot Log Grade	Second 16-Foot Log Grade	Percent of Measurements
Cull	Cull	3 %
2	3	2 %
3	3	2 %
3	4	11 %
3	Utility	1 %
4	Cull	1 %
4	4	56 %
4	Utility	16 %
Utility	Cull	1 %
Utility	Utility	7 %
		100%

Table 14. Log grade for stratum 1 white spruce trees.

## V. FOREST PRODUCTIVITY

### A. Site Index

Tree height has been found as the most reliable indicator of site productivity. In essence, the taller the tree the more productive is the growing site. When height is combined with tree age, the measurements can be reported as a site index number. This number gives the height in feet of a particular stand at a reference base age. Site index of white spruce uses a base age of 100 years whereas site index of aspen uses a base age of 50 years. Site index reflects the combined effect of all environmental factors and is therefore a good index of stand productivity. Site index calculations for white spruce are based on site index equations produced for Interior Alaska; U.S. Forest Service research paper PNW-53. Site index calculations for aspen are based on site index equations produced for Interior Alaska; U.S. Forest Service research paper NOR-2. Balsam poplar measurements were also applied to the aspen NOR-2 values.

	Site Index (Feet)
<b>Stratum 1 White Spruce Sawtimber</b>	
<i>White Spruce</i>	56
<i>Aspen</i>	---
<b>Stratum 2 White Spruce Poletimber Closed</b>	
<i>White Spruce</i>	52
<i>Aspen</i>	---
<b>Stratum 3 White Spruce Poletimber Open</b>	
<i>White Spruce</i>	42
<i>Aspen</i>	---
<b>Stratum 4 Black &amp; White Spruce Reproduction Closed</b>	
<i>White Spruce</i>	35
<i>Aspen</i>	---
<b>Stratum 5 Black &amp; White Spruce Reproduction Open</b>	
<i>White Spruce</i>	29
<i>Aspen</i>	---
<b>Stratum 6 Aspen Poletimber</b>	
<i>White Spruce</i>	68
<i>Aspen</i>	41
<b>Stratum 7 White Spruce Aspen Poletimber</b>	
<i>White Spruce</i>	50
<i>Aspen</i>	45
<b>Stratum 8 White Spruce Balsam Poplar</b>	
<i>White Spruce</i>	---
<i>Balsam Poplar</i>	41

Table 15. Site index by stratum and species.

### B. Timberland Area Age Class

Forest productivity can also be examined in terms of overall age class distribution. Typically as trees become older productivity declines. Hardwoods generally begin to decline after year 80 or 90 when rot becomes more frequent. White spruce is longer lived, but generally starts to decline

after year 180. At this age white spruce becomes more susceptible to rot and insect damage. *Table 16* shows the age class distribution in acres and percent of the total acreage. Over two thirds of the timberland acreage is older than 120 years and 20% of the timberland acreage is older than 180 years. The advanced age of many of the white spruce stands may have contributed to the widespread beetle infestation throughout the project area. Stands between 50 and 80 years of age comprised 16% of the timberland area. Most of these stands were aspen dominated. The age class distribution indicates a lengthy fire return interval and the low site index numbers in *table 15* correspond to stands growing in cold soils covered by moss. The primary disturbance factor for soils in the Copper River basin is the wild fire regime (Swanson 1996. *Susceptibility of permafrost soils to deep thaw after forest fires in interior Alaska, U.S.A. and some ecologic implications.*). Fire results in the clearing of vegetation, partial or entire removal of the organic mat, and thawing of permafrost. Changing these factors has profound effects on the characteristics of the soil profile and subsequently on the trees growing on top. A wet-cold-frozen soil, with permafrost insulated by a thick organic mat can become a dry-warm soil type after a fire. During field measurements, trees that had the greatest 10-year increment growth were almost always associated with warmer soils and thinner moss depth.

Stand Age Class	Average Age	Acres	Percent of Total
50 - 60	59	4,391	2%
60 - 70	68	8,782	4%
70 - 80	74	21,955	10%
80 - 90	81	4,391	2%
90 - 100	96	17,564	8%
100 - 110	103	4,391	2%
110 - 120	112	4,391	2%
120 - 130	127	21,955	10%
130 - 140	138	13,173	6%
140 - 150	146	39,519	18%
150 - 160	152	21,955	10%
160 - 170	161	13,173	6%
180 - 190	181	8,782	4%
190 - 200	196	17,564	8%
200 - 210	201	8,782	4%
210 - 220	213	8,782	4%

Table 16. Percent of area by age class.

*Table 17* reports the average age by individual stratum. From the age data it is evident that strata 4 and 5 are not true reproduction stands, but are in fact timber growing on poor sites. These timber types have significant numbers of trees less than 5 inches in diameter and a limited number of poletimber trees. It is this poletimber component that makes these stands have a potential for providing firewood and biomass resources.

Stratum	Description	Average Age
1	White Spruce Sawtimber	136
2	White Spruce Poletimber Closed	137
3	White Spruce Poletimber Open	169
4	Black & White Spruce Reproduction Closed	150
5	Black & White Spruce Reproduction Open	138
6	Aspen Poletimber	74
7	White Spruce Aspen Poletimber	84
8	White Spruce Balsam Poplar	96

Table 17. Average age by strata.

### C. Regeneration

Another measure of productivity is whether individual timber stands are being replaced by regeneration. Interior Alaska tree species are mostly even-aged and are replaced through natural regeneration following fire, flooding or insect outbreaks. In the absence of disturbance, stands are slowly replaced by understory regeneration. In many cases such as the dense black and white spruce stands, regeneration is poor because of thick moss cover and cold soils. There is a high tree count of small black spruce seedlings, but regeneration of quality crop trees is poor. These stands are slow to regenerate unless a stand replacing disturbance such as wildfire occurs. In other cases stands are actively being replaced even in the absence of disturbance. These stands typically are the aspen poletimber stands that contain a well stocked spruce understory. *Table 18* gives numbers of trees per acre less than 5 inches by species and stratum. Trees are of desirable and acceptable quality as determined in field. Undesirable trees not expected to become future crop trees are not included in the table.

### D. Growth and Mortality Estimates

Growth estimates have been determined through projections made with the timber cruise software TCruise. Periodic annual gross growth has been projected utilizing the past 10-year diameter growth increment and bark thickness measurements collected in the field across all measured diameter classes (5-inch dbh and greater). By collecting both the growth increment and bark thickness measurement, the software is able to discount changes in bark thickness that would affect the accurate determination of diameter growth. Growth was computed by a regression approach for both diameter and height. The desired growth projection interval used was 10 years (i.e. 2009-2019). The increased volume growth was then divided by 10 to calculate an annual growth rate. This volume figure was then divided by the growing stock base (live tree volume) to calculate a percentage growth rate. The trees were grown out initially by ten years instead of just one year because many of the 10-year diameter growth increments were so small that the software calculated an inconsistent growth rate for a one year projection. Diameter-height relationships, diameter growth and calculated bark thickness ratios (Husch et al. 2002. *Forest Mensuration, Fourth Edition.*) are shown in Appendix D. Mortality estimates have been determined by dividing the recently dead volume by 16 years to calculate annual mortality. The 16 year time period corresponds to the beginning of the bark beetle infestation in the project area. These trees were easily identified during field measurements as bark beetle killed trees. The mortality estimates were then subtracted from the gross growth figures to calculate net growth. The average net annual growth for the project area is 10 cubic feet per acre (*table 19*). Growth rates are slightly below Forest Service estimates of between 2 and 3% (Smith et al. 2007. *Forest Resources of the United States, 2007*) for unmanaged interior forests.

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	Trees/Acre
<b>Stratum 1 White Spruce Sawtimber</b>	
<i>Black Spruce</i>	32
<i>White Spruce</i>	841
<b>Total Trees Per Acre</b>	<b>873</b>
<b>Stratum 2 White Spruce Poletimber Closed</b>	
<i>Black Spruce</i>	228
<i>White Spruce</i>	556
<b>Total Trees Per Acre</b>	<b>783</b>
<b>Stratum 3 White Spruce Poletimber Open</b>	
<i>Balsam Poplar</i>	25
<i>Black Spruce</i>	280
<i>White Spruce</i>	410
<b>Total Trees Per Acre</b>	<b>715</b>
<b>Stratum 4 Black &amp; White Spruce Reproduction Closed</b>	
<i>Black Spruce</i>	567
<i>White Spruce</i>	33
<b>Total Trees Per Acre</b>	<b>600</b>
<b>Stratum 5 Black &amp; White Spruce Reproduction Open</b>	
<i>Black Spruce</i>	300
<i>White Spruce</i>	467
<b>Total Trees Per Acre</b>	<b>767</b>
<b>Stratum 6 Aspen Poletimber</b>	
<i>Aspen</i>	250
<i>Balsam Poplar</i>	10
<i>White Spruce</i>	570
<b>Total Trees Per Acre</b>	<b>830</b>
<b>Stratum 7 White Spruce Aspen Poletimber</b>	
<i>Aspen</i>	38
<i>Black Spruce</i>	363
<i>White Spruce</i>	325
<b>Total Trees Per Acre</b>	<b>725</b>
<b>Stratum 8 White Spruce Balsam Poplar</b>	
<i>Aspen</i>	50
<i>Balsam Poplar</i>	240
<i>Birch</i>	60
<i>White Spruce</i>	760
<b>Total Trees Per Acre</b>	<b>1,110</b>

Table 18. Number of trees per acre less than 5 inches dbh by stratum and species.

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	% Annual Growth	% Annual Mortality	% Annual Net Growth	CF Per Acre Per Year Growth	Total Annual Net Growth Cunits	Tons Per Acre Per Year Growth	Annual Net Growth Tons
Stratum 1 White Spruce Sawtimber	2.57%	1.64%	0.93%	12	836	0.20	1,424
Stratum 2 White Spruce Poletimber Closed	2.23%	1.26%	0.97%	10	2,065	0.17	3,537
Stratum 3 White Spruce Poletimber Open	1.91%	1.63%	0.28%	2	640	0.03	1,088
Stratum 4 Black & White Spruce Reproduction Closed	0.98%	0.00%	0.98%	3	331	0.05	562
Stratum 5 Black & White Spruce Reproduction Open	1.79%	0.00%	1.79%	2	1,657	0.02	2,817
Stratum 6 Aspen Poletimber	3.94%	0.00%	3.94%	49	5,718	1.02	11,752
Stratum 7 White Spruce Aspen Poletimber	2.85%	0.13%	2.72%	27	9,198	0.52	17,181
Stratum 8 White Spruce Balsam Poplar	3.21%	0.04%	3.17%	30	3,428	0.6	6,887
Total Live Volume	2.66%	0.85%	1.81%	10	22,607	0.19	41,052

Table 19. Growth and mortality estimates.

### E. Sustained Yield Analysis

Estimates of sustained yield have been made to guide future management decisions. The estimates in this analysis only include the timberland acreage and volume. Dwarf forests are not included. The sustained yield has been calculated using area control, which divides the acreage of each stratum by the rotation age. White spruce and mixed white spruce types use a rotation age of 120 years, which includes 10 years for establishment. The aspen timber type uses a rotation of 80 years, which includes 10 years for establishment. There has been no acreage reductions made for operability concerns. Estimates of operable economic sustainable yield are shown in Section VI.

