Chapter 7. Riparian Vegetation and Large Wood

RIPARIAN VEGETATION

The streamside forest is usually the most important source of large wood in streams. Landslides originating in steep, tributary channels also can deliver wood to streams. Large wood is particularly important in Forest streams because these streams are typically straight and constrained by steep side slopes, which results in higher flow velocities during high water events.

Large wood in channels obstructs flow, thereby creating zones of lower velocity water, gravel deposits, and pools. These features benefit fish and aquatic amphibians. Jams of wood often will trap gravel and cobbles that would otherwise move downstream unimpeded during high flows. These deposits create a preferred substrate for fish spawning and for the production of aquatic insects on which fish feed. Wood in streams can create zones of slower water that provide refuge for young fish during high flows; without these refuge zones, fish get washed into the lower reaches of stream systems where predation and competition for food is greater. The wood also can create the deep pools important for summer survival when low flows do not otherwise provide fish enough cover to escape predators. The deep pools, especially those with nooks and crannies provided by large wood, are favored areas for feeding. Where this complex habitat is present, competition for food is more equitable among fish of various species and sizes.

The species mix and age of the streamside forest has a pronounced influence on the volume of wood in the stream. Older stands with high basal area contribute more wood volume than young stands with low basal area. Also, conifer stands contribute wood that is larger and more long-lived in the stream than do hardwood stands.

Stands along streams regenerate and grow differently than upslope stands. Under natural conditions, conifer regeneration along streams tends to be sparser due to competition from riparian brush and the presence of low terraces that are too moist for conifers. Also, the mortality of young trees by beaver and elk tends to be greater closer to streams. Furthermore, unstable or shallow soils often occur on steep-sided slopes next to streams and may not support a conifer tree once it reaches a certain size. The mortality of older trees next to streams is rarely associated with competition among trees; initial tree density is rarely great enough for self-thinning to occur. Rather, tree mortality often is more associated with stream undercutting, unstable slopes, windthrow, and beaver. Areas not occupied by conifer trees are usually thick with hardwoods or brush, which results in too much shade for supplemental conifer establishment in the understory. Individual conifers that escape competition from brush or hardwoods often grow rapidly in streamside areas due to a year-round abundance of water.

In this chapter, riparian stands throughout the Forest are characterized according to species, stem density, basal area, and crown cover. The next section evaluates the downed wood that would be expected to accumulate in streams as stands of various types mature.

Riparian Mapping and Field Inventory

Using aerial photographs, the analysis team conducted an inventory of streamside stands along all fish-bearing streams. Color orthophotos from 1996 incorporated into a GIS layer provided the base map for delineating stands of different types. Initial stand demarcations were digitized on the computer screen. High quality color aerial photographs (1:12000 scale) from 2002 were then used to refine stand boundaries and identify general classes of conifer and hardwood mixes and stand age. A GIS layer of general stand age based on hillslope trees was used to help estimate the age class of the adjacent streamside stand. The detailed aerial photographs were used to identify the age of stands (using texture) where the streamside stand age was obviously different than the upslope stand age. Areas without trees also were delineated by type where they were visible through the tree cover. The classification components included:

Stand age class	<13 years
	13-24 years
	25-49 years
	50-99 years
	>99 years
Crown cover class	Hardwood (less than 30% conifer)
	Conifer/hardwood (between 30% and 70% conifer)
	Conifer (more than 70% conifer)
Areas without trees	Wide mainline roads
	Wide rivers
	Brush/grass

Because they appeared the same in aerial photographs, no attempt was made to distinguish hardwood-dominated stands that were 50-99 years old from those that were greater than 99 years old. The combined age class for the oldest hardwood trees was labeled as 50-99 years. Streamside forest delineations occurred from the centerline of the stream out to a horizontal lateral distance of 200 feet. Subsequent summaries of streamside stand characteristics were based on 50-foot wide intervals starting from the stream centerline. Summaries were further segregated by stream size (large, medium, small), by region (Coos, Tenmile, Umpqua), and by analysis basin (#1-13).

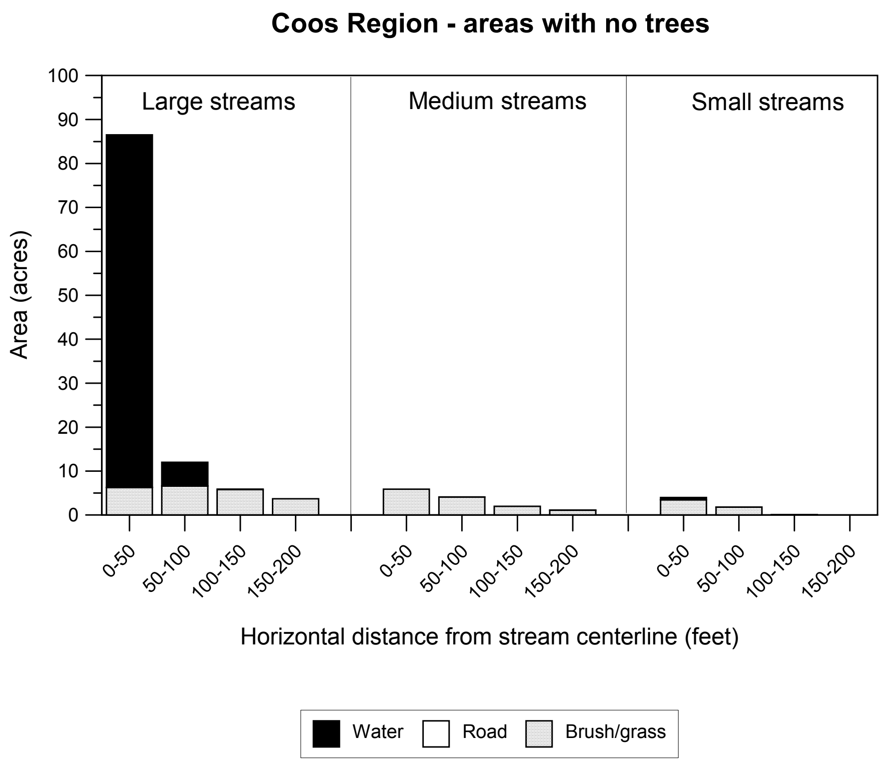
Riparian Vegetation Characteristics

The results of the streamside stand mapping are displayed for Scholfield Creek (Map 7.1) and are generally typical for the Forest. Age classes and conifer/hardwood dominance often vary greatly along a stream and are commonly different between left bank and right bank of a stream. Some of the variation reflects the history of harvesting and road building in the Forest, while some is a result of disturbance by landslides. Young hardwood trees along some of the larger streams, especially in the Tenmile region, are a result of tree invasion into streamside areas that were previously pasture.

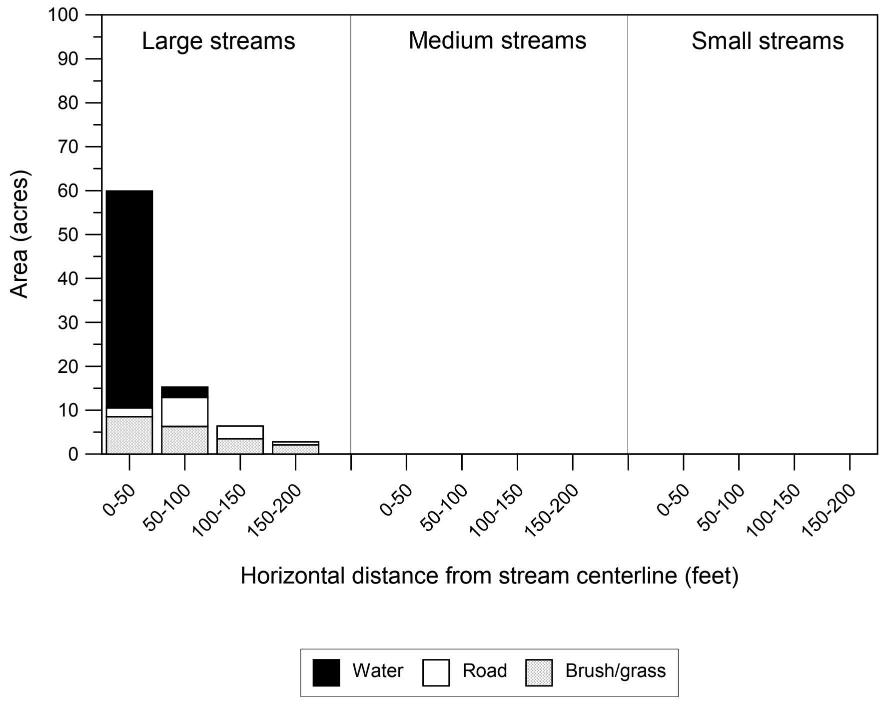
Areas without trees are a sizable component (20% forest-wide) along large streams and within 50 feet of the stream centerline. Within this zone, the percent area without trees is greatest for the Umpqua region (34%) and lowest for the Tenmile region (13%). Open water is the major component of non-forested riparian acreage, followed by areas of brush and grass. However, this varied by region. In the Coos region, most non-forested acreage is due to the open water of the lower West Fork Millicoma River; in the Umpqua region, the major non-forest component is the open water of Mill Creek. In contrast, all non-forested streamside areas in the Tenmile region are brush and grass (Figure 7-1).

Hardwoods are the dominant stand type found within 100 feet of the stream for all stream size classes. Although hardwood dominance decreased with increasing distance from the stream, along large streams hardwoods still occupied 31% of the land 150-200 feet from the stream. Conifer/hardwood stands occupied the majority of the area at distances 100-200 feet from the stream. When summarized by region, conifer-dominated stands never made up a majority of the streamside area for any stream size class or distance interval. Nevertheless, conifer-dominated stands are a majority of the streamside area for some individual subwatersheds.

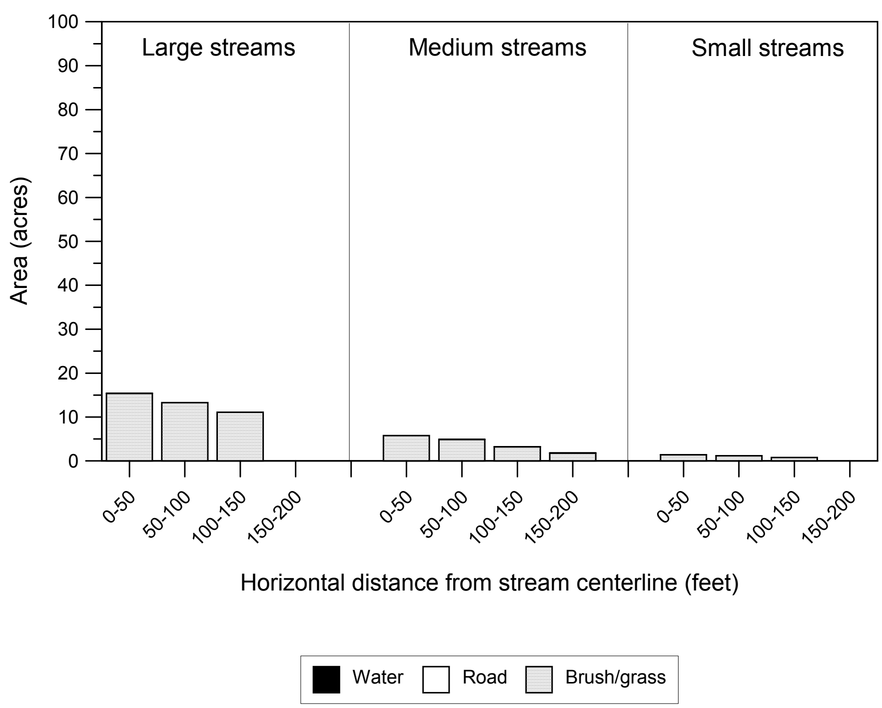
Figure 7-1. The acreage of non-forested areas by type and by stream size for the Coos, Umpqua, and Tenmile regions of the Forest (fish-bearing streams only).