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	Strata Description	Acres	Rota-tion	Acres /Yr.	Net CF/ Ac.	Net CF/Yr.	Net Tons /Ac.	Net Tons/ Yr.	Net BF/ Ac.	Net BF/Yr.
1	Ws Saw	6,756	120	56	1,680	94,584	28	1,576	4,879	274,688
2	Ws Pole Closed	20,637	120	172	1,243	213,765	22	3,783	2,461	423,230
3	Ws Pole Open	30,210	120	252	955	240,421	16	4,028	2,197	553,095
4	Bs-Ws Repro Closed	10,220	120	85	330	28,105	6	511	78	6,643
5	Bs-Ws Repro Open	94,794	120	790	98	77,415	1	790	119	94,004
6	Aspen Pole	11,738	80	147	1,236	181,352	25	3,668	846	124,129
7	Ws-As Pole	33,822	120	282	1,020	287,487	18	5,073	1,007	283,823
8	Ws-Bp	11,372	120	95	957	90,692	19	1,801	1,428	135,327
	<b>Totals</b>	<b>219,550</b>		<b>1,878</b>		<b>1,213,821</b>		<b>21,231</b>		<b>1,894,939</b>
	<b>Species Totals</b>									
	Aspen					242,340		5,054		83,084
	Balsam Poplar					65,348		1,499		129,165
	Birch					4,510		0		3,664
	Black Spruce					71,033		1,218		1,892
	White Spruce					830,590		13,460		1,677,134
	<b>Totals</b>					<b>1,213,821</b>		<b>21,231</b>		<b>1,894,939</b>

Table 20. Sustained yield estimate, total timberland area.

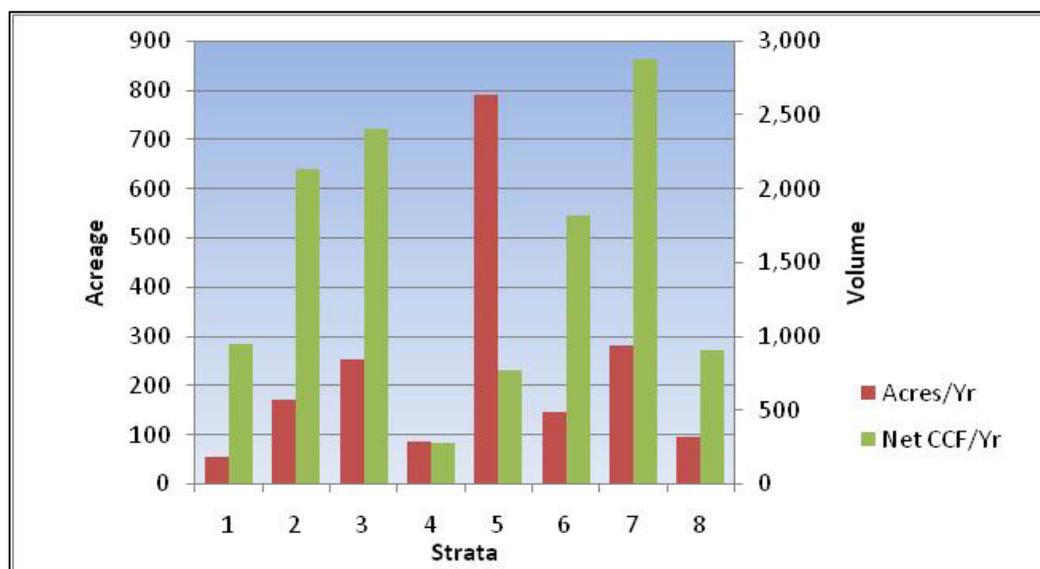


Figure 8. Sustained yield comparison between strata, total timberland area.

## VI. ECONOMIC AVAILABILITY OF SUSTAINABLE BIOMASS FUELS

The economics of available biomass were examined in context to two communities in the project area; Glennallen and Kenny Lake. A proposed wood pellet project and a proposed school biomass heating project are under evaluation in the vicinity of these areas. The proposed wood pellet project is being considered by the Ahtna Native Corporation and likely would be situated near Glennallen. The school biomass heating project would be constructed to supply the Kenny Lake School with wood fired heat and would be constructed on the school grounds. For both these projects to be successful an accurate estimate of economic and sustainable biomass resources is needed. This is especially important in Alaska because there is little urban, logging residue or wood manufacturing wood waste available as a supplemental biomass resource. Energy plantations of fast growing woody crops are also not available. For the most part, the biomass supply for these projects will consist solely of harvested firewood and commercial grade timber. When biomass is used in this form it is referred to as “fuelwood”. This is the most expensive of biomass sources (Ashton et al. 2008. *Woody Biomass Desk Guide and Toolkit*). This supply scenario is quite different than the Lower 48 where biomass projects generally rely on a combination of urban wood waste, mill waste and logging residues.

### A. Current Delivered Costs

Delivered firewood costs and distance to current supply sources were researched for both Glennallen and Kenny Lake. Currently the wood harvests are mostly from State of Alaska timber sales. Delivered prices and distances shown in *Table 20* are from timber sales located at mile 166 of the Glenn Highway. Firewood is hauled and delivered from the harvest site in 8-foot lengths. The timber sale area is in the vicinity of Tolsona Creek which is located on some of the closest state forest lands to Glennallen.

Delivery Location	Delivered Price Per Cord	Cord Configuration	Haul Distance In Road Miles	Working Circle Radius In Miles
Glennallen	\$180	8 Foot Lengths	23	21
Kenny Lake	\$200	8 Foot Lengths	64	47

Table 21. Delivered costs and mileage for firewood sources.

### B. Biomass Volume for Five Working Circles

Delivered firewood costs are highly correlated to haul distances. Generally to accurately ascertain the feasibility of a particular biomass project, harvest operation areas defined in working circles can be analyzed for volume quantity, geographic availability and cost of wood. Although the delivered cost and current working circle radius from the two communities to the mile 166 harvest site has been determined, calculating the economic availability of biomass fuels in an entire working circle is difficult because of lack of established infrastructure and barriers to adding new infrastructure. Major barriers to access include the Trans Alaska Pipeline and the numerous incised river systems. To provide a more realistic calculation of the economic availability of biomass, timberland area within the working circles has been reduced to show the

potential operable areas. *Figures 8 and 9* illustrate five 10-mile working circles with operable timberland areas identified surrounding Glennallen and Kenny Lake. Operable areas were determined through field reconnaissance and discussions with Division of Forestry, Valdez/Copper River Area, forestry personnel. Operable acreage and volume by stratum for the five 10-mile working circles are shown in *tables 21 and 22*. Established delivered costs to Glennallen and Kenny Lake were interpolated to calculate delivered cost per cord by working circle radius mileage (*figure 10*). These values were converted to a green ton basis in *figure 11* by applying the pounds per cubic foot spruce conversion factor (34 pounds/cubic foot).

### **C. Annual Biomass Yield for Five Working Circles**

Volume availability on an annual basis was determined by multiplying the inventory net growth rates percentages by strata (*table 19*) by the operable working circle volume. The annual volume availability for both Glennallen and Kenny Lake are shown in *tables 23 and 24* and *figures 12 and 13*.

The delivered cost information was then applied to the operable available volume to develop supply curves in cunits and tons for Glennallen and Kenny Lake. For this analysis it is assumed that delivered cost per cord is equivalent to a cunit basis (i.e. \$/cord=\$/cunit).

Utilizing the maximum radius of 50 miles if a facility was constructed in Glennallen there would potentially be available on an annual basis a sustainable volume of approximately 4,200 cords. Utilizing this same radius if a facility was constructed in Kenny Lake there would potentially be available on an annual basis a sustainable volume of approximately 2,800 cords. In both cases this volume could be available at a cost of about \$204.00 per cord. It should be noted that delivered fuelwood costs are based on current retail rates for the two communities. If suppliers were contracted to deliver to a single location at a fixed price and volume guarantee, it is likely that the delivered cost would be lower than stated here.

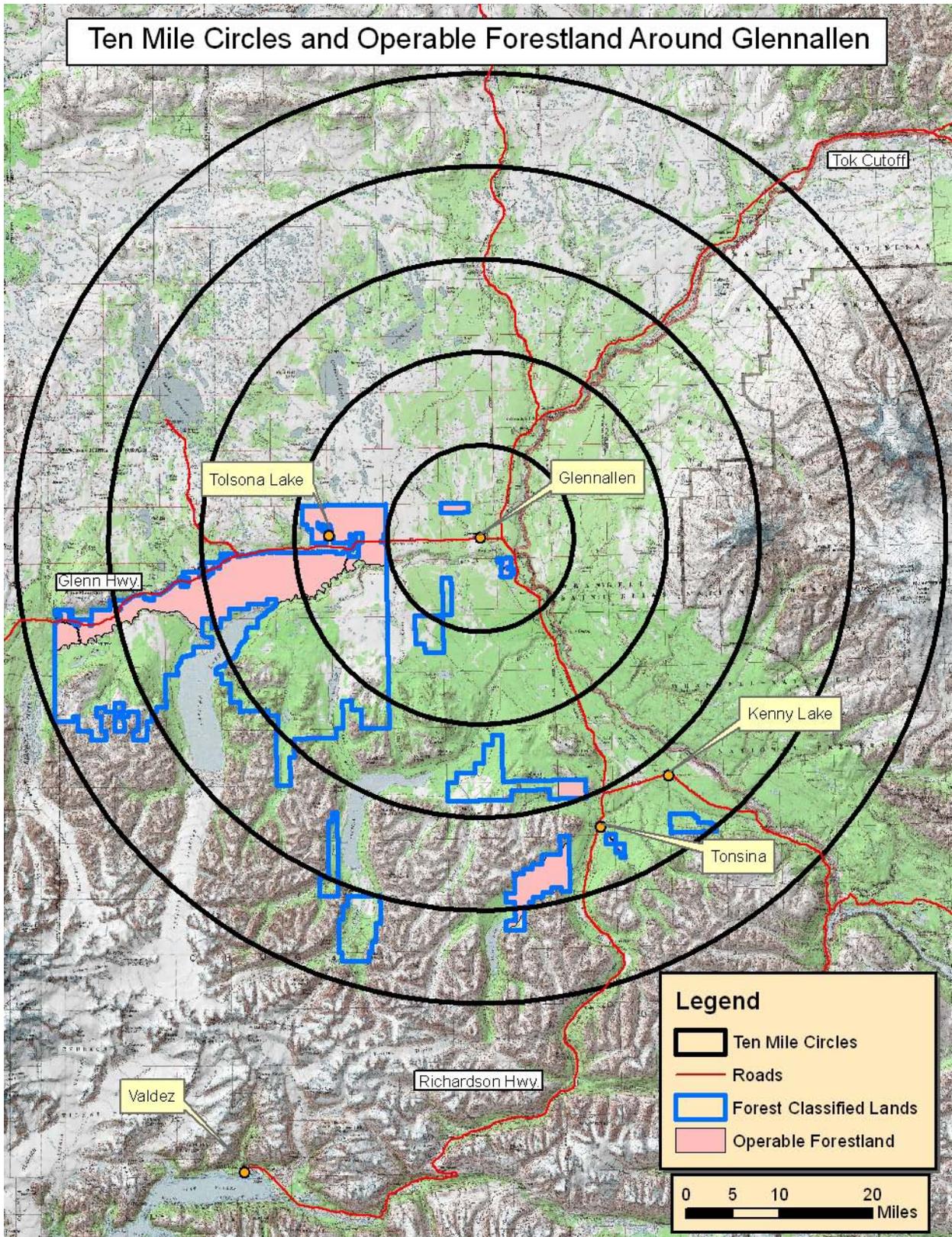


Figure 9. Ten mile circles and operable forestland around Glennallen.

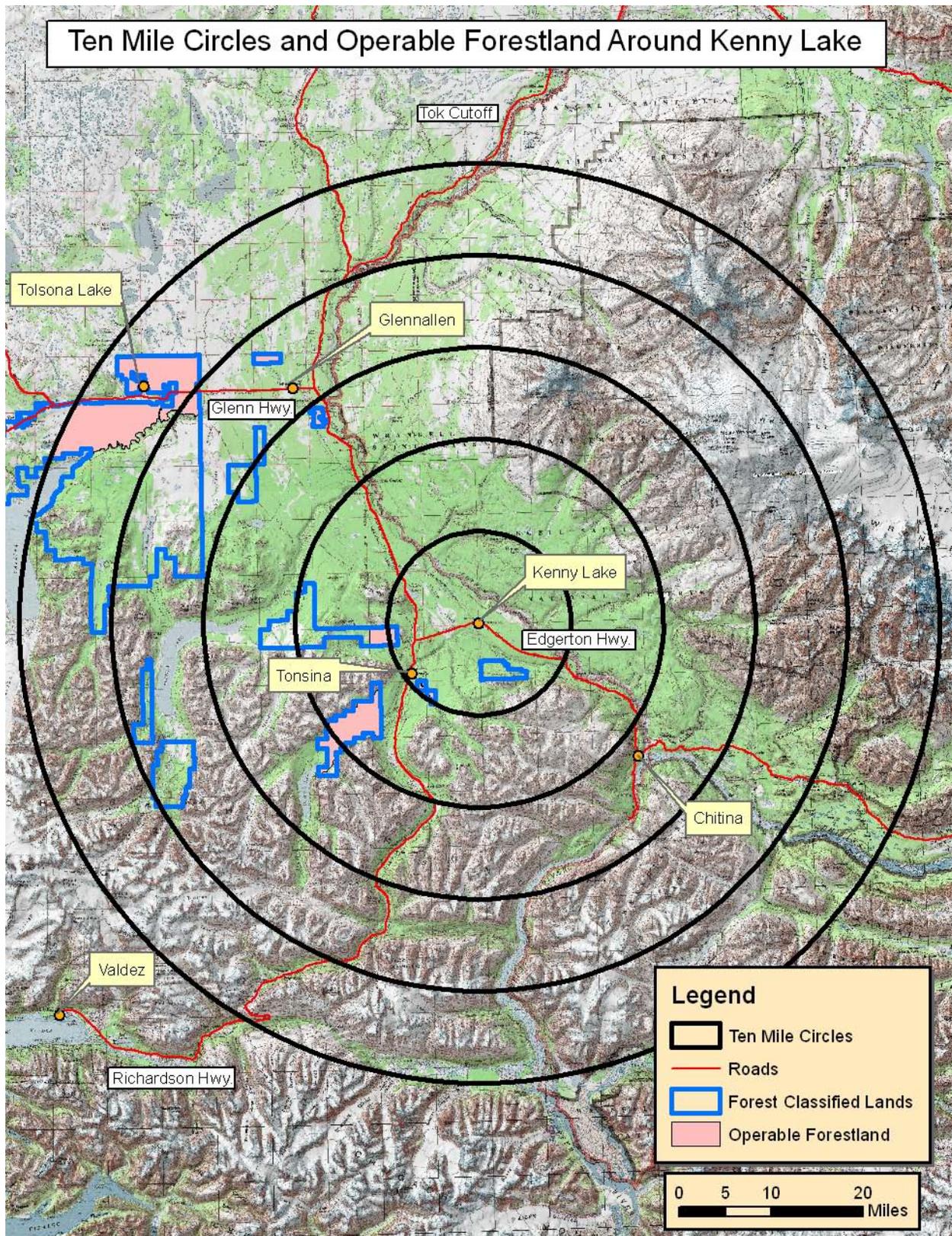


Figure 10. Ten mile circles and operable forestland around Kenny Lake.

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Stratum	0-10 Miles			10-20 Miles			20-30 Miles			30-40 Miles			40-50 Miles			Totals		
	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons
1	204	2,709	4,481	162	2,148	3,553	28	369	610	425	5,656	9,355	423	5,630	9,313	1,241	16,512	27,313
2	316	3,263	5,692	1,707	17,619	30,731	1,343	13,855	24,166	644	6,648	11,595	192	1,982	3,458	4,202	43,369	75,643
3	110	833	1,321	891	6,747	10,696	2,196	16,621	26,348	2,546	19,273	30,552	481	3,639	5,769	6,224	47,114	74,685
4	359	1,184	1,795	3,294	10,872	16,472	1,180	3,895	5,902	306	1,009	1,528	68	224	339	5,207	17,184	26,036
5	77	75	77	11,909	11,671	11,909	8,032	7,871	8,032	4,124	4,042	4,124	1,693	1,659	1,693	25,835	25,318	25,835
6	26	317	667	41	508	1,068	721	8,908	18,738	822	10,157	21,366	52	640	1,346	1,661	20,529	43,184
7	56	565	1,073	429	4,287	8,145	2,913	29,132	55,350	1,333	13,327	25,322	774	7,739	14,704	5,505	55,050	104,594
8	106	1,008	2,014	479	4,557	9,104	232	2,209	4,414	1,012	9,626	19,231	48	458	915	1,878	17,858	35,678
	1,254	9,955	17,119	18,912	58,408	91,678	16,645	82,861	143,561	11,212	69,737	123,074	3,731	21,971	37,537	51,753	242,933	412,968

Table 22. Glennallen area working circle operable acreage and volume.

Stratum	0-10 Miles			10-20 Miles			20-30 Miles			30-40 Miles			40-50 Miles			Totals		
	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons	Acres	Cunits	Tons
1	25	331	547	97	1,295	2,143	204	2,709	4,481	59	787	1,301	129	1,712	2,831	514	6,833	11,303
2	0	0	0	284	2,928	5,107	169	1,745	3,044	510	5,261	9,177	2,044	21,094	36,792	3,007	31,028	54,119
3	69	523	829	1,280	9,688	15,358	92	696	1,103	124	939	1,488	1,818	13,762	21,816	3,383	25,608	40,594
4	0	0	0	154	508	769	60	199	301	406	1,341	2,031	3,881	12,808	19,406	4,502	14,855	22,508
5	104	102	104	1,283	1,257	1,283	76	75	76	286	280	286	16,479	16,150	16,479	18,228	17,864	18,228
6	215	2,654	5,584	543	6,707	14,109	146	1,807	3,802	37	457	962	384	4,751	9,994	1,325	16,377	34,451
7	307	3,066	5,826	932	9,321	17,710	77	767	1,458	119	1,195	2,270	1,423	14,225	27,028	2,857	28,575	54,292
8	67	636	1,271	602	5,723	11,433	381	3,625	7,242	116	1,106	2,210	424	4,028	8,048	1,590	15,118	30,205
	786	7,312	14,160	5,174	37,428	67,913	1,205	11,622	21,506	1,658	11,366	19,726	26,582	88,530	142,395	35,405	156,258	265,699

Table 23. Kenny Lake area working circle operable acreage and volume.

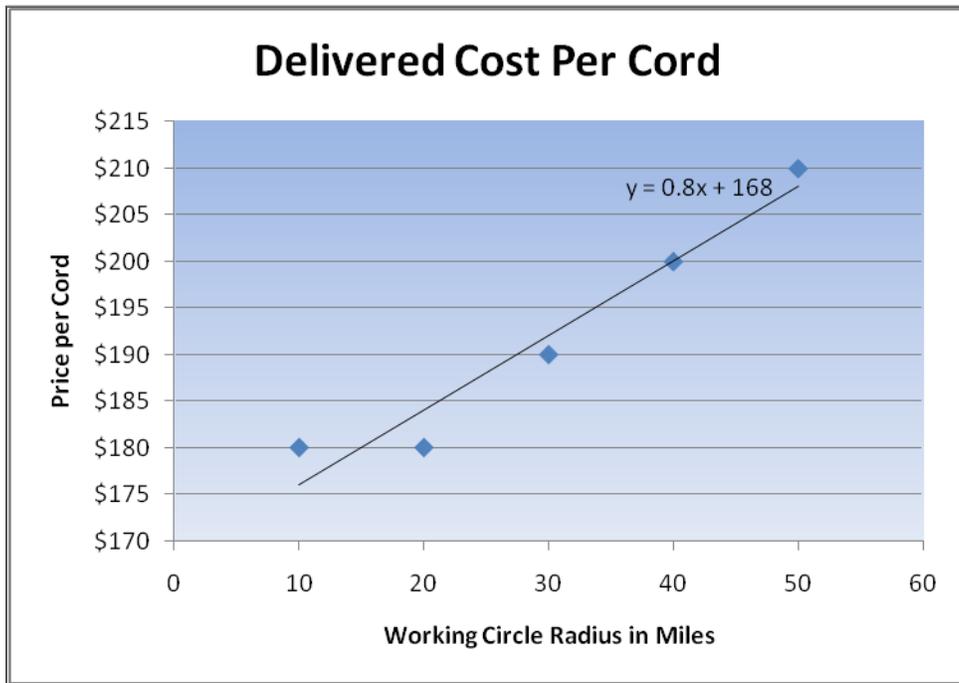


Figure 11. Delivered price per cord by working circle radius.

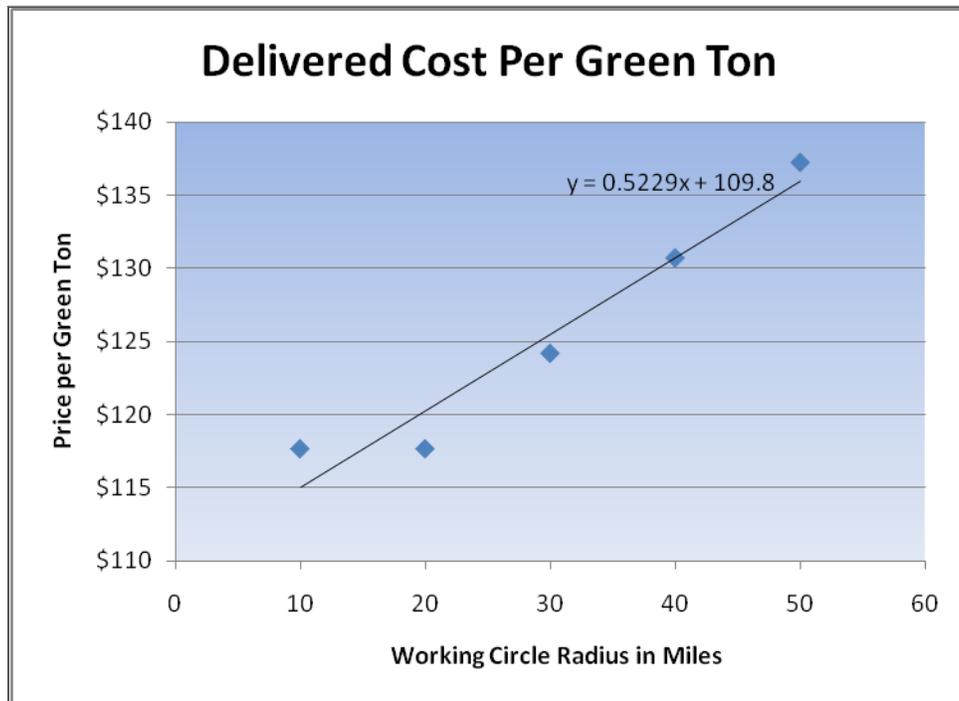


Figure 12. Delivered price per green ton by working circle radius.