Umpqua Region - areas with no trees



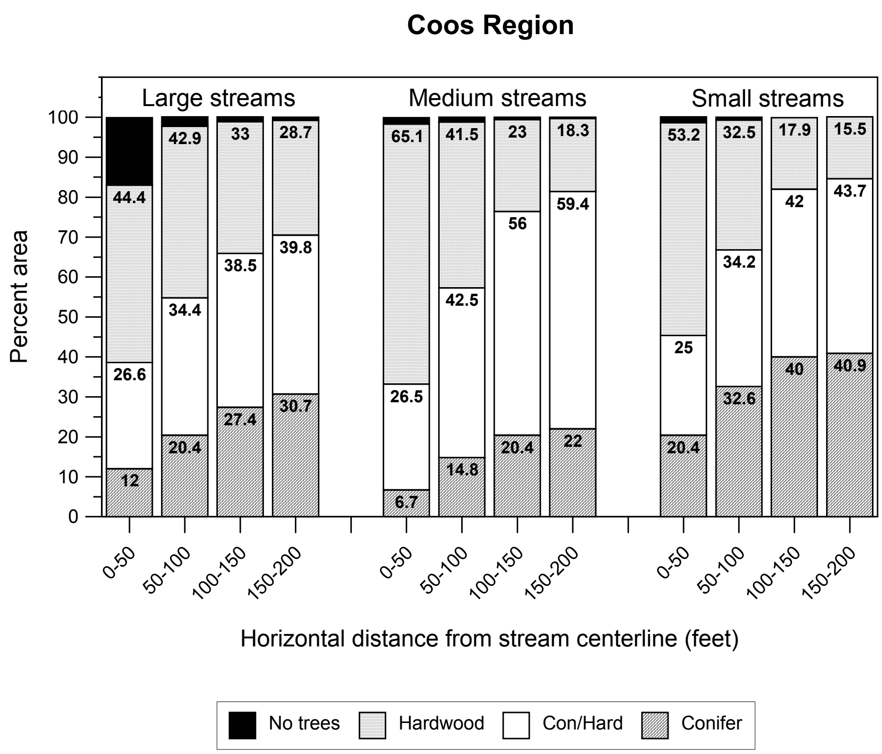
Tenmile Region - areas with no trees

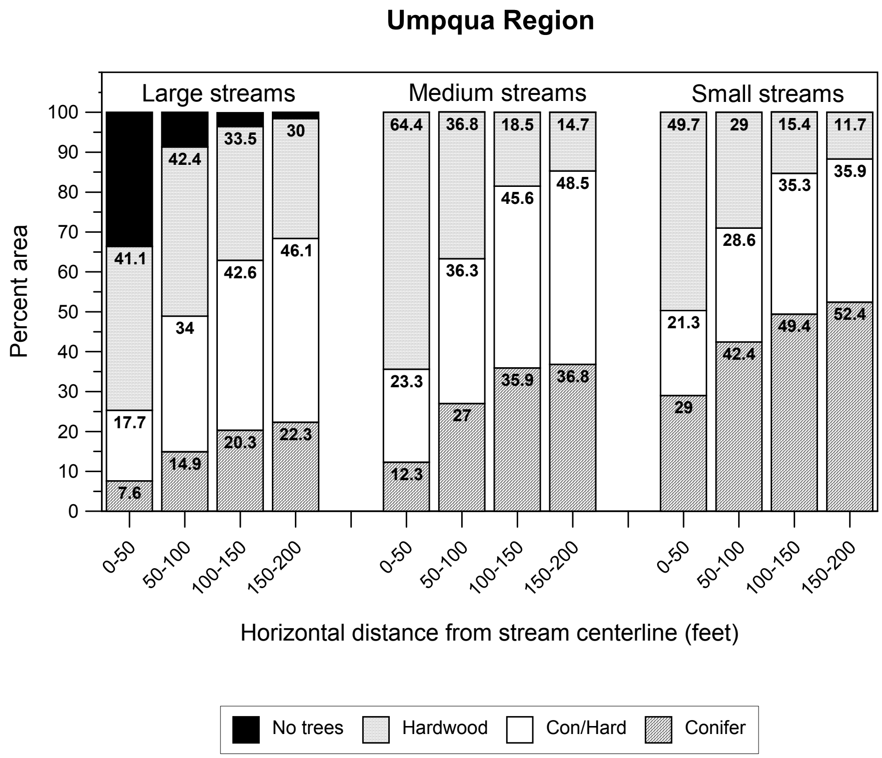


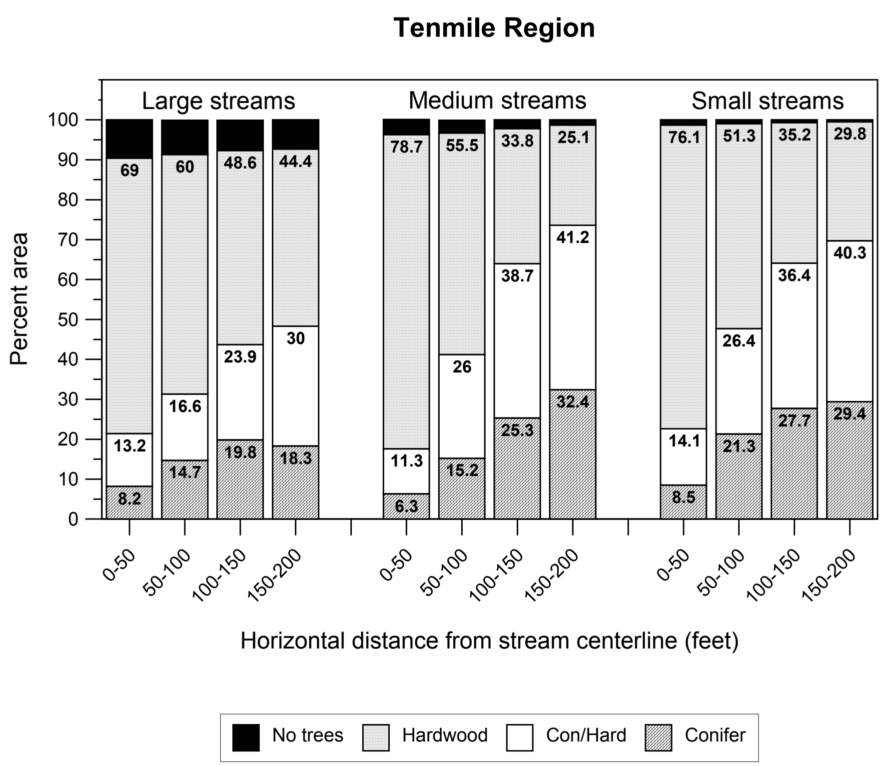
Streamside stand composition in the Coos region is similar to that for the Umpqua region, but with slightly higher conifer dominance along large and small streams (Figure 7-2). In contrast, streamside stands within 100 feet of small and medium streams and out to 200 feet along large streams are much more dominated by hardwoods in the Tenmile region than in the other two regions (Figure 7-2). Among all stream size classes, conifer-dominated stands never made up more than 7% of the trees growing within 50 feet of the stream in the Tenmile region.

Overall, stands 100 years or more old are the most dominant age class along Forest streams, except for the corridor within 50 feet of the stream. This is followed by stands in the 50-99 year and 25-49 year age classes. Young stands along streams are uncommon; where they occur, they are largely a result of debris torrents. Clearcuts between 6-15 years old adjacent to fish-bearing streams usually had a strip of trees retained between the stream and the clearcut. The buffer strips consist mostly of hardwood trees with sparse conifers. Harvest units created in the last 6 years had wider buffers that included more conifer trees with the hardwood trees.

Figure 7-2. The percent riparian stand type by stream size for the Coos, Umpqua, and Tenmile regions of the Forest (fish-bearing streams only).



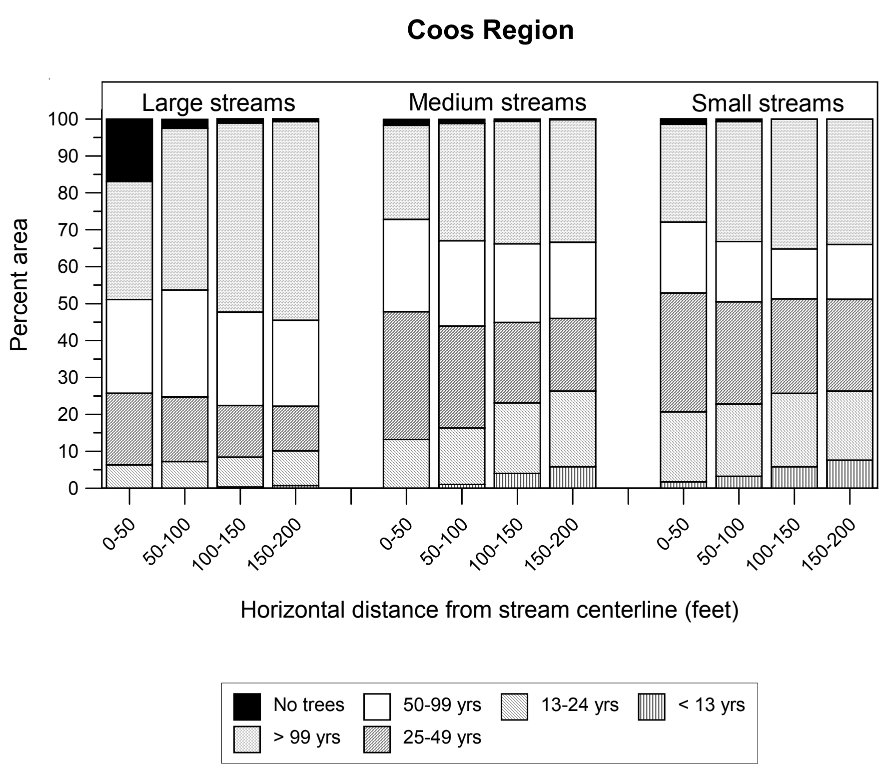

Umpqua Region
Large streams
Medium streams
Small streams
Percent area
0
10
20
30
40
50
60
70
80
90
100
7.6
17.7
41.1
14.9
34
42.4
20.3
42.6
33.5
22.3
46.1
30
12.3
23.3
64.4
27
36.3
36.8
35.9
45.6
18.5
36.8
48.5
14.7
29
21.3
49.7
42.4
28.6
29
49.4
35.3
15.4
52.4
35.9
11.7
0-50
50-100
100-150
150-200
0-50
50-100
100-150
150-200
0-50
50-100
100-150
150-200
Horizontal distance from stream centerline (feet)
No trees
Hardwood
Con/Hard
Conifer

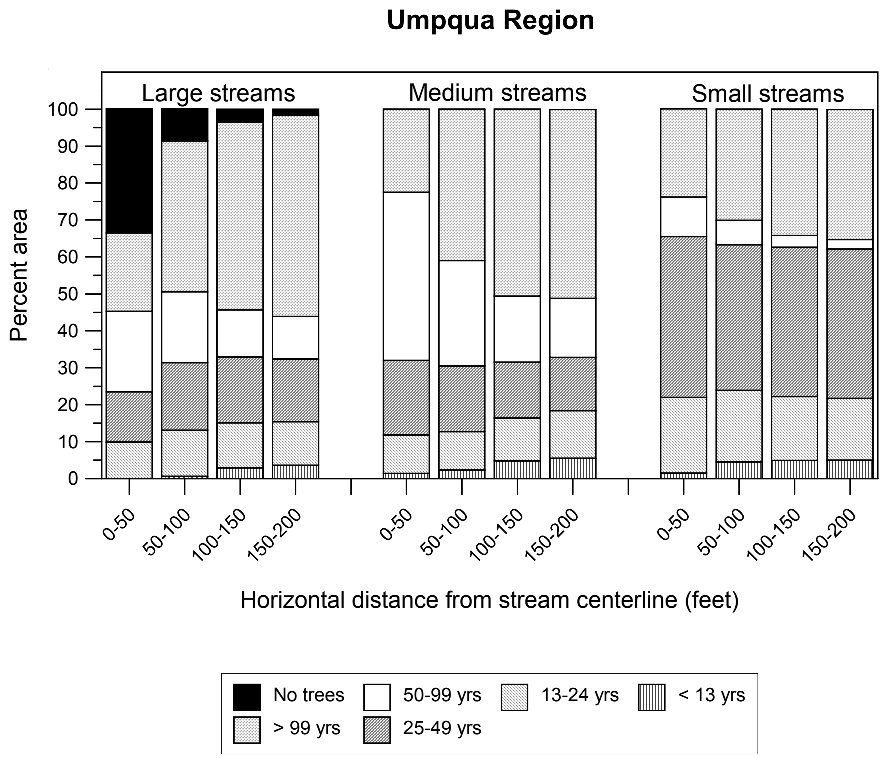

Tenmile Region
Large streams
Medium streams
Small streams
Percent area
0
10
20
30
40
50
60
70
80
90
100
8.2
13.2
69
14.7
16.6
60
19.8
23.9
48.6
18.3
30
44.4
6.3
11.3
78.7
15.2
26
55.5
25.3
38.7
33.8
32.4
41.2
25.1
8.5
14.1
76.1
21.3
26.4
51.3
27.7
36.4
35.2
29.4
40.3
29.8
0-50
50-100
100-150
150-200
0-50
50-100
100-150
150-200
0-50
50-100
100-150
150-200
Horizontal distance from stream centerline (feet)
No trees
Hardwood
Con/Hard
Conifer

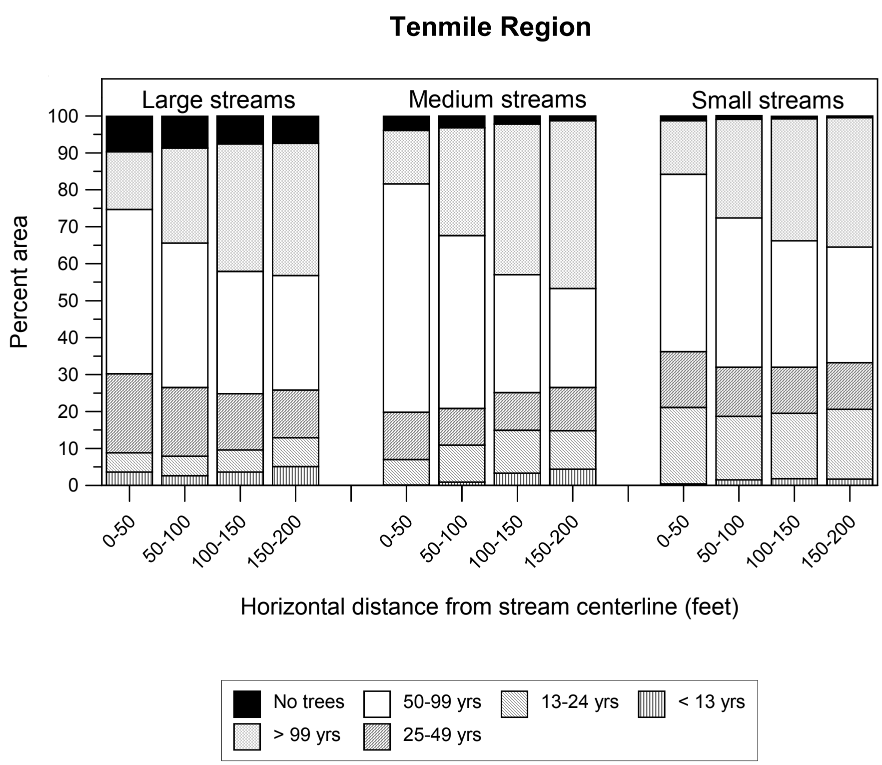
Stands along medium and small streams in the Coos region tend to be younger than same-sized streams in the Umpqua region (Figure 7-3). The acquisition of land by the Forest along the southern edge of the Coos region (i.e., the Marlow Creek drainage), which was harvested in the 1940s and 1950s, accounts some for the skewed age distribution. Streamside areas in the Tenmile region have the lowest percentage of stands older than 99 years (Figure 7-3). Instead, streamside stands age 50-99 years are the most dominant in this region. Appendix A to this report contains complete information on streamside stand composition and age for each of the 13 analysis basins.

Results from a 2001 contracted inventory of selected streamside stands on the Forest (ODF 2001) and nearby streamside stands administered by the BLM (Ursitti 1990) allowed the analysis team to assign stand characteristics (trees per acre, basal area per acre, quadratic mean diameter) to the various combinations of age class and conifer/hardwood ratios incorporated into the overall streamside forest inventory. The Forest study included riparian plots with trees from 20-210 years old and the study on BLM land included riparian plots with trees from 88-408 years old. The minimum tree size counted in the plots was 6 inches DBH. For this analysis, it was assumed that the ratio of conifer to hardwood basal area in field plots was equivalent to the ratio of conifer to hardwood canopy cover, as observed in aerial photographs.

Figure 7-3. The percent riparian stand age by stream size for the Coos, Umpqua, and Tenmile regions of the Forest (fish-bearing streams only).




Umpqua Region
Large streams
Medium streams
Small streams
Percent area
0
10
20
30
40
50
60
70
80
90
100
0-50
50-100
100-150
150-200
Horizontal distance from stream centerline (feet)
No trees
50-99 yrs
13-24 yrs
< 13 yrs
> 99 yrs
25-49 yrs


Tenmile Region
Large streams
Medium streams
Small streams
Percent area
0
10
20
30
40
50
60
70
80
90
100
0-50
50-100
100-150
150-200
Horizontal distance from stream centerline (feet)
No trees
50-99 yrs
13-24 yrs
< 13 yrs
> 99 yrs
25-49 yrs

For each conifer dominance type (conifer, hardwood/conifer, hardwood), tree density and basal area was plotted against age for both conifers and hardwoods (Figures 7-4 and 7-5). Linear regression was used to determine relationships between stand density and stand basal area with age, often using logarithmic transformations of the independent or dependent variable (or both). The transformation that provided the best fit and made sense when extrapolated to age 400 (no negative numbers) was selected. If the regression equation explained less than 20% of the variance around the mean, then a mean value across all stand ages was used. The equations are shown in Table 7-1. The relationships in Table 7-1 that are later used in the analysis of modeling streamside stands are not particularly refined, nor do they explain a large portion of the variance among plots. Nevertheless, they are appropriate for the coarseness of the streamside stand inventory and the type of management questions addressed in the second part of this chapter.