Forest Resources on State Forest Lands In The Copper River Basin A Preliminary Estimate

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Stratum	0-10 Miles		10-20 Miles		20-30 Miles		30-40 Miles		40-50 Miles		Totals	
	Cunits	Tons	Cunits	Tons	Cunits	Tons	Cunits	Tons	Cunits	Tons	Cunits	Tons
1	25	42	20	33	3	6	53	87	52	87	154	254
2	32	55	171	298	134	234	64	112	19	34	421	734
3	2	4	19	30	47	74	54	86	10	16	132	209
4	12	18	107	161	38	58	10	15	2	3	168	255
5	1	1	209	213	141	144	72	74	30	30	453	462
6	12	26	20	42	351	738	400	842	25	53	809	1,701
7	15	29	117	222	792	1,506	363	689	210	400	1,497	2,845
8	32	64	144	289	70	140	305	610	15	29	566	1,131
	132	239	806	1,288	1,577	2,899	1,321	2,514	364	652	4,200	7,592

Table 24. Glennallen area working circle annual volume availability.

Stratum	0-10 Miles		10-20 Miles		20-30 Miles		30-40 Miles		40-50 Miles		Totals	
	Cunits	Tons	Cunits	Tons	Cunits	Tons	Cunits	Tons	Cunits	Tons	Cunits	Tons
1	3	5	12	20	25	42	7	12	16	26	64	105
2	0	0	28	50	17	30	51	89	205	357	301	525
3	1	2	27	43	2	3	3	4	39	61	72	114
4	0	0	5	8	2	3	13	20	126	190	146	221
5	2	2	23	23	1	1	5	5	289	295	320	326
6	105	220	264	556	71	150	18	38	187	394	645	1,357
7	83	158	254	482	21	40	32	62	387	735	777	1,477
8	20	40	181	362	115	230	35	70	128	255	479	958
	215	428	794	1,543	254	498	165	300	1,375	2,314	2,803	5,082

Table 25. Kenny Lake area working circle annual volume availability.

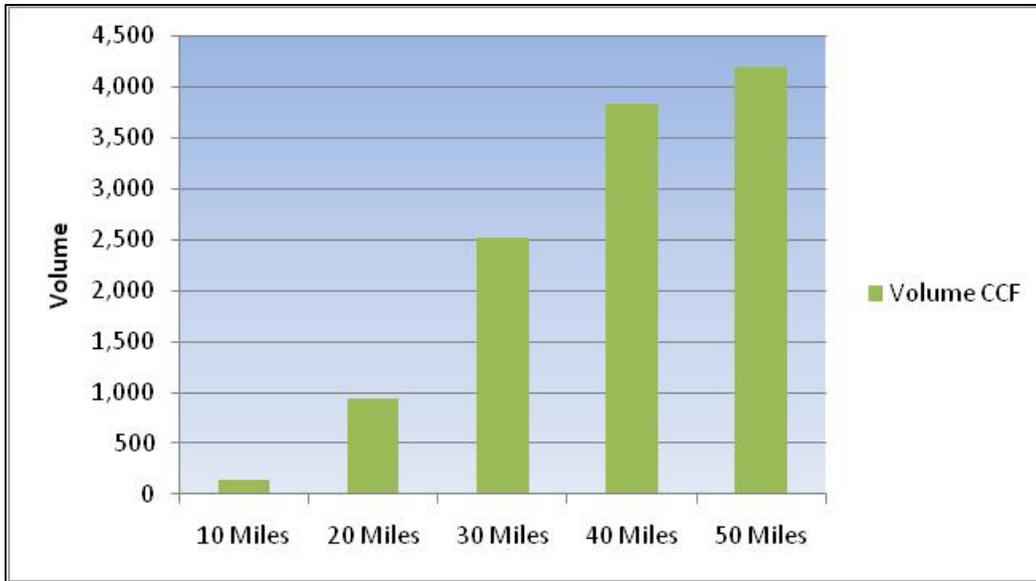


Figure 13. Cumulative volume availability by radii to Glennallen.

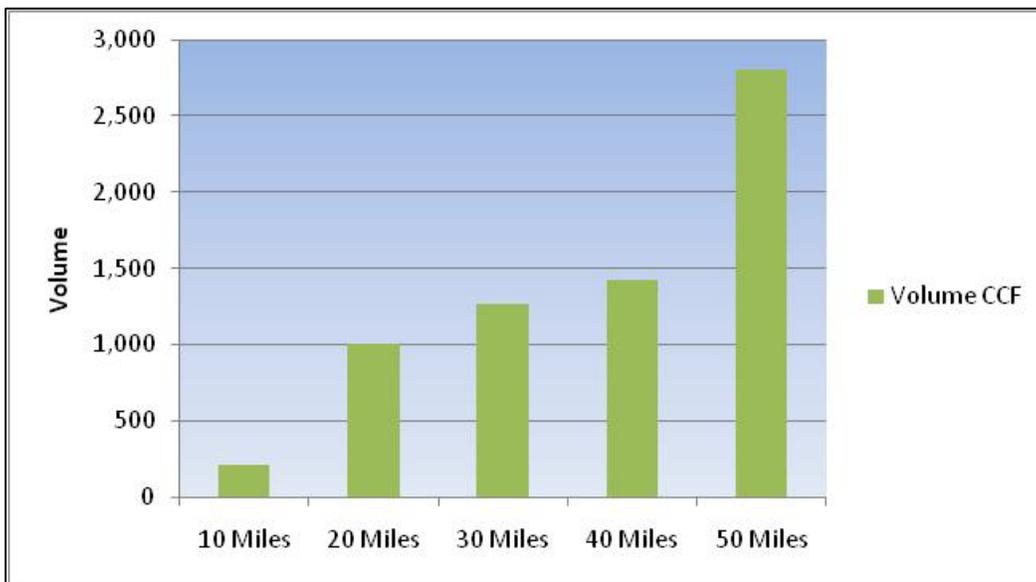


Figure 14. Cumulative volume availability by radii to Kenny Lake.

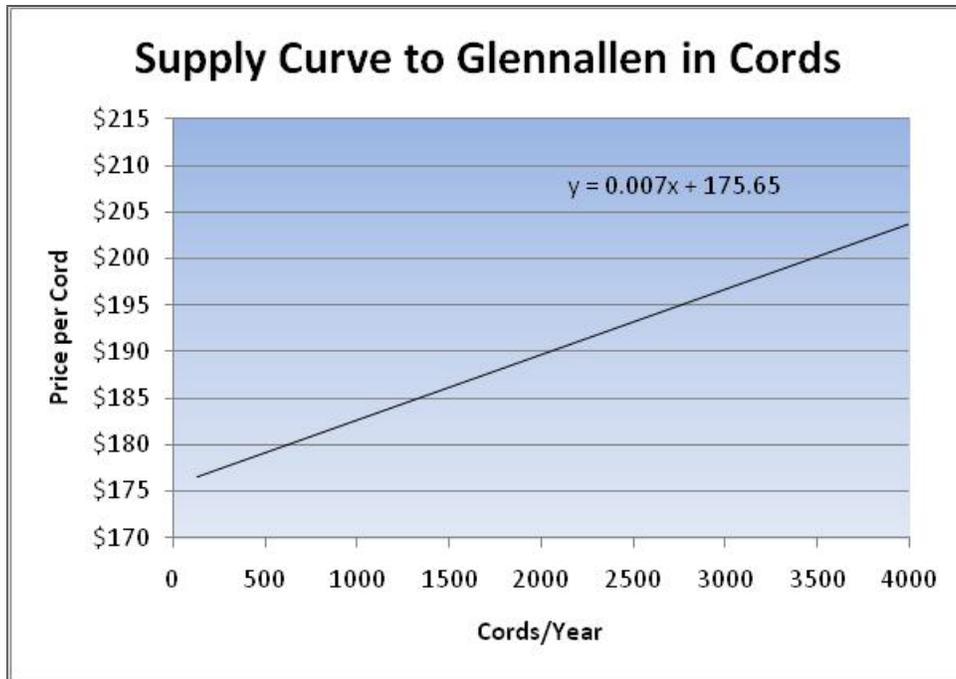


Figure 15. Supply curve for fuelwood in cords to Glennallen.

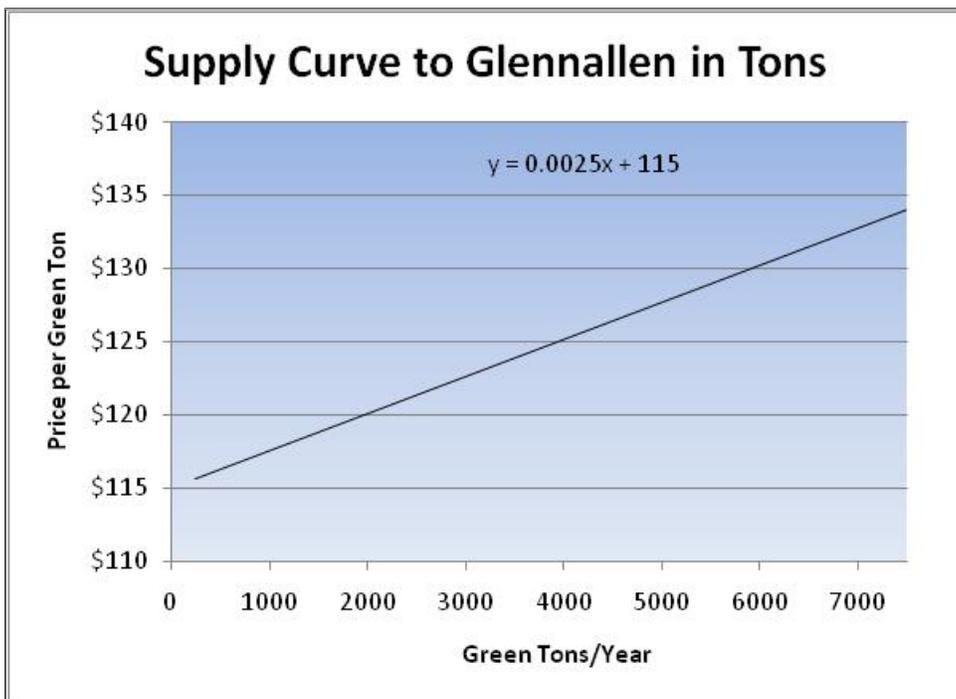


Figure 16. Supply curve for fuelwood in green tons to Glennallen.

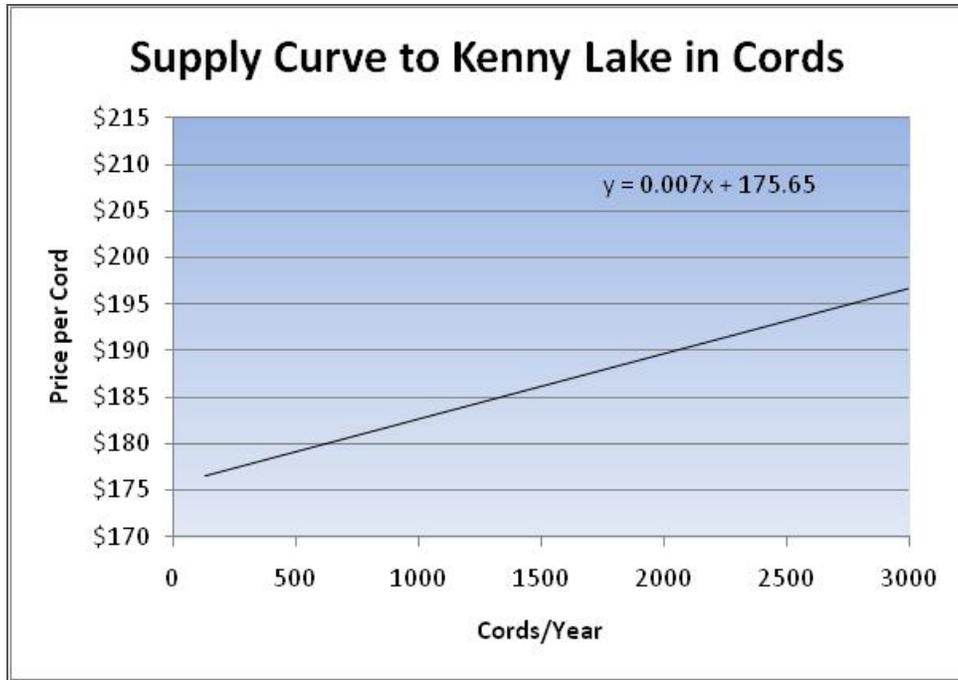


Figure 17. Supply curve for fuelwood in cords to Kenny Lake.

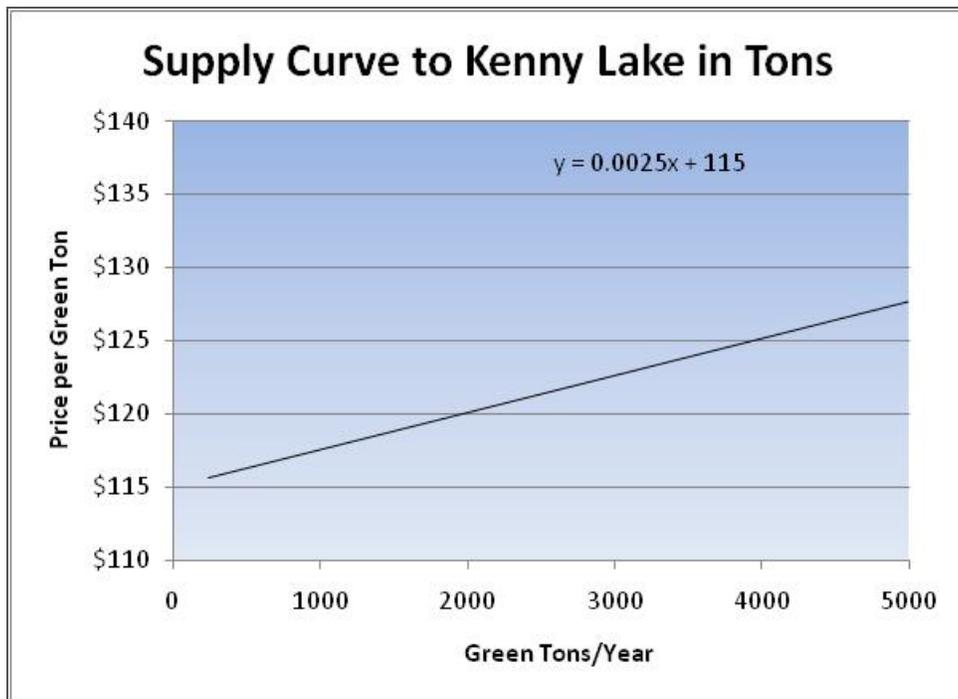


Figure 18. Supply curve for fuelwood in green tons to Kenny Lake.

## VII. LITERATURE CITED

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Appendix A  
Volume Per Acre and Total Volume by Stratum, Species and Size Class

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**Stratum 1 White Spruce Sawtimber**

**Acreage = 6,756**

	<i>Trees/</i>	<i>BA/</i>	<i>Gross</i>	<i>Net</i>	<i>Gross</i>	<i>Net</i>	<i>Gross</i>	<i>Net</i>	<i>Total</i>	<i>Total</i>	<i>Total</i>	<i>Total</i>	<i>Total</i>	<i>Total</i>
	<i>Ac</i>	<i>Ac</i>	<i>CF/</i>	<i>CF/</i>	<i>Tons/</i>	<i>Tons/</i>	<i>BF/</i>	<i>BF/</i>	<i>Gross</i>	<i>Net</i>	<i>Gross</i>	<i>Net</i>	<i>Gross</i>	<i>Net</i>
			<i>Ac</i>	<i>Ac</i>	<i>Ac</i>	<i>Ac</i>	<i>Ac</i>	<i>Ac</i>	<i>CF</i>	<i>CF</i>	<i>Tons</i>	<i>Tons</i>	<i>BF</i>	<i>BF</i>
<i>Aspen</i>														
Saw Live	1	0	0	0	0	0	4	2	0	0	0	0	27,406	13,703
<b>Species Totals</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>4</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>27,406</b>	<b>13,703</b>
<i>Balsam Poplar</i>														
Saw Live	1	1	13	10	0	0	25	21	88,120	68,660	1,895	1,476	169,489	139,703
<b>Species Totals</b>	<b>1</b>	<b>1</b>	<b>13</b>	<b>10</b>	<b>0</b>	<b>0</b>	<b>25</b>	<b>21</b>	<b>88,120</b>	<b>68,660</b>	<b>1,895</b>	<b>1,476</b>	<b>169,489</b>	<b>139,703</b>
<i>Black Spruce</i>														
Pole Live	6	1	9	9	0	0			62,258	59,358	1,058	1,009		
<b>Species Totals</b>	<b>6</b>	<b>1</b>	<b>9</b>	<b>9</b>	<b>0</b>	<b>0</b>			<b>62,258</b>	<b>59,358</b>	<b>1,058</b>	<b>1,009</b>		
<i>White Spruce</i>														
Saw Dead	19	14	315	253	5	4	1,376	1,084	2,126,561	1,710,649	36,152	29,081	9,296,153	7,324,679
Pole Live	97	26	431	420	7	7			2,912,468	2,837,792	49,512	48,242		
Pole Dead	28	8	124	97	2	2			835,589	652,897	14,205	11,099		
Saw Live	66	42	929	891	16	15	3,935	3,772	6,279,970	6,020,914	106,759	102,356	26,585,020	25,486,309
<b>Species Totals</b>	<b>210</b>	<b>91</b>	<b>1,799</b>	<b>1,661</b>	<b>31</b>	<b>28</b>	<b>5,311</b>	<b>4,856</b>	<b>12,154,588</b>	<b>11,222,252</b>	<b>206,628</b>	<b>190,778</b>	<b>35,881,173</b>	<b>32,810,988</b>
<b>Strata Totals</b>	<b>218</b>	<b>93</b>	<b>1,821</b>	<b>1,680</b>	<b>31</b>	<b>29</b>	<b>5,340</b>	<b>4,879</b>	<b>12,304,965</b>	<b>11,350,270</b>	<b>209,581</b>	<b>193,264</b>	<b>36,078,068</b>	<b>32,964,395</b>

**Stratum 2 White Spruce Poletimber Closed**

**Acreage = 20,637**

<i>Balsam Poplar</i>														
Pole Live	0	0	4	1	0	0			73,218	18,304	1,574	394		
Saw Live	2	2	31	28	1	1	129	116	645,907	581,316	13,887	12,498	2,667,625	2,400,863
<b>Species Totals</b>	<b>2</b>	<b>2</b>	<b>35</b>	<b>29</b>	<b>1</b>	<b>1</b>	<b>129</b>	<b>116</b>	<b>719,124</b>	<b>599,620</b>	<b>15,461</b>	<b>12,892</b>	<b>2,667,625</b>	<b>2,400,863</b>
<i>Black Spruce</i>														
Saw Live	0	0	3	2	0	0	14	11	57,917	41,722	985	709	281,153	224,922
Pole Dead	6	1	15	14	0	0			306,975	288,667	5,219	4,907		
Pole Live	39	8	81	78	1	1			1,674,196	1,604,515	28,461	27,277		
<b>Species Totals</b>	<b>45</b>	<b>9</b>	<b>99</b>	<b>94</b>	<b>2</b>	<b>2</b>	<b>14</b>	<b>11</b>	<b>2,039,088</b>	<b>1,934,904</b>	<b>34,664</b>	<b>32,893</b>	<b>281,153</b>	<b>224,922</b>
<i>White Spruce</i>														
Pole Live	153	37	514	509	9	9			10,613,252	10,508,418	180,425	178,643		
Saw Dead	12	8	157	149	3	3	631	604	3,239,586	3,067,961	55,073	52,155	13,021,917	12,473,360
Saw Live	33	19	422	414	7	7	1,766	1,729	8,707,599	8,533,795	148,029	145,075	36,453,452	35,683,715
Pole Dead	14	4	50	49	1	1			1,035,865	1,007,843	17,610	17,133		
<b>Species Totals</b>	<b>212</b>	<b>68</b>	<b>1,143</b>	<b>1,120</b>	<b>19</b>	<b>19</b>	<b>2,397</b>	<b>2,334</b>	<b>23,596,301</b>	<b>23,118,018</b>	<b>401,137</b>	<b>393,006</b>	<b>49,475,369</b>	<b>48,157,075</b>
<b>Strata Totals</b>	<b>259</b>	<b>79</b>	<b>1,277</b>	<b>1,243</b>	<b>22</b>	<b>21</b>	<b>2,540</b>	<b>2,461</b>	<b>26,354,514</b>	<b>25,652,542</b>	<b>451,263</b>	<b>438,792</b>	<b>52,424,147</b>	<b>50,782,860</b>