Table 7-1. Regression equations relating stand density and basin area to stand age for streamside areas.

Parameter		Regression Equation	Adjusted R^2	P value	Sample Size
Stand density (trees per acre)					
Conifer dominated stands	Conifer trees	Y = 183 – 24.7 * ln(Age)	0.35	0.001	26
	Hardwood trees	Average value of 36	---	---	26
Conifer/hardwood stands	Conifer trees	Y = 97 – 15.0 * ln(Age)	0.26	0.007	23
	Hardwood trees	Y = 76 – 0.165 * Age	0.24	0.014	21
Hardwood dominated stands	Conifer trees	$Y = 131 * Age^{-0.683}$	0.27	--	14
	Hardwood trees	$Y = 375 * Age^{-0.354}$	0.29	0.04	14
Stand Basal Area (sq. ft. per acre)					
Conifer dominated stands	Conifer trees	Y = -65.6 + 59.8*ln(Age)	0.27	0.003	26
	Hardwood trees	Average value of 32	---	---	26
Conifer/hardwood stands	Conifer trees	Average value of 77	---	---	24
	Hardwood trees	$Y = 20 * Age^{0.321}$ *for < 90 years*	0.43	0.005	15
		Y = 94.5 – 0.192 * Age *for >= 90 years*	0.31	0.09	8
Hardwood dominated stands	Conifer trees	Average value of 15	---	---	20
	Hardwood trees	$Y = 20.2 * Age^{0.360}$ *For < 120 years*	0.20	0.05	17
		$Y = 16309 * Age^{-1.032}$ *For >= 120 years*	0.94	0.02	4

Figure 7-4. Relationship between stand density and age for conifer-dominated, conifer/hardwood, and hardwood-dominated stands. The regression line for conifers is shown as a solid line and as a dashed line for hardwoods.

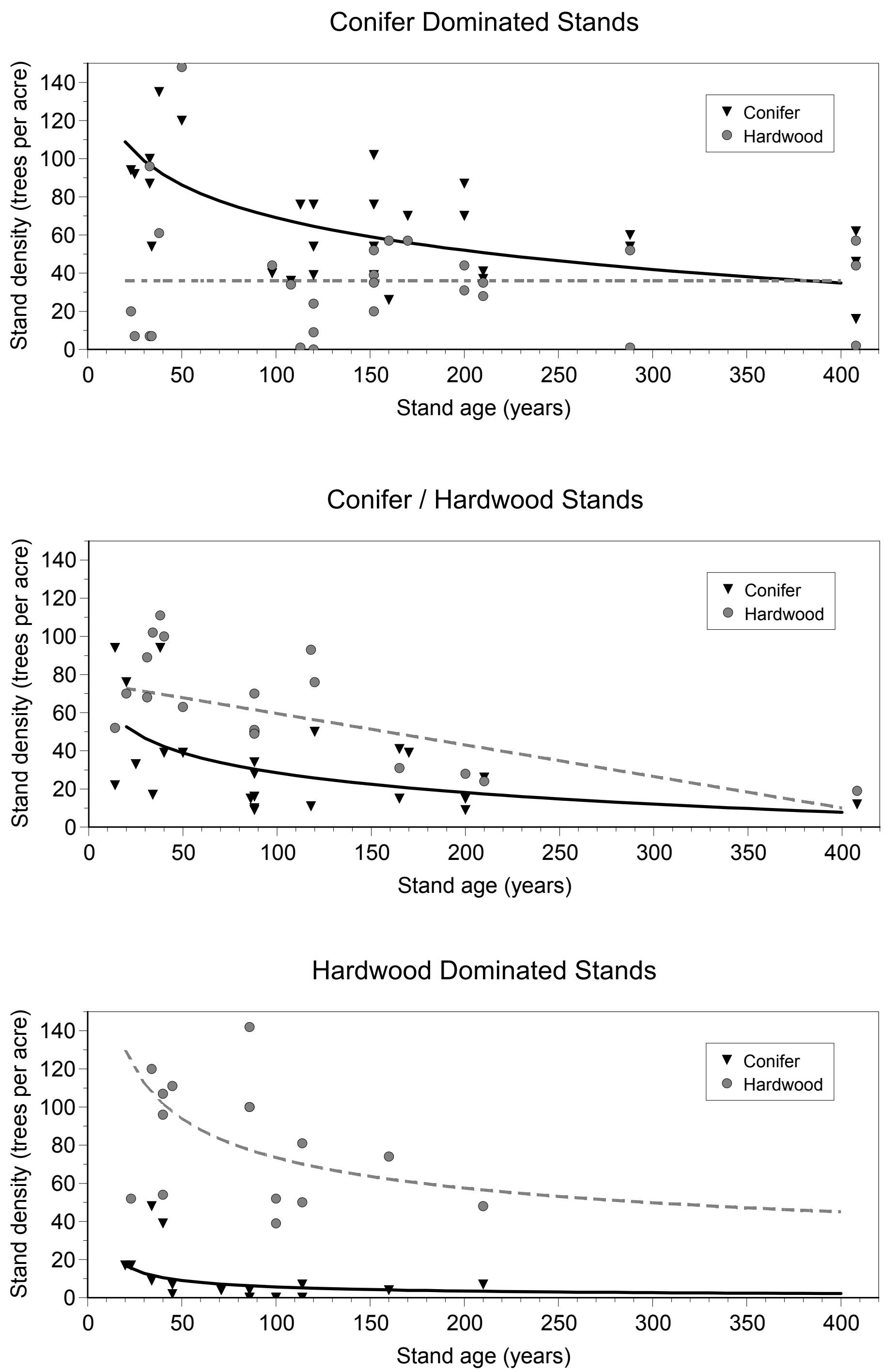
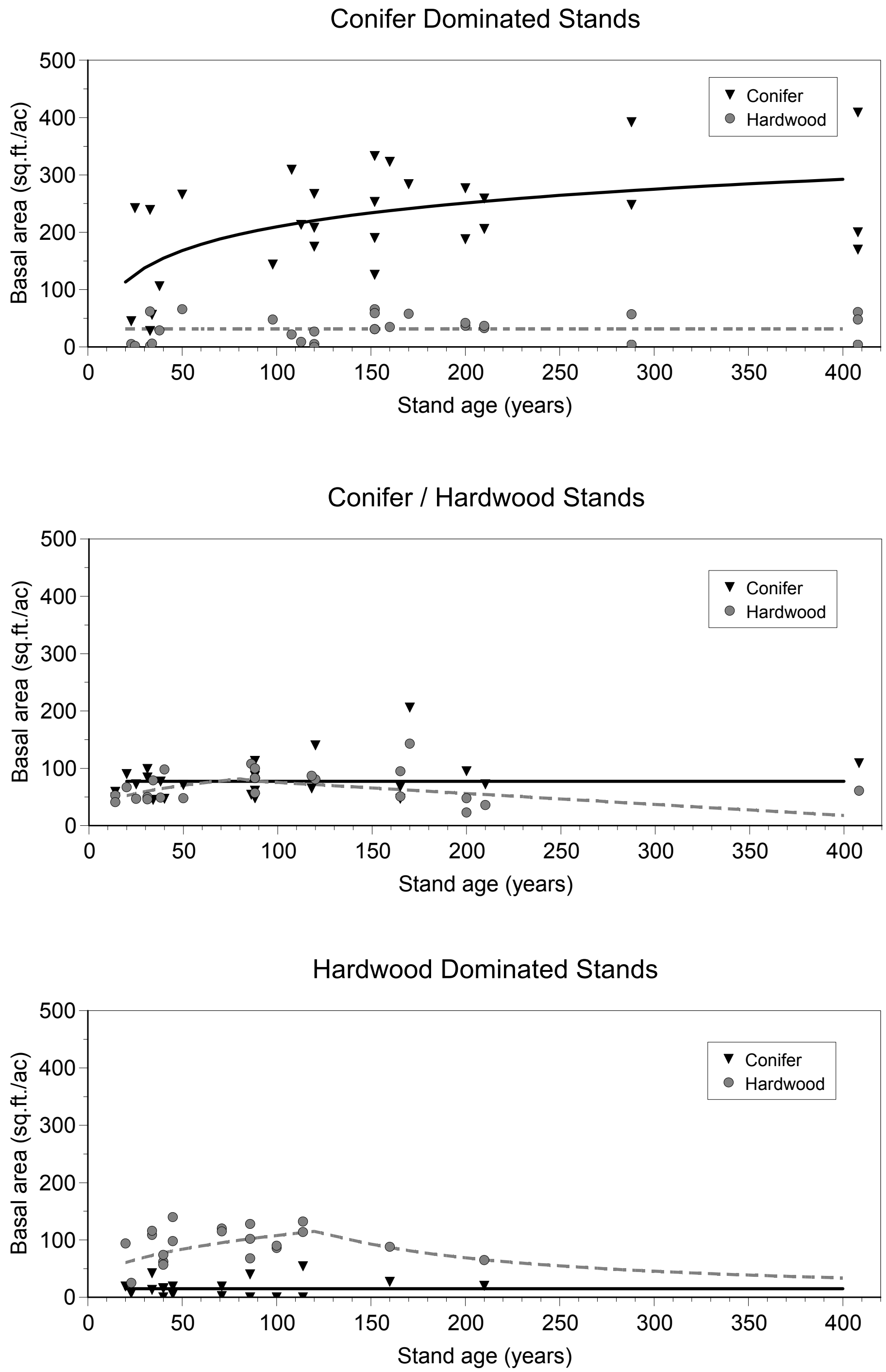
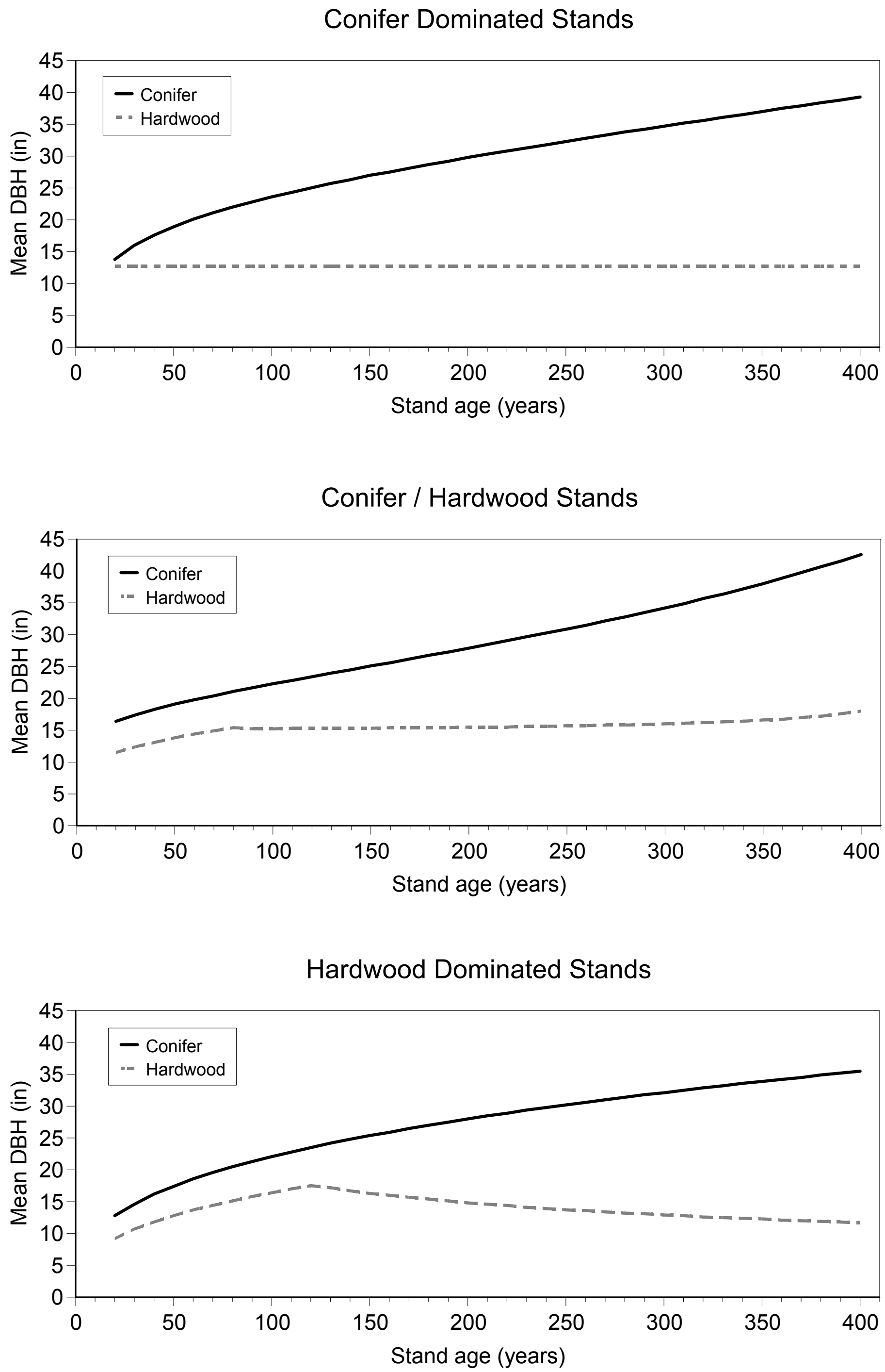


Figure 7-5. Relationship between stand basal area and age for conifer-dominated, conifer/hardwood, and hardwood-dominated stands. The regression line for conifers is shown as a solid line and as a dashed line for hardwoods.



The quadratic mean diameter for both conifer and hardwood trees was calculated by dividing stand basal area by stand density (Figure 7-6).

Figure 7-6. Relationship between mean diameter (DBH) and age for conifer-dominated, conifer/hardwood, and hardwood- dominated stands.



The above equations were used (or mean values if the R-square value was less than 0.20) to estimate values for conifer and hardwood density and basal area for each permutation of stand type and age class, using the midpoint of each age class (Table 7-2).

Table 7-2. Streamside stand characteristics by stand type and age class as summarized from Figures 7-4 to 7-6.

Stand Type	Age Range and Midpoint	Conifer Density (stems/ac)	Hardwood Density (stems/ac)	Conifer Basal Area (sq. ft./ac)	Hardwood Basal Area (sq. ft./ac)	Conifer Diameter (inches)	Hardwood Diameter (inches)
Conifer	13-24 (19)	110	36	110	32	13.6	12.7
	25-49 (37)	94	36	150	32	17.2	12.7
	50-99 (75)	76	36	192	32	21.5	12.7
	99-160 (130)	63	36	225	32	25.7	12.7
Conifer/ Hardwood	13-24 (19)	53	73	77	52	16.3	11.4
	25-49 (37)	43	70	77	64	18.0	12.9
	50-99 (75)	33	64	77	80	20.7	15.2
	99-160 (130)	25	55	77	70	24.0	15.3
Hardwood	13-24 (19)	18	132	15	59	12.5	9.1
	25-49 (37)	11	104	15	75	15.7	11.5
	50-99 (75)	7	81	15	97	20.0	14.8
	99-160 (130)	5	67	15	107	24.2	17.2

Note: The minimum diameter (DBH) of included trees is 6 inches.

Tree height was estimated using relationships derived from information on dominant and codominant trees as measured in streamside plots of various stand ages throughout the Forest (ODF 2001). Since the majority of conifers currently growing along streams are Douglas-fir and most hardwoods are red alder, regression equations for these two species were developed to represent conifers and hardwoods in general:

$$\text{Conifer tree height (feet)} = -189.8 + 114.6 * \ln(DBH) - 1.029 * DBH$$

$$\text{Adjusted } R^2 = 0.91,\ P = 0.0001,\ n = 204$$

$$\text{Hardwood tree height (feet)} = -16.9 + 36.5 * \ln(DBH)$$

$$\text{Adjusted } R^2 = 0.34,\ P = 0.00001,\ n = 199$$

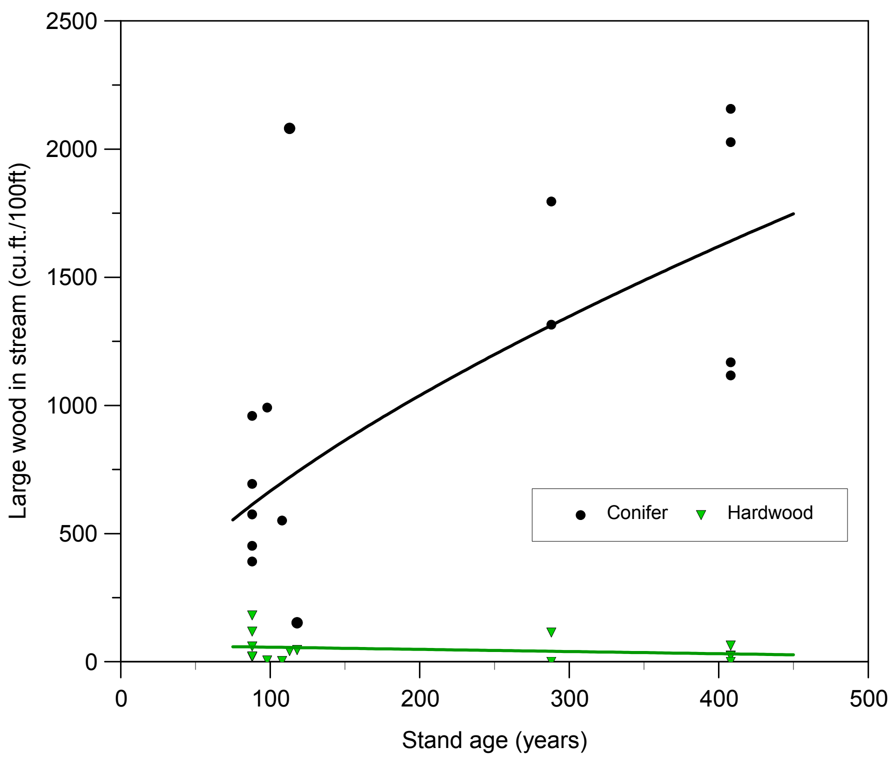
where DBH is in inches and “ln” is the natural logarithm.

The above results illustrate that streamside forests along fish-bearing streams in the Forest are highly heterogeneous both longitudinally and laterally from the stream centerline. Stand characteristics, such as average diameter and tree density, also vary widely among plots, even for a given stand type (conifer/hardwood dominance by age class). This variability results in only fair correlations between stand characteristics and age using the available plot data. Nevertheless, these relationships are preferable to using an upslope stand growth model, such as ORGANON (Hann et al. 1995) to characterize changes in streamside stands over time. Upslope stand growth models assume that self-thinning is the main mechanism for tree mortality, and not unstable slopes or windthrow. In addition, since streamside forests have relatively low initial conifer density, upslope stand growth models invariably under-predict mortality.

LARGE WOOD IN THE AQUATIC SYSTEM

Large wood usually becomes abundant in streams only after the streamside stand reaches an age of several centuries, although localized large accumulations can occur due to windthrow, landslides, or major channel shifts. Large wood in streams bordered by older, undisturbed streamside forests was inventoried on nearby BLM land to the east and south of the Forest (Ursitti 1990), and provides a perspective on natural wood loads. None of the streams had been intentionally cleared of large wood over the last few decades. Results from this study indicate that wood volume was two-fold greater in streams bordered by 300- to 400-year-old stands than those bordered by 100-year-old stands (Figure 7-7). Nearly all instream wood was conifer in spite of an abundance of hardwoods in some of the streamside stands, thereby illustrating the short-lived nature of hardwood in streams. Results from this study were used by the analysis team to provide a benchmark for comparing large wood loading in streams on the Forest.

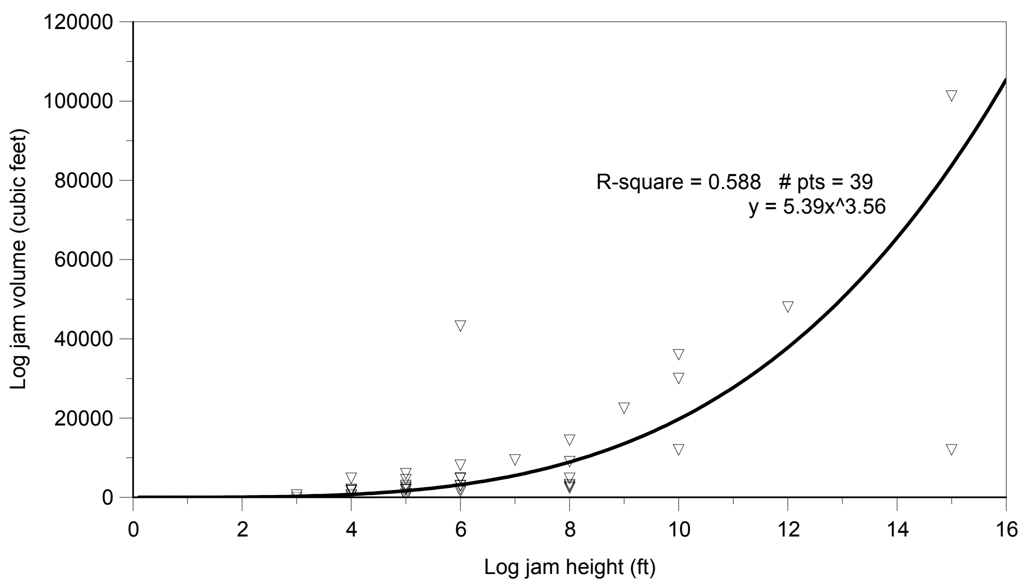
Figure 7-7. Large wood in undisturbed streams bordered by stands 88-408 years old on BLM ownership south and east of the Forest (Ursitti 1990).



Further evidence that large wood was more abundant in streams prior to Forest management was available from 1960s surveys of logjams. Stream surveys of the West Fork Millicoma River watershed were conducted through a joint effort of the Oregon Fish Commission and the Oregon Game Commission to collect baseline stream information for a proposed dam located just below the confluence with Trout Creek. The surveyors mapped stream substrate, identified fish species present, and provided information on the location and extent of possible obstructions to fish passage, which were generally logjams.

Survey information was compiled and entered into a GIS by the Coos Watershed Association. The surveys contain information about the location and character of logjams, and usually an estimate of the jam dimensions (height, length, width). Only for about one-quarter of the jams, the surveyor made a height measurement. Therefore, a correlation relationship was derived between height and volume for those logjams that had complete measurements (Figure 7-8), and then applied to those jams with only a height measurement in order to estimate volume.

Figure 7-8. Relationship between logjam height and logjam volume.



Volumes were multiplied by 0.7 to account for the space between the logs in a jam. This was done so that comparisons could be made between the logjam survey results and results from current large wood surveys, for which the volume of every log is determined. The results from five streams in the West Fork Millicoma River Basin that were relatively undisturbed during the 1960s are shown in Table 7-3. The few jams that were actually beaver dams, piles of brush, logging slash, or a result of logs floated against a bridge abutment are excluded from the summary. All surveys were done in 1963 except for the Elk Creek survey, which was done in 1967.

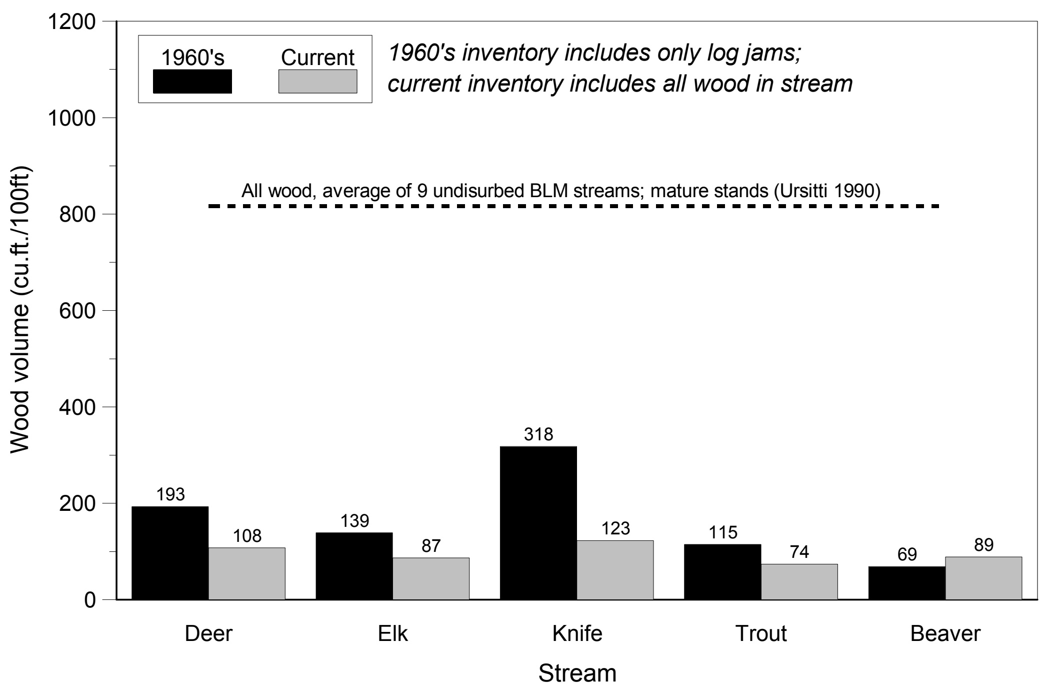
Table 7-3. Volume of wood in logjams during the 1960s for five relatively undisturbed Forest streams.

Stream	Logjam Wood Volume* (cu. ft.)	Distance Surveyed (mi.)	Number of Jams	Unit wood Volume (cu. ft. per100 ft.)
Deer	7,150	0.70	4	193
Elk	59,430	8.10	8	139
Knife	33,110	1.97	9	318
Trout	18,220	3.00	4	115
Beaver	2,922	0.81	2	69
Combined	**120,832**	**14.58**	**27**	**157**

* 30% porosity assumed based on visual observation of existing logjams.

The combined wood volume within logjams for these five streams was 157 cubic feet per 100 feet of stream, ranging from 69 cubic feet of stream for Beaver Creek to 318 cubic feet per 100 feet of stream for Knife Creek. These 1960s values for logjam wood volume averaged 1.7 times higher than the wood volume indicated by current surveys where all wood (not just jams) was measured (Figure 7-9). Obviously, if all wood in streams had been measured during the 1960s surveys, the volume difference would be even greater. The average wood volume in nine nearby, undisturbed BLM streams bordered by mature timber is about five times higher than log jam wood volumes in the West Fork Millicoma River tributaries during the 1960s. This suggests that only a minor portion of all wood volume in a stream is contained within logjams.

Figure 7-9. Wood volume in logjams during 1960s surveys versus total wood volume in streams during current surveys. Also shown is total wood volume in undisturbed streams bordered by mature timber (88-118 years old) for nearby BLM land.



Information from the ODFW stream surveys conducted in the 1990s, 2001, and 2002 (Aquatic Inventory Project, physical habitat surveys) was used to evaluate current levels of large wood in Forest streams. Some streams had multiple surveys; in these cases, the most recent survey was used. Large wood has been intentionally added to some stream segments on the Forest over the last few years (see Chapter 8, *Aquatic Organisms and Their Habitat*). However, in most cases the stream survey took place prior to the wood placement projects.

The ODFW surveys included a majority of the known fish-bearing streams in the Forest. The inventory of large wood in the surveys included all wood pieces that are partially or completely within the active channel width of the stream. It also included wood suspended over the channel. All pieces greater than 10 feet long and greater than 4 inches in diameter were included in the inventory. These specifications also applied to the BLM surveys.

Wood volume (cubic feet per 100 feet of stream) was summarized for each stream reach in the ODFW habitat surveys. The ODFW reaches varied considerably in length, with breaks between reaches often occurring at the confluences of major tributaries. Reaches were about 1 mile long on average. The ODF stream size classification system was assigned to each ODFW reach. Sometimes the ODFW reaches included more than one stream size. In these cases, a combined size class was used. For example, if the downstream end of a survey reach began on a medium size stream and ended where the stream was classified as small, the size class assigned to that reach was medium/small. For this analysis, a *river* size class was added in order to segregate the West Fork Millicoma River downstream of its confluence with Elk Creek and Mill Creek downstream of Loon Lake. In addition to wood volume, the density of key pieces for each reach was calculated. Key pieces are large logs in the stream that are at least 24 inches in diameter and at least 33 feet long. Key piece density provides an indicator of the stability of wood jams in a stream.

Currently, wood volume in Forest streams with an active channel width less than 40 feet averages 28% of the wood volume in nearby reference streams bordered by 88- to 118-year-old timber, and 14% of the wood volume in those reference streams bordered by old-growth timber (Table 7-4). Streams on the Forest that are 40- to 100-feet wide have less than one-half of the wood found in smaller streams. Wood is equally low for all regions of the Forest.