**Stratum 3 White Spruce Poletimber Open** *Acreage = 30,210*

	<i>Trees/ Ac</i>	<i>BA/ Ac</i>	<i>Gross CF/ Ac</i>	<i>Net CF/ Ac</i>	<i>Gross Tons/ Ac</i>	<i>Net Tons/ Ac</i>	<i>Gross BF/ Ac</i>	<i>Net BF/ Ac</i>	<i>Total Gross CF</i>	<i>Total Net CF</i>	<i>Total Gross Tons</i>	<i>Total Net Tons</i>	<i>Total Gross BF</i>	<i>Total Net BF</i>
<i>Black Spruce</i>														
Pole Live	19	4	55	51	1	1			1,666,630	1,538,205	28,333	26,149		
<b>Species Totals</b>	<b>19</b>	<b>4</b>	<b>55</b>	<b>51</b>	<b>1</b>	<b>1</b>			<b>1,666,630</b>	<b>1,538,205</b>	<b>28,333</b>	<b>26,149</b>		
<i>White Spruce</i>														
Saw Live	23	18	393	376	7	6	1,725	1,650	11,871,722	11,344,273	201,819	192,853	52,112,939	49,852,971
Saw Dead	8	8	170	124	3	2	758	547	5,131,434	3,745,998	87,234	63,682	22,893,674	16,510,874
Pole Live	97	26	341	330	6	6			10,308,739	9,969,919	175,249	169,489		
Pole Dead	13	5	80	74	1	1			2,414,382	2,240,895	41,044	38,095		
<b>Species Totals</b>	<b>142</b>	<b>57</b>	<b>984</b>	<b>904</b>	<b>17</b>	<b>15</b>	<b>2,483</b>	<b>2,197</b>	<b>29,726,277</b>	<b>27,301,086</b>	<b>505,347</b>	<b>464,118</b>	<b>75,006,612</b>	<b>66,363,845</b>
<b>Strata Totals</b>	<b>162</b>	<b>61</b>	<b>1,039</b>	<b>955</b>	<b>18</b>	<b>16</b>	<b>2,483</b>	<b>2,197</b>	<b>31,392,907</b>	<b>28,839,291</b>	<b>533,679</b>	<b>490,268</b>	<b>75,006,612</b>	<b>66,363,845</b>

**Stratum 4 Black & White Spruce Reproduction Closed** *Acreage = 10,220*

<i>Black Spruce</i>														
Pole Live	158	27	233	224	4	4			2,377,726	2,291,060	40,421	38,948		
<b>Species Totals</b>	<b>158</b>	<b>27</b>	<b>233</b>	<b>224</b>	<b>4</b>	<b>4</b>			<b>2,377,726</b>	<b>2,291,060</b>	<b>40,421</b>	<b>38,948</b>		
<i>White Spruce</i>														
Pole Live	34	8	92	88	2	1			939,167	900,278	15,966	15,305		
Saw Live	0	1	18	18	0	0	78	78	184,010	184,010	3,128	3,128	798,249	798,249
<b>Species Totals</b>	<b>34</b>	<b>9</b>	<b>110</b>	<b>106</b>	<b>2</b>	<b>2</b>	<b>78</b>	<b>78</b>	<b>1,123,177</b>	<b>1,084,288</b>	<b>19,094</b>	<b>18,433</b>	<b>798,249</b>	<b>798,249</b>
<b>Strata Totals</b>	<b>192</b>	<b>36</b>	<b>343</b>	<b>330</b>	<b>6</b>	<b>6</b>	<b>78</b>	<b>78</b>	<b>3,500,902</b>	<b>3,375,348</b>	<b>59,515</b>	<b>57,381</b>	<b>798,249</b>	<b>798,249</b>

**Stratum 5 Black & White Spruce Reproduction Open** *Acreage = 94,794*

<i>Black Spruce</i>														
Pole Live	14	2	12	12	0	0			1,130,595	1,130,595	19,220	19,220		
<b>Species Totals</b>	<b>14</b>	<b>2</b>	<b>12</b>	<b>12</b>	<b>0</b>	<b>0</b>			<b>1,130,595</b>	<b>1,130,595</b>	<b>19,220</b>	<b>19,220</b>		
<i>White Spruce</i>														
Pole Live	23	5	60	60	1	1			5,676,144	5,676,144	96,494	96,494		
Saw Live	5	3	43	26	1	0	199	119	4,082,890	2,449,734	69,409	41,645	18,830,040	11,298,024
<b>Species Totals</b>	<b>28</b>	<b>8</b>	<b>103</b>	<b>86</b>	<b>2</b>	<b>1</b>	<b>199</b>	<b>119</b>	<b>9,759,034</b>	<b>8,125,878</b>	<b>165,904</b>	<b>138,140</b>	<b>18,830,040</b>	<b>11,298,024</b>
<b>Strata Totals</b>	<b>41</b>	<b>10</b>	<b>115</b>	<b>98</b>	<b>2</b>	<b>2</b>	<b>199</b>	<b>119</b>	<b>10,889,629</b>	<b>9,256,473</b>	<b>185,124</b>	<b>157,360</b>	<b>18,830,040</b>	<b>11,298,024</b>

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**Stratum 6 Aspen Poletimber**

*Acreage = 11,738*

	<i>Trees/ Ac</i>	<i>BA/ Ac</i>	<i>Gross CF/ Ac</i>	<i>Net CF/ Ac</i>	<i>Gross Tons/ Ac</i>	<i>Net Tons/ Ac</i>	<i>Gross BF/ Ac</i>	<i>Net BF/ Ac</i>	<i>Total Gross CF</i>	<i>Total Net CF</i>	<i>Total Gross Tons</i>	<i>Total Net Tons</i>	<i>Total Gross BF</i>	<i>Total Net BF</i>
<i>Aspen</i>														
Saw Live	27	13	188	180	4	4	395	383	2,204,397	2,115,318	47,395	45,479	4,632,947	4,500,628
Pole Live	258	56	818	796	18	17			9,597,461	9,343,289	206,345	200,881		
<b>Species Totals</b>	<b>285</b>	<b>69</b>	<b>1,005</b>	<b>976</b>	<b>22</b>	<b>21</b>	<b>395</b>	<b>383</b>	<b>11,801,858</b>	<b>11,458,607</b>	<b>253,740</b>	<b>246,360</b>	<b>4,632,947</b>	<b>4,500,628</b>
<i>Balsam Poplar</i>														
Pole Live	3	1	8	0	0	0			93,705	937	2,015	20		
<b>Species Totals</b>	<b>3</b>	<b>1</b>	<b>8</b>	<b>0</b>	<b>0</b>	<b>0</b>			<b>93,705</b>	<b>937</b>	<b>2,015</b>	<b>20</b>		
<i>White Spruce</i>														
Saw Live	10	6	105	105	2	2	463	463	1,234,291	1,234,291	20,983	20,983	5,431,381	5,431,381
Pole Live	36	11	159	155	3	3			1,871,499	1,817,778	31,815	30,902		
<b>Species Totals</b>	<b>46</b>	<b>17</b>	<b>265</b>	<b>260</b>	<b>4</b>	<b>4</b>	<b>463</b>	<b>463</b>	<b>3,105,790</b>	<b>3,052,069</b>	<b>52,798</b>	<b>51,885</b>	<b>5,431,381</b>	<b>5,431,381</b>
<b>Strata Totals</b>	<b>334</b>	<b>87</b>	<b>1,278</b>	<b>1,236</b>	<b>26</b>	<b>25</b>	<b>857</b>	<b>846</b>	<b>15,001,353</b>	<b>14,511,613</b>	<b>308,553</b>	<b>298,265</b>	<b>10,064,328</b>	<b>9,932,009</b>

**Stratum 7 White Spruce Aspen Poletimber**

*Acreage = 33,822*

<i>Aspen</i>														
Pole Live	55	16	291	290	6	6			9,828,210	9,806,933	211,307	210,849		
Saw Live	9	4	59	54	1	1	107	95	1,980,575	1,816,029	42,582	39,045	3,618,148	3,221,334
<b>Species Totals</b>	<b>64</b>	<b>20</b>	<b>349</b>	<b>344</b>	<b>8</b>	<b>7</b>	<b>107</b>	<b>95</b>	<b>11,808,784</b>	<b>11,622,962</b>	<b>253,889</b>	<b>249,894</b>	<b>3,618,148</b>	<b>3,221,334</b>
<i>Birch</i>														
Pole Live	3	1	10	8	0	0			345,641	276,513	8,641	6,913		
Saw Live	1	1	10	8	0	0	16	13	348,475	278,780	8,712	6,969	551,137	440,910
<b>Species Totals</b>	<b>4</b>	<b>2</b>	<b>21</b>	<b>16</b>	<b>1</b>	<b>0</b>	<b>16</b>	<b>13</b>	<b>694,116</b>	<b>555,293</b>	<b>17,353</b>	<b>13,882</b>	<b>551,137</b>	<b>440,910</b>
<i>Black Spruce</i>														
Pole Live	18	3	33	26	1	0			1,130,633	869,490	19,221	14,781		
Pole Dead	7	2	23	21	0	0			770,936	693,842	13,106	11,795		
<b>Species Totals</b>	<b>25</b>	<b>5</b>	<b>56</b>	<b>46</b>	<b>1</b>	<b>1</b>			<b>1,901,569</b>	<b>1,563,332</b>	<b>32,327</b>	<b>26,577</b>		
<i>White Spruce</i>														
Saw Live	23	13	214	205	4	3	942	899	7,245,420	6,924,067	123,172	117,709	31,852,141	30,412,704
Pole Live	119	29	412	409	7	7			13,945,757	13,845,312	237,078	235,370		
<b>Species Totals</b>	<b>142</b>	<b>42</b>	<b>627</b>	<b>614</b>	<b>11</b>	<b>10</b>	<b>942</b>	<b>899</b>	<b>21,191,177</b>	<b>20,769,379</b>	<b>360,250</b>	<b>353,079</b>	<b>31,852,141</b>	<b>30,412,704</b>
<b>Strata Totals</b>	<b>235</b>	<b>68</b>	<b>1,052</b>	<b>1,020</b>	<b>20</b>	<b>19</b>	<b>1,065</b>	<b>1,007</b>	<b>35,595,646</b>	<b>34,510,967</b>	<b>663,818</b>	<b>643,432</b>	<b>36,021,425</b>	<b>34,074,948</b>

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**Stratum 8 White Spruce Balsam Poplar**

*Acreage = 11,372*

	<i>Trees/ Ac</i>	<i>BA/ Ac</i>	<i>Gross CF/ Ac</i>	<i>Net CF/ Ac</i>	<i>Gross Tons/ Ac</i>	<i>Net Tons/ Ac</i>	<i>Gross BF/ Ac</i>	<i>Net BF/ Ac</i>	<i>Total Gross CF</i>	<i>Total Net CF</i>	<i>Total Gross Tons</i>	<i>Total Net Tons</i>	<i>Total Gross BF</i>	<i>Total Net BF</i>
<i>Aspen</i>														
Pole Live	13	3	25	23	1	0			288,886	259,998	6,211	5,590		
<b>Species Totals</b>	<b>13</b>	<b>3</b>	<b>25</b>	<b>23</b>	<b>1</b>	<b>0</b>			<b>288,886</b>	<b>259,998</b>	<b>6,211</b>	<b>5,590</b>		
<i>Balsam Poplar</i>														
Saw Live	39	29	460	419	10	9	1,276	1,140	5,225,964	4,769,035	112,358	102,534	14,506,346	12,964,955
Pole Live	44	13	213	212	5	5			2,421,503	2,405,248	52,062	51,713		
<b>Species Totals</b>	<b>83</b>	<b>42</b>	<b>672</b>	<b>631</b>	<b>14</b>	<b>14</b>	<b>1,276</b>	<b>1,140</b>	<b>7,647,466</b>	<b>7,174,283</b>	<b>164,421</b>	<b>154,247</b>	<b>14,506,346</b>	<b>12,964,955</b>
<i>White Spruce</i>														
Saw Live	3	3	64	60	1	1	279	263	729,444	686,556	12,401	11,671	3,176,093	2,992,709
Saw Dead	0	0	7	6	0	0	30	24	79,945	63,956	1,359	1,087	346,429	277,143
Pole Live	87	19	243	237	4	4			2,764,577	2,691,810	46,998	45,761		
<b>Species Totals</b>	<b>90</b>	<b>23</b>	<b>314</b>	<b>303</b>	<b>5</b>	<b>5</b>	<b>310</b>	<b>288</b>	<b>3,573,966</b>	<b>3,442,323</b>	<b>60,757</b>	<b>58,519</b>	<b>3,522,522</b>	<b>3,269,852</b>
<b>Strata Totals</b>	<b>185</b>	<b>68</b>	<b>1,012</b>	<b>956</b>	<b>20</b>	<b>19</b>	<b>1,585</b>	<b>1,428</b>	<b>11,510,319</b>	<b>10,876,603</b>	<b>231,389</b>	<b>218,357</b>	<b>18,028,869</b>	<b>16,234,807</b>