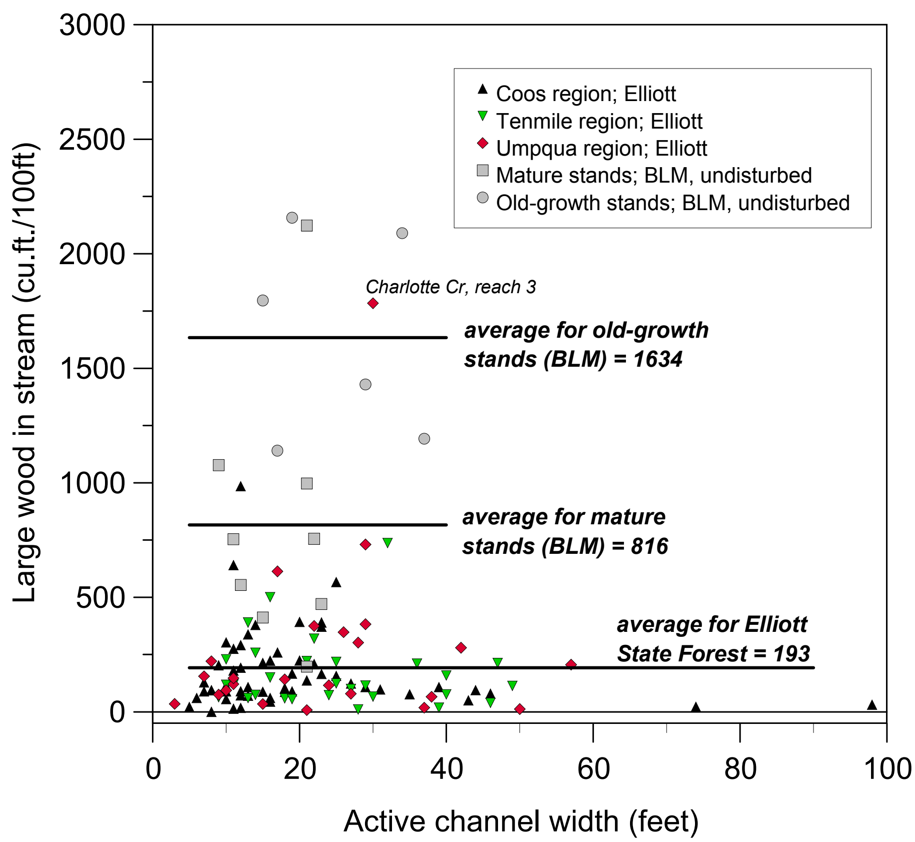
Although the number of key pieces per 100 feet of stream averages about the same for the Coos and Tenmile regions, it is about one-half as much for the Umpqua region (Table 7-4). The density of key pieces in channels greater than 40 feet wide is about one-third that of narrower streams.

Variability in wood abundance among reaches is high for both the Forest fish habitat surveys and the BLM reference streams. Nevertheless, only 2 out of 193 stream reaches on the Forest have wood loadings that exceed the average for the reference reaches (Figure 7-10). For streams less than 40 feet wide, there is no correlation between wood loading and active channel width for either Forest streams or the BLM reference streams.

Table 7-4. Large wood volume in Forest streams, by region, and in BLM reference streams (mean values weighted by reach length).

Location	No. Reaches	Mean Wood Volume (cu. ft. per 100 ft.)	Standard Deviation Wood Volume (cu. ft. per 100 ft.)	Mean Number of Key Pieces (#/100 ft.)
Elliott State Forest				
Active channel width less than 40 feet				
Coos region	51	195	177	0.39
Tenmile region	25	197	170	0.31
Umpqua region	21	166	363	0.17
Combined	97	191	240	0.33
Active channel width 40 to 100 feet	13	65	84	0.10
BLM reference streams				
Active channel width less than 40 feet				
88- to 118-yr-old stands	9	816	564	---
288- to 408-yr-old stands	6	1,634	445	---

Figure 7-10. Large wood volume in Forest streams, by region, as compared to the volume of wood in BLM reference streams.



For stream reaches with an active channel width less than 40 feet, analysis basin #7 (Johnson Creek) has the highest wood loading at 380 cubic feet per 100 feet (Table 7-5). Relatively high amounts of large wood also are found in basin #8 (especially high in Palouse Creek), basin #2 (Charlotte Creek and Luder Creek), Johanneson Creek in basin #3, and Noble Creek in basin #5. Analysis basin #4 (Scholfield Creek) and #1 (Footlog Creek) has the lowest wood abundance at 33 and 95 cubic feet per 100 feet, respectively. These drainages have roads parallel to the stream in their lower reaches and wood may have been removed during road construction. Wood volume and density of key pieces do not vary appreciably with stream size class, except that large streams greater than 40-feet wide and rivers have considerably less wood (Table 7-6).

Table 7-5. Average values for large wood in streams by analysis basin, weighted by reach length.

Region	Basin	Wood Volume in Streams (cu. ft. per 100 ft.)	
		Active channel width <40 ft.	Active channel width >40 ft.
Coos	8	343	---
	9	---	31 (WF Millicoma)
	10	169	---
	11	180	50 (WF Millicoma)
	12	115	38 (Elk, WF Millicoma)
Tenmile	5	177	---
	6	164	---
	7	380	122 (Johnson)
Umpqua	1	95	---
	2	310	206 (Charlotte)
	3	163	12 (Dean)
	4	33	280 (Scholfield)
	13	---	---

Basins with no streams sampled indicated by '---'.

Table 7-6. Large wood in streams by stream size class.

Stream Size Class	Average Wood Volume (cu. ft. per 100 ft.)	No. of Reaches	Average Number of Key Pieces (#/100 ft.)
Small	188	25	0.33
Medium/Small	380	19	0.71
Medium	195	19	0.32
Large/Medium	216	12	0.37
Average of above	*242*		*0.42*
Large ACW* <40 ft.	166	17	0.21
ACW >40 ft.	115	9	0.20
River**	27	2	0.06

* ACW = active channel width
** West Fork Millicoma River downstream of Elk Creek confluence

Many Forest stream reaches were cleared of large wood during timber harvest or road construction. Others were cleared of large wood during the 1960s and 1970s under the mistaken belief that logjams created widespread barriers to the upstream movement of salmon and steelhead. The low wood volume documented in the ODFW inventories reflects these past stream cleaning activities. Reduced wood in Forest streams also resulted from tree removal near or to the edge of streams in older harvest units. Without fresh inputs of wood into channels, the net volume decreases due to decay and downstream movement.

Modeling Streamside Stands and Large Wood

Evaluating the future amount of wood likely to accumulate in streams involves the straightforward calculation of wood additions and subtractions. Wood additions to a stream can include:

- Trees falling into the stream.
- The intentional placement of logs in a stream.
- Log deposition by landslides that reach the stream.

Wood subtractions to a stream can include:

- Log volume loss due to decay and abrasion.
- The intentional removal of logs in a stream.
- Downstream movement of logs during high flows.

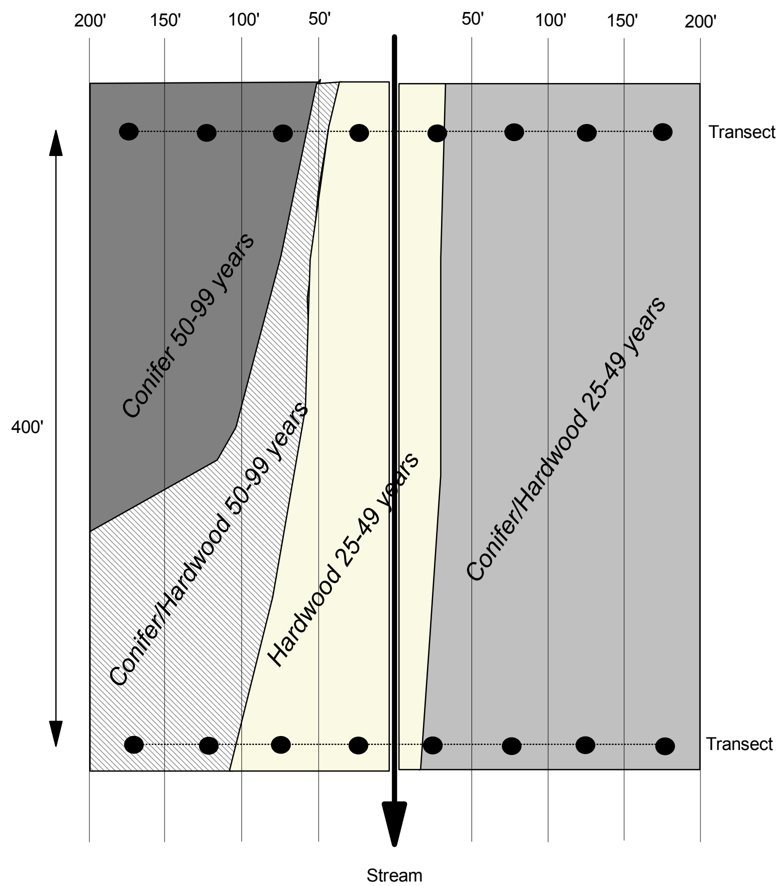
The current difficulty in modeling large wood in streams is a lack of basic information about some of these processes. The long-term addition of wood to streams by landslides is poorly understood since no inventories exist of the amount of wood that accumulates within landslide-prone areas under various management histories. Furthermore, little is known about the portion of wood moved into streams when a landslide occurs. Similarly, little is known about the downstream floating and fate of logs during high flows for streams of various sizes, although casual observation of Forest streams suggests that log movement is limited mostly to streams classified as large. Since the intentional removal of logs from streams is no longer allowed under the Forest Practices Act, this does not need to be included when evaluating the large wood budget of a stream.

In recent years, some progress has been made on techniques for evaluating the input of large wood by streamside stands, and the loss of wood volume in streams over time due to decay (Van Sickle and Gregory 1990, Welty et al. 2002). The analysis team included an application of these methods to fish-bearing streams in the Forest, realizing that other important processes such as wood additions (landslides) and losses (downstream movement) cannot be quantified. Understanding the relationship between the amount and type of trees retained along streams during timber harvest and the future accumulation of wood can lead to better decisions on stream protection practices.

The analysis team adapted methods from the RAIS (Riparian Aquatic Interaction Simulator) model (Welty et al. 2002) to forecast wood inputs from streamside stands and the loss of wood in streams due to decay. However, this model was not used directly because it currently has several software bugs that make critical subroutines unusable. Instead, a spreadsheet version of the model was created and tailored to address various issues pursued in this analysis. The following discussion provides a summary of the subroutines and relationships that went into the spreadsheet version of the model.

The GIS coverage for riparian vegetation and wood loadings from ODFW habitat surveys provided a spatially explicit representation of current stand and stream conditions for fish-bearing streams. An application was developed in ArcInfo to sample a cross section of the riparian vegetation GIS coverage every 400 feet along fish-bearing streams. Since the Forest includes about 161 miles of fish-bearing streams, the total number of transects was 2,125. The vegetation was noted at 4 locations each side of the stream at 50-foot intervals from the stream, beginning 25 feet from stream centerline (Figure 7-11). The large wood model was constructed to track trees that fall from each of these 50-foot bands along the stream.

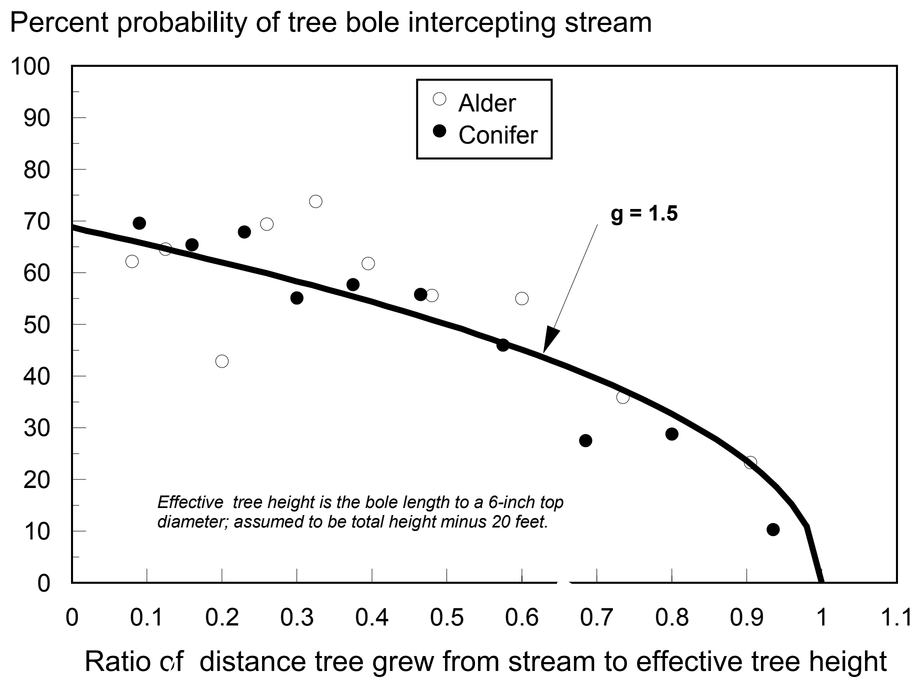
Figure 7-11. An illustration of how streamside stands were characterized using the GIS coverage of fish-bearing streams within the Forest. Filled circles indicate points along transects (spaced 50 feet) with 400-foot-long spacing between transects.



The current wood loading in the channel at each transect was determined from reach averages in the ODFW habitat surveys. For those fish-bearing stream segments with no habitat survey (61 miles Forest-wide), values were assigned based on measured values for nearby streams of similar size (Table 7-5).

The large wood model provides the option of assigning a tree fall bias. A study of windthrown buffer trees in the central and northern Coast Range indicates that, on average, trees are about twice as likely to fall directly towards a stream as they are to fall directly uphill (Andrus and Froehlich 1992). Figure 7-12 provides an empirical probability distribution that shows the likelihood of a tree ending up in a stream depending on its relative distance from the stream. This relationship predicts that a 140-foot tall tree with an effective height of 120 feet would have a 66% chance of hitting the stream upon falling if it grew 10 feet from the stream, and a 30% chance if it grew 100 feet from the stream (downhill bias, g = 1.5).

Figure 7-12. The probability of a tree landing in the stream as a function of its relative distance from the stream for observed fall patterns (Andrus and Froehlich 1992).



Percent probability of tree bole intercepting stream:

P = ((90-z) / 180 * (1 + (g/360 * (90+z))) * 100

where : z = arcsin(Distance / Effective Tree height)

Observed fall pattern based on 405 alder trees and 506 conifer trees. Windthrown trees from streamside buffers in the Oregon coast range (Andrus and Froehlich 1989).