<b>Grand Totals = 219,550 Acres</b>	<b>146,550,235 Gross Cubic Feet</b>	<b>138,373,108 Net Cubic Feet</b>
	<b>247,251,739 Gross Board Feet</b>	<b>222,449,137 Net Board Feet</b>

Appendix B  
Stand Tables Per Acre by Stratum and Species

Forest Resources on State Forest Lands In The Copper River Basin A Preliminary Estimate

<i>DBH</i>	<i># of Trees</i>	<i>BA</i>	<i>Gross CF</i>	<i>Net CF</i>	<i>Gross Tons</i>	<i>Net Tons</i>	<i>Gross BF</i>	<i>Net BF</i>	
<b>Stratum 1 White Spruce Sawtimber</b>						<b>Acreage = 6,756</b>			
<i>Aspen</i>									
9	1	0	0	0	0	0	4	2	
<b>Totals</b>	1	0	0	0	0	0	4	2	
<i>Balsam Poplar</i>									
10	0	0	3	2	0	0	3	2	
11	1	1	6	4	0	0	6	4	
13	0	0	4	3	0	0	16	14	
<b>Totals</b>	1	1	13	10	0	0	25	21	
<i>Black Spruce</i>									
5	1	0	1	1	0	0			
6	5	1	8	8	0	0			
<b>Totals</b>	6	1	9	9	0	0			
<i>White Spruce</i>									
5	16	2	22	22	0	0			
6	29	6	73	71	1	1			
7	40	11	177	166	3	3			
8	28	10	181	167	3	3			
9	34	16	321	301	5	5	841	801	
10	30	16	350	325	6	6	1,441	1,337	
11	13	9	197	181	3	3	843	769	
12	10	8	186	176	3	3	819	781	
13	5	5	125	97	2	2	572	440	
14	2	3	80	79	1	1	378	376	
15	2	3	48	43	1	1	223	194	
16	2	2	38	32	1	1	194	157	
<b>Totals</b>	210	91	1,799	1,661	31	28	5,311	4,856	
<b>Totals for stratum White Spruce Sawtimber</b>		<b>218</b>	<b>93</b>	<b>1,821</b>	<b>1,680</b>	<b>31</b>	<b>29</b>	<b>5,340</b>	<b>4,879</b>

<b>Stratum 2 White Spruce Poletimber Closed</b>						<b>Acreage = 20,637</b>		
<i>Balsam Poplar</i>								
13	1	1	14	10	0	0	40	36
15	0	1	10	9	0	0	43	39
16	0	1	10	9	0	0	46	41
<b>Totals</b>	2	2	35	29	1	1	129	116
<i>Black Spruce</i>								
5	21	3	24	24	0	0		
6	16	3	34	33	1	1		
7	5	1	19	18	0	0		
8	3	1	18	17	0	0		
10	0	0	3	2	0	0	14	11
<b>Totals</b>	45	9	99	94	2	2	14	11

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<i>DBH</i>	<i># of Trees</i>	<i>BA</i>	<i>Gross CF</i>	<i>Net CF</i>	<i>Gross Tons</i>	<i>Net Tons</i>	<i>Gross BF</i>	<i>Net BF</i>
<i>White Spruce</i>								
5	33	4	35	35	1	1		
6	62	13	158	156	3	3		
7	40	11	173	171	3	3		
8	19	7	104	102	2	2		
9	23	11	196	193	3	3	287	381
10	16	9	188	185	3	3	494	758
11	8	4	84	79	1	1	270	325
12	5	4	102	102	2	2	445	445
13	3	2	54	54	1	1	240	237
15	2	1	33	32	1	1	151	147
17	0	0	9	8	0	0	49	40
19	0	0	6	3	0	0		
<b>Totals</b>	212	68	1,143	1,120	19	19	1,935	2,334
<b>Totals for stratum</b>	<b>White Spruce</b>	<b>Poletimber</b>	<b>Closed</b>					
	259	79	1,277	1,243	22	21	2,078	2,461

**Stratum 3 White Spruce Poletimber Open** *Acreage = 30,210*

<i>Black Spruce</i>								
5	8	1	9	8	0	0		
6	4	1	12	11	0	0		
7	6	2	21	20	0	0		
8	2	1	14	12	0	0		
<b>Totals</b>	19	4	55	51	1	1		
<i>White Spruce</i>								
5	22	4	28	27	0	0		
6	24	5	54	52	1	1		
7	25	7	96	92	2	2		
8	29	10	160	155	3	3		
9	16	7	133	128	2	2	200	199
10	6	3	61	52	1	1	262	223
11	3	2	49	47	1	1	209	199
12	7	5	115	109	2	2	502	476
13	4	4	74	64	1	1	315	269
14	2	2	43	40	1	1	192	180
15	2	2	52	49	1	1	237	224
16	1	1	18	9	0	0	86	41
17	1	1	26	18	0	0	121	86
18	1	1	21	10	0	0	98	46
19	0	1	16	15	0	0	75	69
23	0	1	19	18	0	0	92	91
24	0	1	19	19	0	0	93	92
<b>Totals</b>	142	57	984	904	17	15	2,483	2,197
<b>Totals for stratum</b>	<b>White Spruce</b>	<b>Poletimber</b>	<b>Open</b>					
	162	61	1,039	955	18	16	2,483	2,197

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<i>DBH</i>	<i># of Trees</i>	<i>BA</i>	<i>Gross CF</i>	<i>Net CF</i>	<i>Gross Tons</i>	<i>Net Tons</i>	<i>Gross BF</i>	<i>Net BF</i>
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**Stratum 4 Black & White Spruce Reproduction Closed** *Acreage = 10,220*

*Black Spruce*

5	108	16	105	101	2	2		
6	33	6	64	61	1	1		
7	12	3	41	40	1	1		
8	5	2	23	22	0	0		

<b>Totals</b>	158	27	233	224	4	4		
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*White Spruce*

6	21	4	40	38	1	1		
7	13	4	48	46	1	1		
8	0	0	4	4	0	0		
10	0	1	18	18	0	0	78	78

<b>Totals</b>	34	9	110	106	2	2	78	78
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<b>Totals for stratum Black &amp; White Spruce Reproduction Closed</b>								
	192	36	343	330	6	6	78	78

**Stratum 5 Black & White Spruce Reproduction Open** *Acreage = 94,794*

*Black Spruce*

5	14	2	12	12	0	0		
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<b>Totals</b>	14	2	12	12	0	0		
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*White Spruce*

6	12	2	18	18	0	0		
7	7	2	25	25	0	0		
8	4	1	17	17	0	0		
10	5	3	43	26	1	0	199	119

<b>Totals</b>	28	8	103	86	2	1	199	119
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<b>Totals for stratum Black &amp; White Spruce Reproduction Open</b>								
	41	10	115	98	2	2	199	119

**Stratum 6 Aspen Poletimber** *Acreage = 11,738*

*Aspen*

5	91	13	162	160	3	3		
6	83	16	211	206	5	4		
7	51	14	228	221	5	5		
8	27	10	176	167	4	4		
9	17	7	116	110	2	2	95	88
10	12	4	47	45	1	1	74	72
11	5	3	58	58	1	1	188	186
12	0	0	8	8	0	0	38	37

<b>Totals</b>	285	69	1,005	976	22	21	395	383
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Forest Resources on State Forest Lands In The Copper River Basin A Preliminary Estimate

<i>DBH</i>	<i># of Trees</i>	<i>BA</i>	<i>Gross CF</i>	<i>Net CF</i>	<i>Gross Tons</i>	<i>Net Tons</i>	<i>Gross BF</i>	<i>Net BF</i>
<i>Balsam Poplar</i>								
8	3	1	8	0	0	0		
<i>Totals</i>	3	1	8	0	0	0		
<i>White Spruce</i>								
5	3	0	0	0	0	0		
6	7	1	14	14	0	0		
7	5	1	26	25	0	0		
8	14	5	73	71	1	1		
9	9	4	60	58	1	1	53	53
10	2	1	17	17	0	0	74	74
11	5	2	24	24	0	0	107	107
13	2	2	31	31	1	1	137	137
15	1	1	20	20	0	0	92	92
<i>Totals</i>	46	17	265	260	4	4	463	463
<i>Totals for stratum</i>	<i>Aspen Poletimber</i>							
	334	87	1,278	1,236	26	25	857	846

**Stratum 7 White Spruce Aspen Poletimber** *Acreage = 33,822*

<i>Aspen</i>								
6	24	5	83	83	2	2		
7	12	3	64	64	1	1		
8	15	5	109	109	2	2		
9	8	4	66	65	1	1	39	39
10	4	2	28	23	1	0	68	56
<i>Totals</i>	64	20	349	344	8	7	107	95
<i>Birch</i>								
7	3	1	10	8	0	0		
9	1	1	10	8	0	0	16	13
<i>Totals</i>	4	2	21	16	1	0	16	13
<i>Black Spruce</i>								
5	7	1	4	4	0	0		
6	3	1	4	4	0	0		
7	15	4	48	39	1	1		
<i>Totals</i>	25	5	56	46	1	1		
<i>White Spruce</i>								
5	12	2	17	17	0	0		
6	59	12	143	141	2	2		
7	34	9	139	138	2	2		
8	11	4	75	75	1	1		
9	10	5	83	75	1	1	277	239
10	5	2	40	40	1	1	178	178
11	5	3	48	48	1	1	209	209
12	6	4	60	60	1	1	179	179
13	1	1	22	21	0	0	99	94
<i>Totals</i>	142	42	627	614	11	10	942	899
<i>Totals for stratum</i>	<i>White Spruce Aspen Poletimber</i>							
	235	68	1,052	1,020	20	19	1,065	1,007

Forest Resources on State Forest Lands In The Copper River Basin A Preliminary Estimate