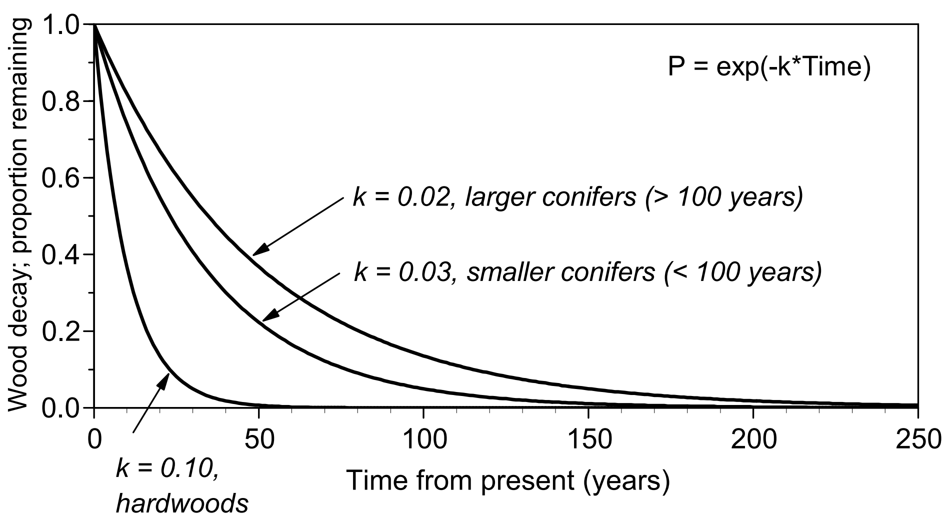
Key information needed for modeling wood losses from streams is the decay rate of logs of various species. Some information on the decay of conifer wood from southeast Alaska streams of various sizes was available from Murphy and Koski (1989). Similar studies on the decay of wood on uplands were conducted by Lambert and others (1980) and Sollins (1982). In these studies, a first-order decay function was used to describe wood volume losses over time. The function is:

$$P = exp(-k * X)$$

where Y is the proportion of wood remaining;
k is the decay rate; and
X is the time from the present in years.

The analysis team used a *k* value of 0.03 for conifers less than 100 years old. A *k* value of 0.02 was used for conifer logs greater than 100 years old; an adjustment based on the ability of large diameter and tight-ringed conifer logs to better resist decay that originates from the outer layers of a log (Harmon et al. 1986). A resurvey of alder logs in Oregon Coast Range streams 12 years after the original survey indicated that a *k* value of 0.10 was appropriate for applying to hardwoods (Heimann 1988). The loss functions using the selected *k* factors are shown in Figure 7-13.

Figure 7-13. Proportion of wood volume remaining as a function of time for conifer and hardwood logs in streams.



The analysis team used the empirical stand relationships in Table 7-1 to model the type (conifer or hardwood), number, diameter, and length of logs provided to streams by the streamside forest for each 10-year time interval, up to a maximum age of 300 years. Fallen trees less than 30 years old were assumed to be of such small size that they would have little influence on the overall volume of wood in streams. The model was run for three stand composition types (conifer-dominated, conifer/hardwood, and hardwood-dominated). Volume results were expressed as cubic feet of wood per 100 feet of stream.

A simple model run was made with the assumption that any preexisting large wood in the stream at year 0 was gone by year 30, and that the streamside stand was of uniform age to the edge of the stream. These assumptions correspond to the timber harvest and stream management practices of 20-50 years ago, when trees were typically harvested to the edge of a stream, merchantable logs were removed from streams, or logs were removed to "clean" the stream.

The amount of wood expected to accumulate in a stream varied greatly by stand composition. Streams bordered by conifer-dominated stands reached a net wood volume of about 770 cubic feet per 100 feet of stream by year 200, while the volume of wood in streams bordered by conifer-hardwood stands was one-half that amount (Figure 7-14). Streams bordered by hardwood-dominated stands had only 10% of the volume of those bordered by conifer-dominated stands.

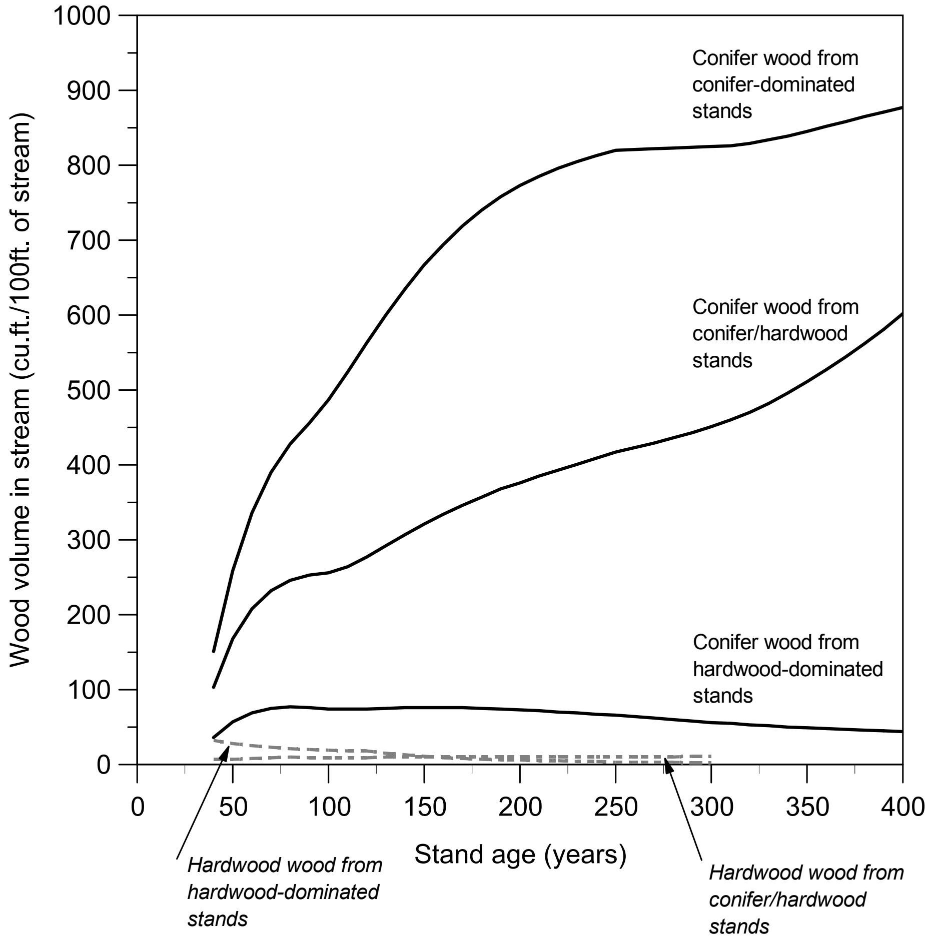
Beyond year 70, nearly all the volume of wood in streams was conifer (Figure 7-14). The volume of hardwood entering streams beyond year 70 is probably underestimated since the model has no mechanism for dealing with the production of hardwood volume for uneven-aged hardwood stands. Nevertheless, hardwood logs decay so quickly that they do little to influence the net volume of wood in the stream.

Wood volume in streams bordered by conifer-dominated streams plateau at about year 200 while streams with hardwood-dominated streams reached their greatest net volume at year 70 (Figure 7-14). The modeled net volume of wood in streams is less than that measured within undisturbed, reference streams on nearby BLM land (Table 7-7). This suggests that, in addition to logs originating from the streamside forest, a considerable amount of large wood in streams originates from landslides where large wood in draws is allowed to accumulate at natural volumes.

Table 7-7. Modeled large wood volume in comparison to measured values for Forest streams (<40 feet wide) and BLM reference streams.

Large Wood Volume	Mean Wood Volume (cu. ft. per 100 ft.)
Modeled wood volume (at year 200)	
Conifer-dominated stands	770
Conifer/hardwood stands	390
Hardwood stands	80
Measured wood volume, Elliott State Forest	
All stand types and ages	190
Measured wood volume, BLM reference streams (most were conifer-dominated stands)	
88 to 118 years old	820
288 to 408 years old	1,630

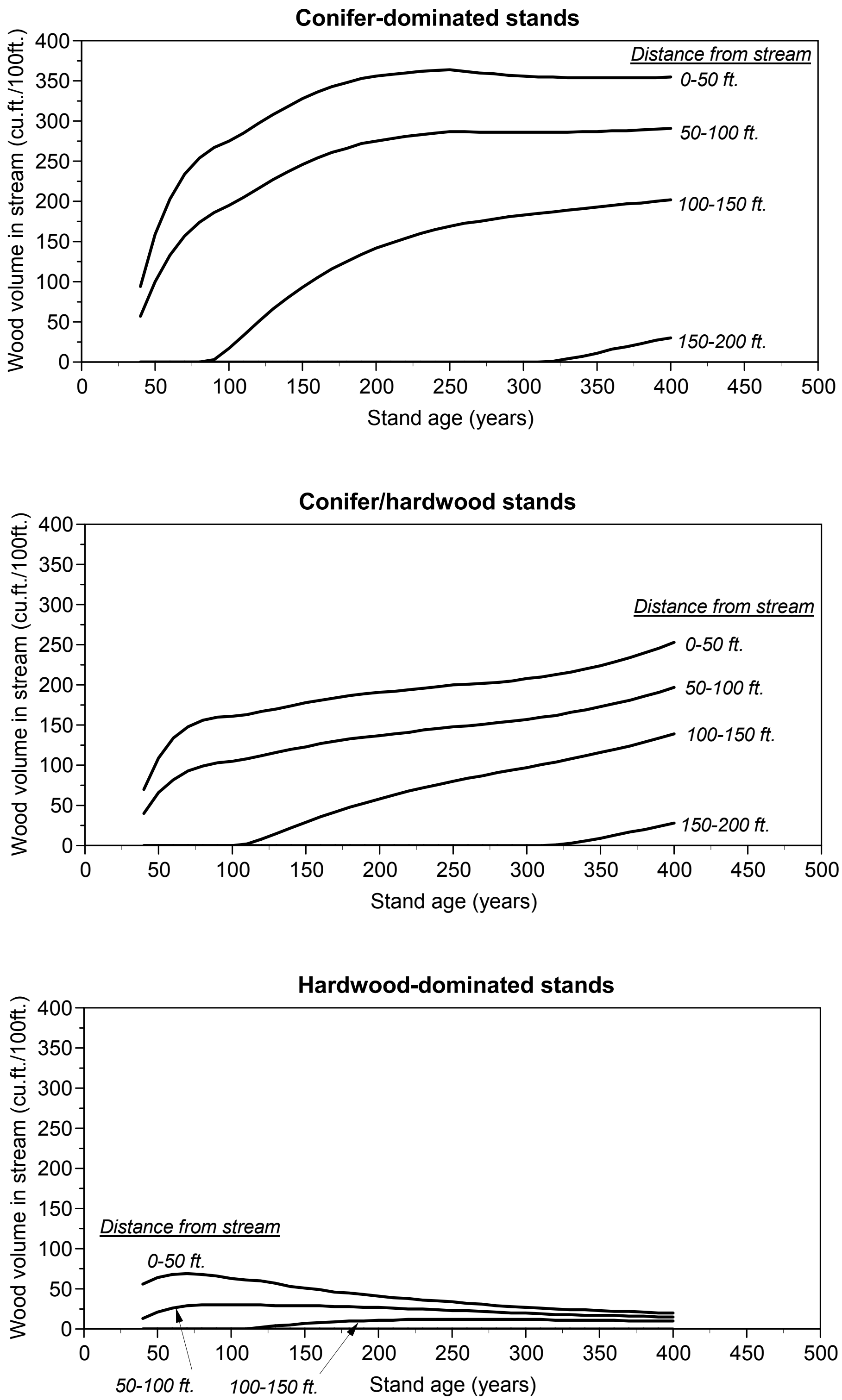
Figure 7-14. Modeled changes in conifer and hardwood wood volume for streams bordered by conifer-dominated, conifer/hardwood, and hardwood-dominated stands (assumes wood from the previous stand does not persist beyond year 30.)



These modeling results indicate that at year 200, most (85%) of the wood that has accumulated in the stream originates from the trees growing within 100 feet of the channel (Figure 7-15). However, the proportion originating from the 100- to 150-foot distance interval increases considerably from year 200 to year 300 for conifer-dominated and conifer/hardwood stands. Very little large wood within the stream originates from the 150- to 200-foot distance since the effective height (total height minus 20 feet) of dominant and codominant conifers exceeds 150 feet only for old stands. For the same reason, nearly all hardwood trees that end up in the stream originate from land within 50 feet of the stream.

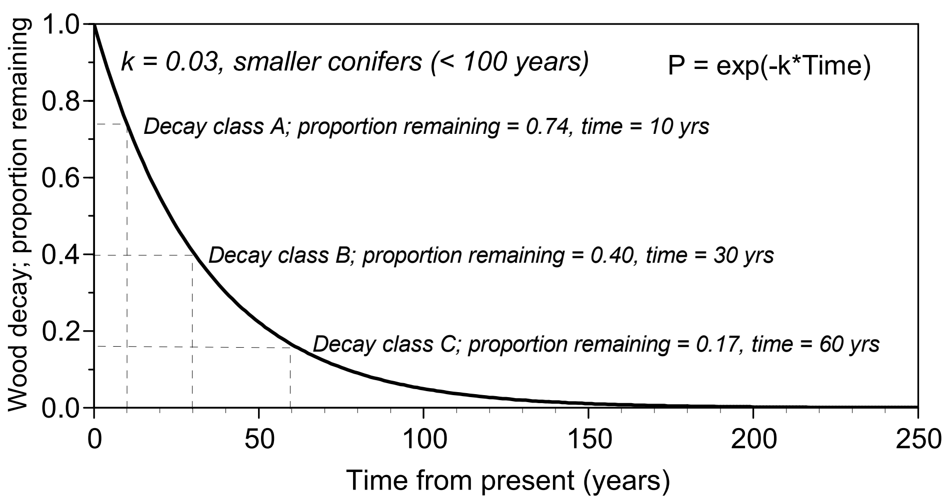
When modeling large wood in streams, the decay of initial wood in the stream (at year 0) needs to be tracked separately from the wood provided by the streamside stand (beyond year 0). Some of this initial wood consists of old logs in advanced stages of decay while some may be relatively sound. As discussed previously, since many Forest streams had in-channel wood intentionally removed over the last four decades, the composition of the current or previous stand provides little insight on the decay status of the wood in the stream.

Figure 7-15. Modeled net volume of large wood in streams and the distance class from which it originated.



The ODFW habitat surveys do not provide information on decay classes for the large wood inventoried in Forest streams in the mid-1990s. Consequently, the analysis team used results of a detailed large wood survey of 63 coastal southwest Washington streams (Bilby and Andrus, unpublished data) to better understand the wood decay classes of large wood currently in streams. The study area was a managed forest landscape that included both plantations and fire stands up to 100 years old. Some stream cleaning also occurred in this area. Focusing only on streams bordered by young plantations with no buffer trees retained during harvest, 34% of the conifer wood had intact bark and sound wood (decay class A), 41% was partially decayed but was still structurally sound (decay class B), and 25% was in advanced stages of decay without much structural integrity (decay class C). An estimate was made of where each decay class fell along a graph of proportion of wood remaining and time, assuming a *k* factor of 0.03 (Figure 7-16).

Figure 7-16. The positions for large wood of various decay classes along a decay curve where the k factor is 0.03 (smaller conifers).



In the model, loss of this initial wood due to decay was calculated by decay class and summed for each time increment. For example, the average value of current wood abundance as measured for Forest streams (193 cu. ft. per 100 ft.) is displayed in Figure 7-17. After 50 years, 17% of the initial volume is still present while only 2% is present after 100 years.

Adding the initial (current) wood volume in streams and projected declines to the logs provided by the maturing streamside stand, a more complete picture of net changes in wood emerges (Figure 7-18). Until the new stand begins yielding functional large wood at age 30, large wood in the stream declines rapidly as the initial wood decays. Large wood abundance increases to initial levels between years 30 and 50 for streams bordered by conifer-dominated and conifer/hardwood stands; streams bordered by hardwood stand never again approach the initial wood volume level.

Figure 7-17. Calculated decline in initial wood volume over time for the average Forest stream, as a composite of three decay classes.

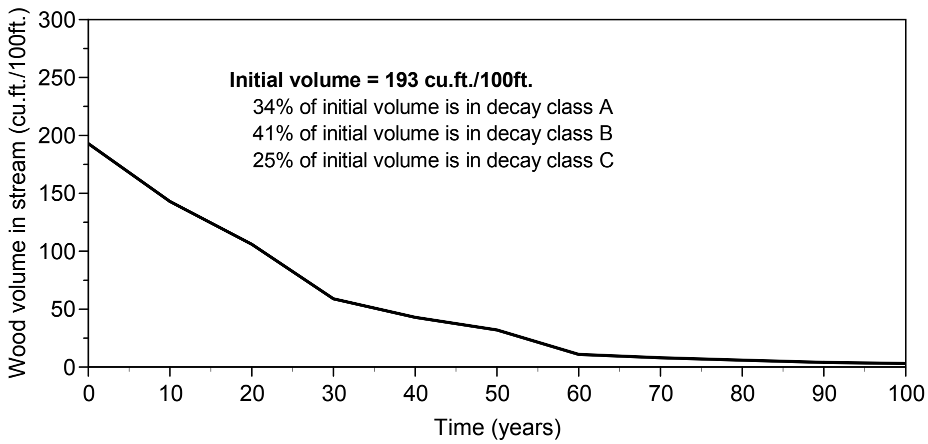
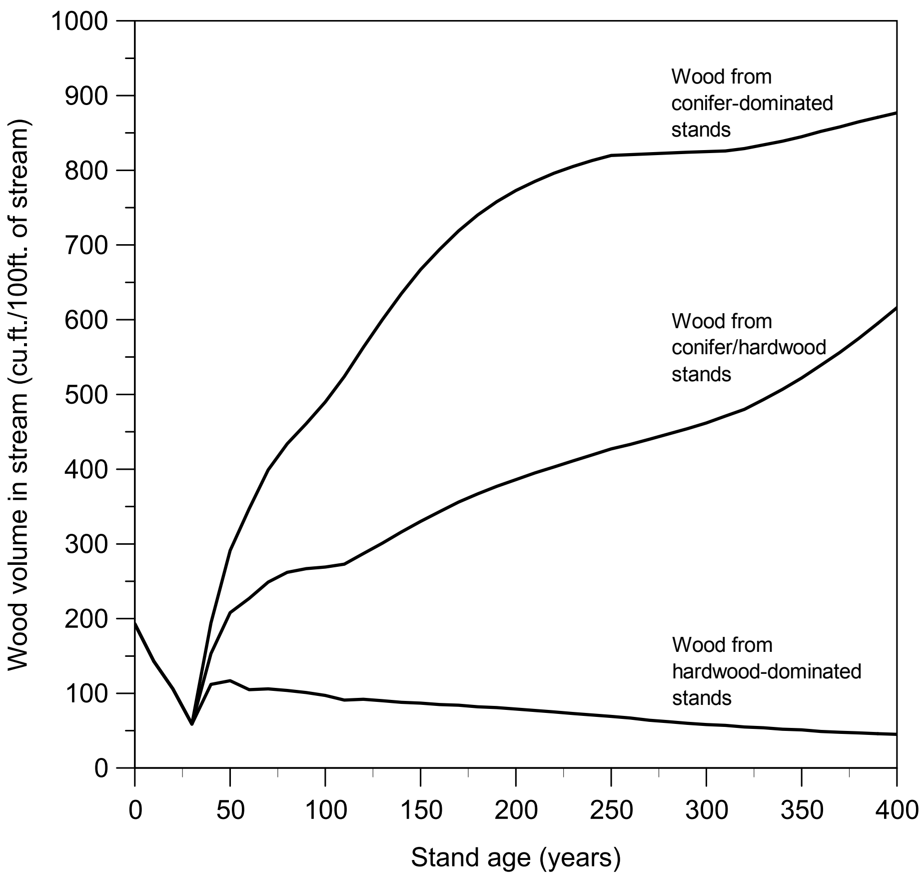


Figure 7-18. Modeled large wood in streams combining the wood initially in the stream at time of stand initiation (assumes a Forest-wide average of 193 cu. ft. per 100 ft.) plus the wood added by the developing streamside stand.



The simplified example shown in Figure 7-18 does not apply to most stream segments on the Forest since stand type and age are rarely the same for each side of the stream and for the entire distance 200 feet out from the stream centerline. In addition, initial wood volume varies widely among stream segments.

The heterogeneous nature of stands typically next to streams is illustrated in Figure 7-19 for Deer Creek, 2,800 feet downstream of the upper extent of fish use. An older conifer/hardwood stand grows on the left bank, a hardwood-dominated stand grows on the right bank out to 100 feet, and the remainder of the right bank is a conifer/hardwood plantation 12-24 years old. The current in-channel wood is 165 cubic feet per 100 feet; within 50 years, most of that will have decayed (Table 7-8). During the first 100 years, much of the wood comes from the left bank where older trees occupy the area within 100 feet of the stream. Within 300 years, the band 100-150 feet from the stream also provides sizable amounts of instream wood. Very little wood comes from beyond 150 feet. The hardwood stand growing on the right bank produces moderately small amounts of wood, with most of this coming from trees growing within 50 feet of the stream. After 50 years, this component becomes minimal. The young conifer/hardwood plantation growing beyond the older hardwood stand on the right bank yields very little wood until 300 years from the present, which originates mostly from trees growing no further than 150 feet from the stream. Adding the wood originating from all distance classes to the initial wood in the stream (or that which remains at any time) indicates that this stream segment will probably experience only modest gains in large wood over the next 100 years. Within 300 years, wood volume increases to about 2.6 times that initially in the stream (Table 7-8).

Figure 7-19. Stand type and age for Deer Creek, 2,800 feet upstream of the mouth.

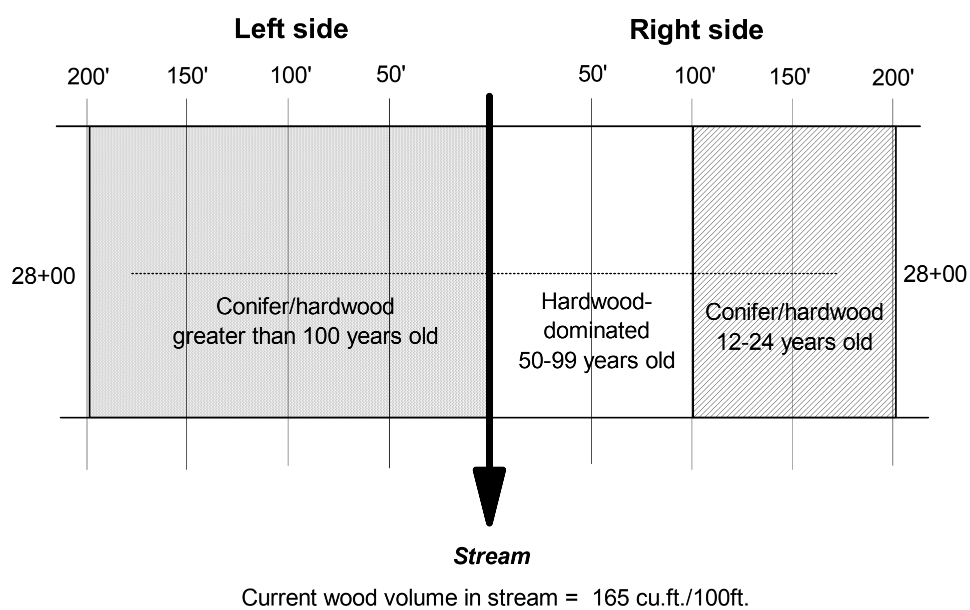


Table 7-8. Modeled large wood in Deer Creek (2,800 feet upstream of the mouth) from the current year to 300 years in the future.

Time from Present	Left Side of Stream (cu. ft. per 100 ft.)				Right Side of Stream (cu. ft. per 100 ft.)				Initial Wood in Stream (cu. ft. per 100 ft.)	Summed Wood in Stream (cu. ft. per 100 ft.)
	Conifer/hardwood >100 yrs				Hardwood-dom. 50-100 yrs		Conifer/hardwood 12-24 yrs			
	200-150'	150-100'	100-50'	50-0'	0-50'	50-100'	100-150'	150-200'		
0	---	---	---	---	---	---	---	---	165	165
50	0	24	66	94	30	15	0	0	32	261
100	0	36	72	98	23	14	4	0	3	250
300	19	79	108	140	13	10	52	1	0	422

The analysis team prepared a database showing current and modeled future large wood volumes for fish-bearing streams at various time intervals up to 300 years from the present. Large wood volume was modeled at intervals of 400 feet along all fish-bearing streams, and incorporated the decay of existing large wood in streams and the wood inputs and decay associated with the existing streamside stand. For purposes of display, results for the 400-foot intervals were averaged over distances of 1 mile or less. Results were reported for each unnamed tributary of a named stream, with tributaries labeled numerically in order from most upstream to most downstream. Unnamed tributaries were less than 1 mile long, except for tributary #1 of Scholfield Creek. Results for named streams were summed by 1-mile increments, starting at the most upstream end of fish use (or the property line in some cases). The most downstream segment was usually less than 1-mile long, stopping at the Forest property line. Appendix B provides a listing of the individual segments, along with their current and modeled future large wood volumes (at years 50, 100, 200, and 300).

Current large wood volume and the volume predicted 200 years from the present are displayed in Map 7.2 in a relative ranking. The 25% of stream segments that currently have the most amount of large wood are displayed as a green along the left side of the stream centerline (facing downstream), while the 25% of stream segments that currently have the least amount are displayed as a red line. Along the right side of the stream centerline are the relative rankings for large wood volume modeled for 200 years in the future. A blue line indicates the stream segment is among the 25% of segments with the greatest wood volume, while a lavender line indicates it is among the 25% of segments with the least wood volume.

The current abundance of wood in a stream segment was generally unrelated to the amount of large wood expected 200 years from now. For example, while wood volume in the lower mile of Footlog Creek is currently one of the lowest on the Forest (34 cu. ft. per 100 ft.), it is projected to be among the 25% of stream segments with the greatest wood volume (417 cu. ft. per 100 ft.) within 200 years (Map 7.2, Appendix B).

The average wood volume currently in fish-bearing streams is about the same for the three regions. However, sizable differences are predicted to develop by 300 years in the future. The Tenmile region has the lowest predicted wood volume at 300 years. Values are predicted to be 2.3 times higher for stream segments in the Umpqua region and 2.7 times higher for the Coos region (Table 7-9).

Up to two-fold differences in large wood volume is predicted to occur among individual analysis basins 300 years in the future (Table 7-9). The volume of large wood within some basins departed sharply from their regional averages (Figure 7-20). Future amounts of large wood were greatest for basins #2, #11, #12, and #13 and lowest for basins #7, #10, and #5.

Table 7-9. Current and projected large wood volume in Forest streams by analysis basin.

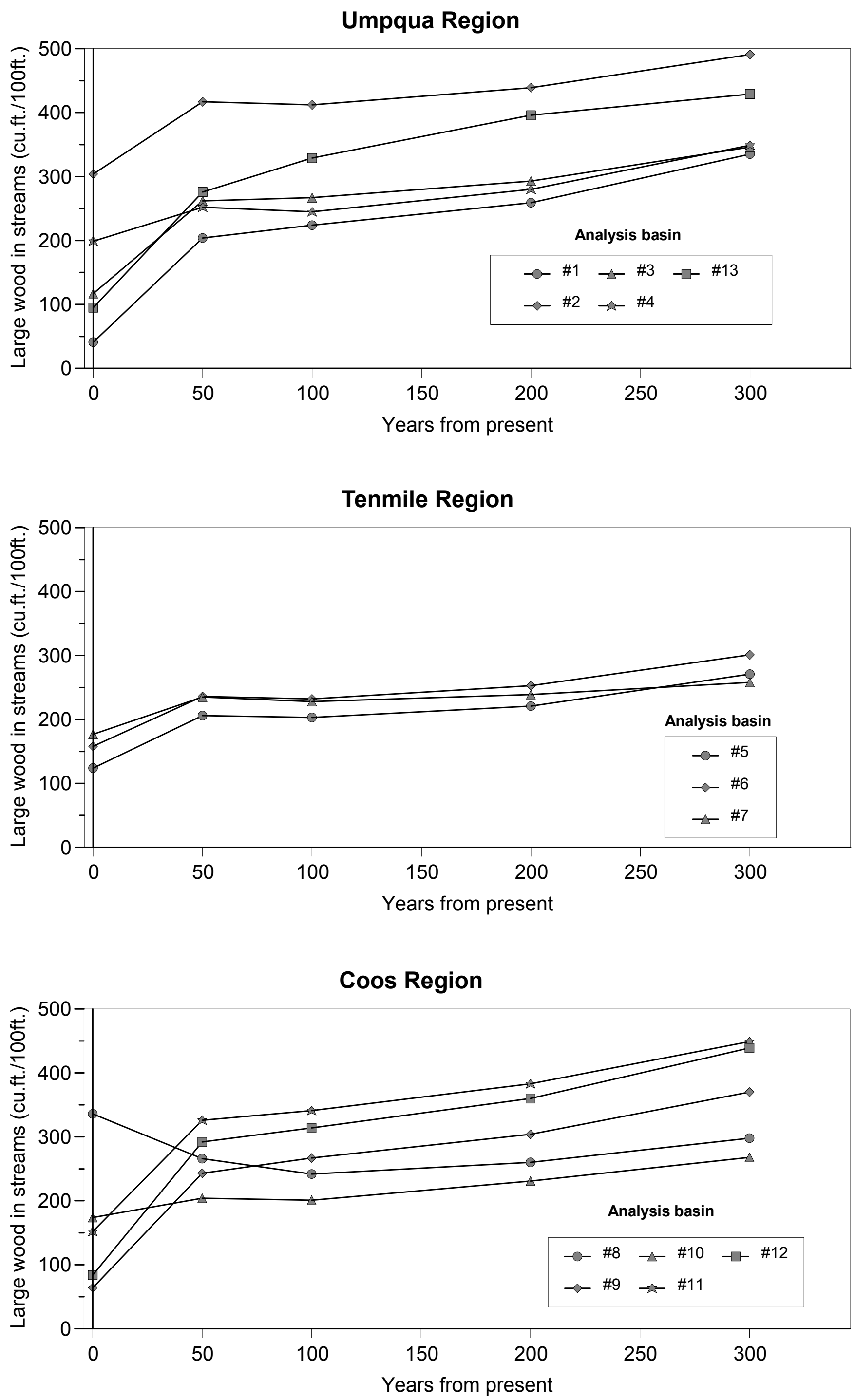
Region	Analysis Basin	Mean Large Wood Volume (cu. ft. per 100 ft. of stream)				
		0 years	50 years	100 years	200 years	300 years
Umpqua	1	41	204	224	259	335
	2	304	417	412	439	491
	3	117	262	267	293	346
	4	199	252	245	280	349
	13	95	276	329	396	429
	Combined	**144**	**272**	**283**	**318**	**378**
Tenmile	5	124	206	203	221	271
	6	158	236	232	253	301
	7	177	235	228	239	258
	Combined	**150**	**224**	**219**	**236**	**276**
Coos	8	336	266	242	260	298
	9	64	243	267	304	370
	10	174	204	201	231	268
	11	152	326	341	383	449
	12	84	292	314	360	439
	Combined	**133**	**283**	**297**	**336**	**401**
Total		**139**	**270**	**279**	**313**	**372**