<i>DBH</i>	<i># of Trees</i>	<i>BA</i>	<i>Gross CF</i>	<i>Net CF</i>	<i>Gross Tons</i>	<i>Net Tons</i>	<i>Gross BF</i>	<i>Net BF</i>
<b>Stratum 8 White Spruce Balsam Poplar</b>						<b>Acreage = 11,372</b>		
<i>Aspen</i>								
6	7	2	13	12	0	0		
7	6	2	12	11	0	0		
<b>Totals</b>	13	3	25	23	1	0		
<i>Balsam Poplar</i>								
6	17	3	29	29	1	1		
7	4	1	24	23	1	0		
8	15	5	85	84	2	2		
9	19	9	139	136	3	3	21	20
10	15	8	138	134	3	3	185	183
11	7	5	98	92	2	2	244	235
12	2	2	41	34	1	1	157	146
13	2	3	55	52	1	1	220	212
14	2	4	48	32	1	1	253	178
17	1	2	15	13	0	0	195	167
<b>Totals</b>	83	42	672	631	14	14	1,276	1,140
<i>White Spruce</i>								
5	29	4	35	35	1	1		
6	36	7	86	86	1	1		
7	8	2	28	27	0	0		
8	11	4	74	70	1	1		
9	3	1	20	18	0	0		
11	1	1	22	19	0	0	98	84
12	2	1	28	27	0	0	120	118
13	0	0	7	6	0	0	30	24
14	0	1	14	14	0	0	61	61
<b>Totals</b>	90	23	314	303	5	5	310	288
<b>Totals for stratum</b>		<b>White Spruce</b>	<b>Balsam Poplar</b>					
	185	68	1,012	956	20	19	1,585	1,428

Appendix C  
Log Grade by Stratum

Forest Resources on State Forest Lands In The Copper River Basin A Preliminary Estimate

Puget Sound Log Scaling and Grading Bureau Specifications

Species	Grade No.	Gross Diameter	Gross Length	Minimum Volume	Surface	Annual Ring Count	Slope of Grain
White/Black Spruce	1	20 Inches	16 Feet		75% Clear	8 per Inch	< 3 inches/foot
	2	12 Inches	12 Feet		50% Clear, Knots < 2.5 inches in diameter	8 per Inch	< 2 inches/foot
	3	6 Inches	12 Feet	50 BF Net			May include excessive slope with deduction
	4	5 Inches	12 Feet	10 BF Net			
Aspen/Birch	1	16 Inches	8 Feet		75% Clear		
	2	12 Inches	8 Feet		50% Clear		
	3	10 Inches	8 Feet	10 BF Net			
Balsam Poplar	1	10 Inches	8 Feet		< 4 Knots per log		
	2	6 Inches	8 Feet				
	4	5 Inches	8 Feet	10 BF Net			
All Species	5	4 Inches	12 Feet	10 BF Net			
Utility Logs	Logs do not meet sawmill grades, but are suitable for the production of firm usable chips to an amount not less than 50% of gross scale. A log that is burned or charred or is not mechanically barkable, shall not qualify as a Utility Log.						

## Log Grade Report by Strata

*Grade 1st Log   Grade 2nd Log   # Of Trees Measured   % Of Trees Measured*

### Stratum 1

#### White Spruce Sawtimber

##### *Aspen*

5	5	1	100%
---	---	---	------

*Total for Aspen*

1

##### *Balsam Poplar*

5	5	3	100%
---	---	---	------

*Total for Balsam Poplar*

3

##### *White Spruce*

		4	3%
--	--	---	----

2	3	2	2%
---	---	---	----

3	3	2	2%
---	---	---	----

3	4	13	11%
---	---	----	-----

3	5	1	1%
---	---	---	----

4		1	1%
---	--	---	----

4	4	67	57%
---	---	----	-----

4	5	19	16%
---	---	----	-----

5		1	1%
---	--	---	----

5	5	8	7%
---	---	---	----

*Total for White Spruce*

118

*Total for Stratum 1*

122

### Stratum 2

#### White Spruce Poletimber Closed

##### *Balsam Poplar*

2	5	2	67%
---	---	---	-----

5	5	1	33%
---	---	---	-----

*Total for Balsam Poplar*

3

##### *Black Spruce*

5	5	1	100%
---	---	---	------

*Total for Black Spruce*

1

##### *White Spruce*

		3	6%
--	--	---	----

2	4	1	2%
---	---	---	----

2	5	1	2%
---	---	---	----

3	3	1	2%
---	---	---	----

3	4	9	19%
---	---	---	-----

4	4	24	51%
---	---	----	-----

4	5	6	13%
---	---	---	-----

5	5	2	4%
---	---	---	----

*Total for White Spruce*

47

*Total for Stratum 2*

51

*Grade 1st Log   Grade 2nd Log   # Of Trees Measured   % Of Trees Measured*

**Stratum 3**

White Spruce Poletimber Open

*White Spruce*

			1	3%
	2	3	2	5%
	3	3	1	3%
	3	4	4	10%
	3	5	3	8%
	4		1	3%
	4	4	18	45%
	4	5	7	18%
	5		1	3%
	5	5	2	5%
<i>Total for White Spruce</i>			40	
<i>Total for Stratum 3</i>			40	

**Stratum 4**

Black & White Spruce Reproduction Closed

*White Spruce*

	3	4	1	50%
	4	5	1	50%
<i>Total for White Spruce</i>			2	
<i>Total for Stratum 4</i>			2	

**Stratum 5**

Black & White Spruce Reproduction Open

*White Spruce*

	5		1	50%
	5	5	1	50%
<i>Total for White Spruce</i>			2	
<i>Total for Stratum 5</i>			2	

**Stratum 6**

Aspen Poletimber

*Aspen*

	4		1	7%
	4	4	10	67%
	4	5	4	27%
<i>Total for Aspen</i>			15	

*White Spruce*

	2	3	1	14%
	3	4	1	14%
	4	4	5	71%
<i>Total for White Spruce</i>			7	
<i>Total for Stratum 6</i>			22	

Forest Resources on State Forest Lands In The Copper River Basin A Preliminary Estimate

*Grade 1st Log   Grade 2nd Log   # Of Trees Measured   % Of Trees Measured*

**Stratum 7**

White Spruce Aspen Poletimber

*Aspen*

4		1	25%
4	5	2	50%
5	5	1	25%

Total for Aspen

4

*Birch*

4	4	1	100%
---	---	---	------

Total for Birch

1

*White Spruce*

4		1	9%
4	4	6	55%
4	5	3	27%
5		1	9%

Total for White Spruce

11

Total for Stratum 7

16

**Stratum 8**

White Spruce Balsam Poplar

*Balsam Poplar*

1	2	7	15%
1	4	1	2%
2	2	11	23%
2	3	5	11%
2	4	8	17%
2	5	5	11%
4		1	2%
4	4	1	2%
4	5	1	2%
5	5	7	15%

Total for Balsam Poplar

47

*White Spruce*

3	4	2	33%
4	4	1	17%
5	5	3	50%

Total for White Spruce

6

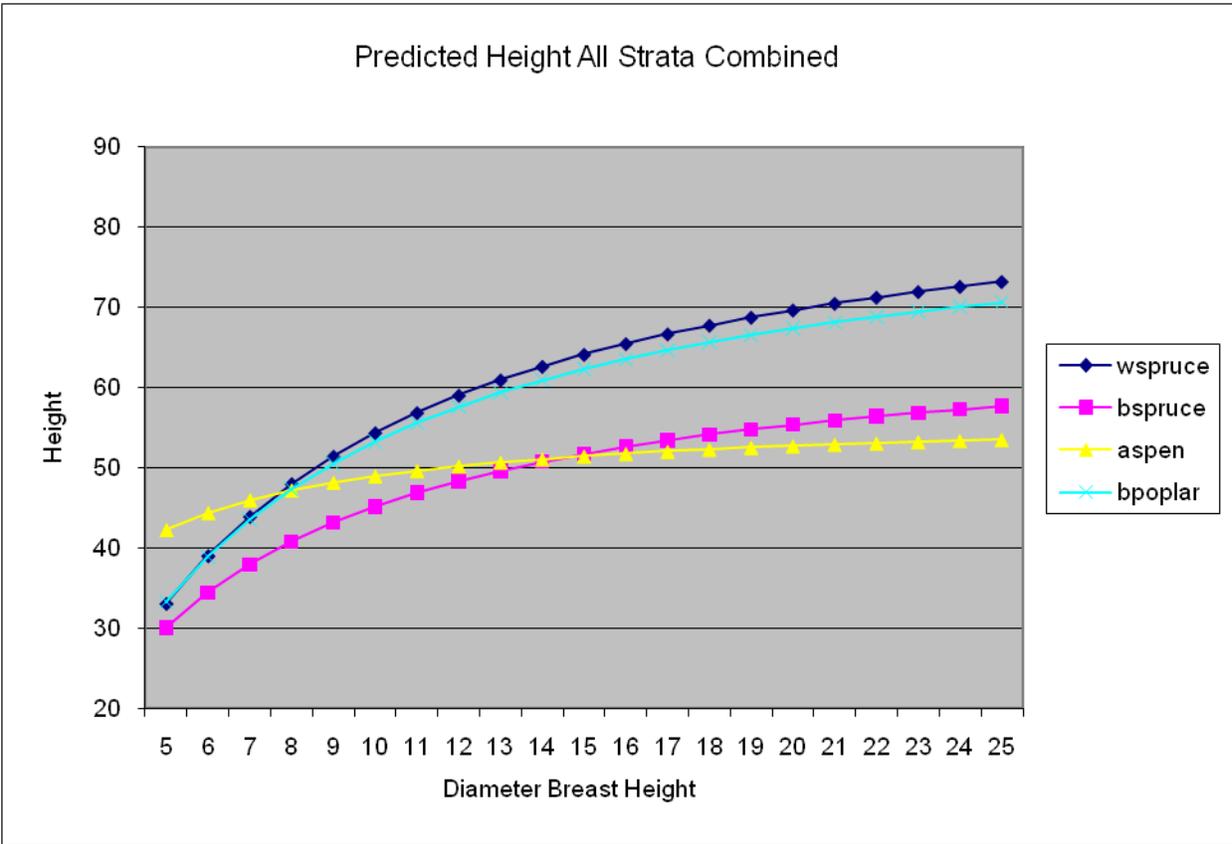
Total for Stratum 8

53

**Grand Total Trees Measured**

308

Appendix D  
Diameter/Height Relationships, Ten Year Growth, and Bark Thickness



Reciprocal dbh height prediction model:

$$ht_{top} = ae^{\frac{-b}{dbh^c}}$$

Species	A Coefficient	B Coefficient	C Coefficient
White Spruce	89.28	-4.9598	1
Black Spruce	67.86	-4.0686	1
Aspen	56.78	-1.4744	1
Balsam Poplar	85.23	-4.7001	1

"e" is a numerical constant that is equal to 2.71828

The corresponding Excel equation appears as follows:

Height = A Coefficient\*POWER (e, B Coefficient/dbh)

Ten Year Radial Growth and Bark Thickness by Species

Species	Radial Growth (In.)	Single Bark Thickness (In.)
Aspen	(47 detail records) Average= 0.36	0.35
Balsam Poplar	(38 detail records) Average= 0.27	1.13
Birch	(2 detail records) Average= 0.27	0.40
Black Spruce	(35 detail records) Average= 0.08	0.39
White Spruce	(303 detail records) Average= 0.28	0.41

Bark Thickness Ratio by Species

	DBH	DIB*	Bark Thickness Ratio
Aspen	(47 detail records) Sum= 366.20	333.20	0.910
Balsam Poplar	(38 detail records) Sum= 450.70	365.00	0.810
Birch	(2 detail records) Sum= 16.80	15.20	0.905
Black Spruce	(35 detail records) Sum= 222.10	195.00	0.878
White Spruce	(303 detail records) Sum= 2,878.90	2,632.10	0.914
<b>Grand Total</b>	<b>Sum= 3,934.70</b>	<b>3,540.50</b>	<b>0.900 Average All Species</b>

\*DIB = Diameter Inside Bark