EVALUATION OF MANAGEMENT OPTIONS

Evaluating Forest-wide policies on tree retention along streams and creating buffer designs for specific sites can be done using the modeling approach presented above. In this section, the analysis team presents an evaluation of various stream management scenarios that were requested by Forest staff. Three scenarios, presented in question format are:

1. How much would the future volume of large wood in streams increase if buffers were expanded from their current width (about 150 feet each side of a fish-bearing stream) to 200 feet?
2. How much would the future volume of large wood in streams change if hardwood-dominated stands were retained no more than 50 feet from the stream and the next 150 feet clearcut harvested and planted to conifers?
3. How much wood would need to be placed in a stream today to ensure that wood volume in the future does not drop below some desired level?

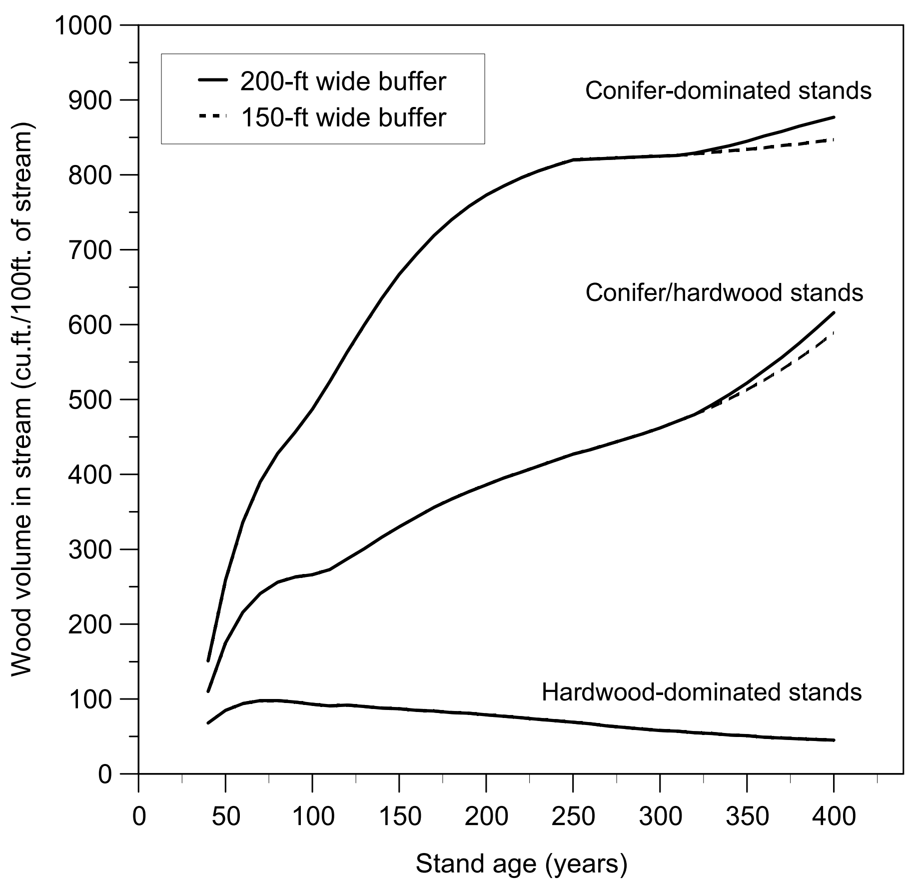
Figure 7-20. Current and projected large wood in Forest streams by analysis basin.



Scenario 1. Increasing buffer width to 200 feet each side of stream. Model results indicate that few trees growing more than 150 feet from the stream end up in the stream. The reason is two-fold. First, the effective height (total height minus 20 feet) of the average conifer tree is less than 150 feet until the trees reach about 230 years old. Secondly, even trees with an effective height greater than 150 have only a small probability of hitting the stream at such distances. For example, a 170-foot tall tree growing 150 feet from the stream has only a 22% probability of landing in the stream when it falls (Figure 7-12).

The numerical differences in stream wood volume between a 150-foot-wide and a 200-foot-wide buffer can be explored by examining the wood that accumulates in streams bordered each side by conifer-dominated, conifer/hardwood, and hardwood-dominated stands. To simplify this analysis, the initial large wood in the channel is assumed to be zero. Differences in wood volume that accumulate in the stream over time are nearly the same for 150-foot-wide and 200-foot-wide buffers (Figure 7-21). Differences show up for conifer-dominated and conifer/hardwood stands only after trees exceed 330 years old.

Figure 7-21. Differences in large wood for streams with 150- and 200-foot-wide buffers.



Scenario 2. Retain hardwood-dominated stands only to 50 feet and establish new plantation beyond 50 feet. About one-half of the land within 100 feet of streams on the Forest currently supports hardwood-dominated stands, while about one-quarter of the land 100-200 feet from streams supports hardwood-dominated stands (Figure 2-5). Some of this area is probably too moist or unstable to support conifer trees, yet conifer stumps are found beneath the current hardwoods in other areas, thereby suggesting that hardwoods are more common along streams now than they were prior to road building and timber harvest on the Forest.

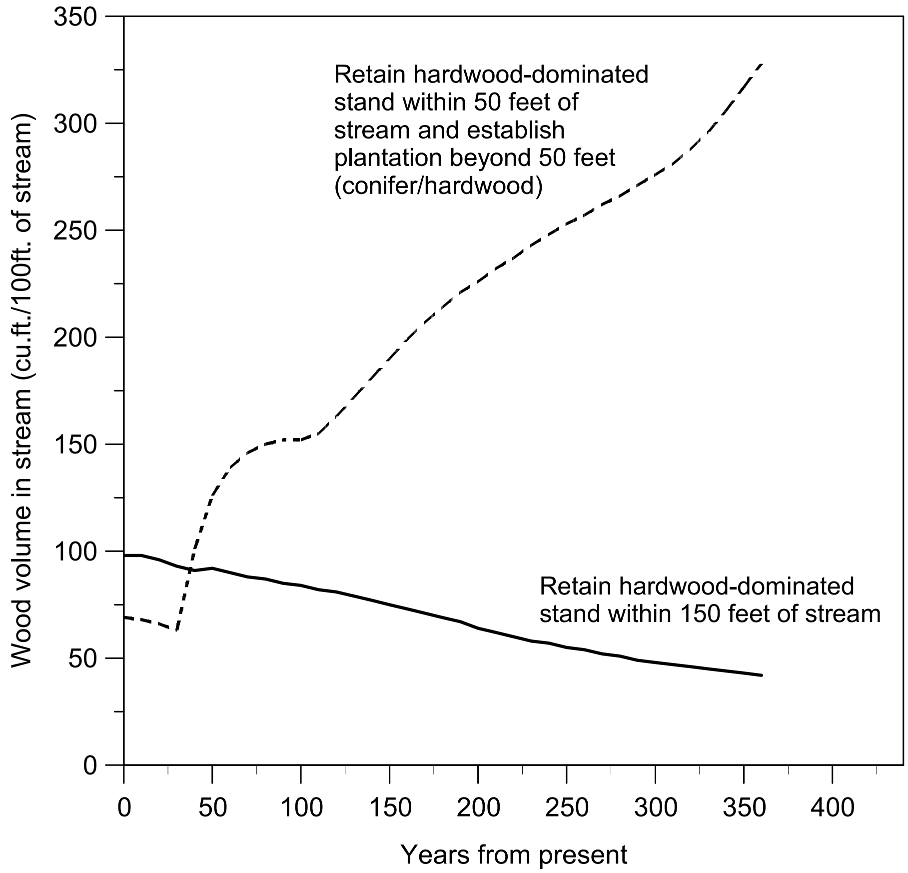
The scenario to retain a relatively narrow buffer of hardwood trees along a stream during adjacent timber harvesting, combined with aggressive conifer regeneration beyond the buffer, has been part of the Forest Practices Act since 1994 as an "alternative plan." The stated goal is to increase the number of conifer trees near streams in the future, realizing some short-term losses in large wood will occur by limiting the hardwood buffer to a narrow width. This option is available to land managers only for sites where regeneration of conifers is physically possible.

The difference in wood volume between these two buffer strategies are modeled and shown in Figure 7-22. Timber harvest was assumed to occur when the hardwood stand was 70 years old. It also was assumed that due to the difficulty of establishing conifers next to streams and buffers, the new plantation beyond 50 feet would be a conifer/hardwood stand rather than a conifer-dominated stand.

During the first 40 years, retaining a 50-foot-wide hardwood buffer resulted in slightly less wood than retaining a 150-foot-wide hardwood buffer (Figure 7-22). Thereafter, the new plantation beyond 50 feet produced wood that quickly outpaced wood produced by the wide hardwood buffer.

Under this model run, it is assumed that a new conifer/hardwood plantation is established up to the edge of the 50-foot-wide hardwood buffer. A number of factors act to frustrate conifer regeneration success next to streamside buffers. First, aerial applications of herbicides are conducted to ensure that no spray gets in the water or damages the buffer. Often this results in inadequate brush control within areas near the buffer and reduced conifer regeneration success. Secondly, logging slash can accumulate at the lower end of steep harvest units near the buffers, thereby reducing available tree planting spots. Furthermore, tree mortality at the lower end of harvest units is often greater due to mountain beaver, which prefer the moist soils near streams.

Figure 7-22. Comparison of retaining hardwood-dominated stand within 150 feet of stream versus retaining only first 50 feet and establishing new plantation beyond 50 feet.



Scenario 3. Placement of logs in streams to maintain a desired wood level over time. The placement of logs in a stream for the purpose of boosting levels of wood to some desired level could occur when adjacent slopes are harvested or it can be a separate activity where there is road access. The amount of wood added depends on how much wood is contributed by the streamside stand and at what interval logs are placed. In evaluating this scenario, the following assumptions have been made:

- Placed logs decay at a relatively slow rate (k=0.02).
- The streamside stand is 70 years old when the first log placement is made; subsequent placements can occur every 70 years thereafter.
- A buffer of trees 150 feet wide each side of the stream is maintained.
- The volume of wood in the stream cannot decline below 386 cubic feet per 100 feet, which is twice the current volume for the average stream in the Forest.

Modeling results indicate that no wood needs to be added to streams bordered by conifer-dominated stands in order to maintain a minimum wood volume of 386 cubic feet per 100 feet (Figure 7-23). Similarly, streams bordered by conifer/hardwood stands only required an addition of 290 cubic feet per 100 feet at time = 0 to maintain this minimum volume for the next 300 years. In contrast, streams bordered by hardwood-dominated stands required the placement of about 850 cubic feet per 100 feet of wood every 70 years in order to maintain the minimum volume. These results indicate the importance of streamside stands in maintaining wood levels in streams. Without adequate wood provided by a streamside stand, the intentional placement of logs needs to occur often and large amounts need to be added.

LARGE WOOD ORIGINATING FROM STEEP DRAWS

Results from the 1996 ODF landslide study (Robison et al. 1999) indicated that only a portion of upslope landslides actually end up in fish-bearing streams, and even fewer result in persistent jams of wood, rock, and coarse sediments. Overall, the material (soil, rock, and logs) in debris jams in fish-bearing streams averaged only 8 cubic yards/100 feet of stream. In the 1996 study, the lack of logjams associated with landslides may have been due to some receiving streams being large enough to transport the material far downstream during the high water. It also may have been due to the removal of logs from contributing draws on slopes that have been clearcut harvested over the last few decades. However, even for draws within mature stands, the wood load seems low. These mature stands are at an age (90-140 years) where trees are healthy and at a density for which little mortality would be expected because of competition.

The analysis team inspected several draws within an old-growth stand (visually estimated to be about 300 years old) in Dry Creek and found wood loading to be very high. Logs were piled about 10 feet deep in the upper sections of headwater channels or draws. Because systematic data has not been collected on large wood abundance within draws surrounded by stands of various ages in the central Coast Range, no conclusions can be made on how draws accumulate wood as stands age.

Ranking the ability of a draw to deliver wood to a stream can be important when determining where to leave trees for benefiting fish within harvest units. Retaining trees along draws that have a high probability of delivering wood to a fish-bearing stream when a landslide occurs would better meet the goals of improving structural habitat for fish, rather than retaining trees along a draw with a small chance of delivering wood to the stream.

There is a coarse method for estimating whether landslides routed down tributary channels are likely to reach a fish-bearing stream. A study of landslides in steep sandstone terrain in the Coast Range (Benda and Cundy 1990) led to a rule-of-thumb about where landslides stop within channel systems. It was concluded that most landslides made their way down through a channel system as long as the angle at channel junctions was less than 70 degrees and the channel slope was more than 6% (Figure 7-24, left panel). This assumes that the landslide remains confined by steep hillslopes. If the gradient of the contributing channel was 20% or more, then the landslide would continue downstream past the confluence, irrespective of confluence angle (Figure 7-24, right panel).

Figure 7-23. Modeled levels of wood in streams where the combination of wood falling from the streamside stand and placed wood is used to maintain a given amount of wood through time.

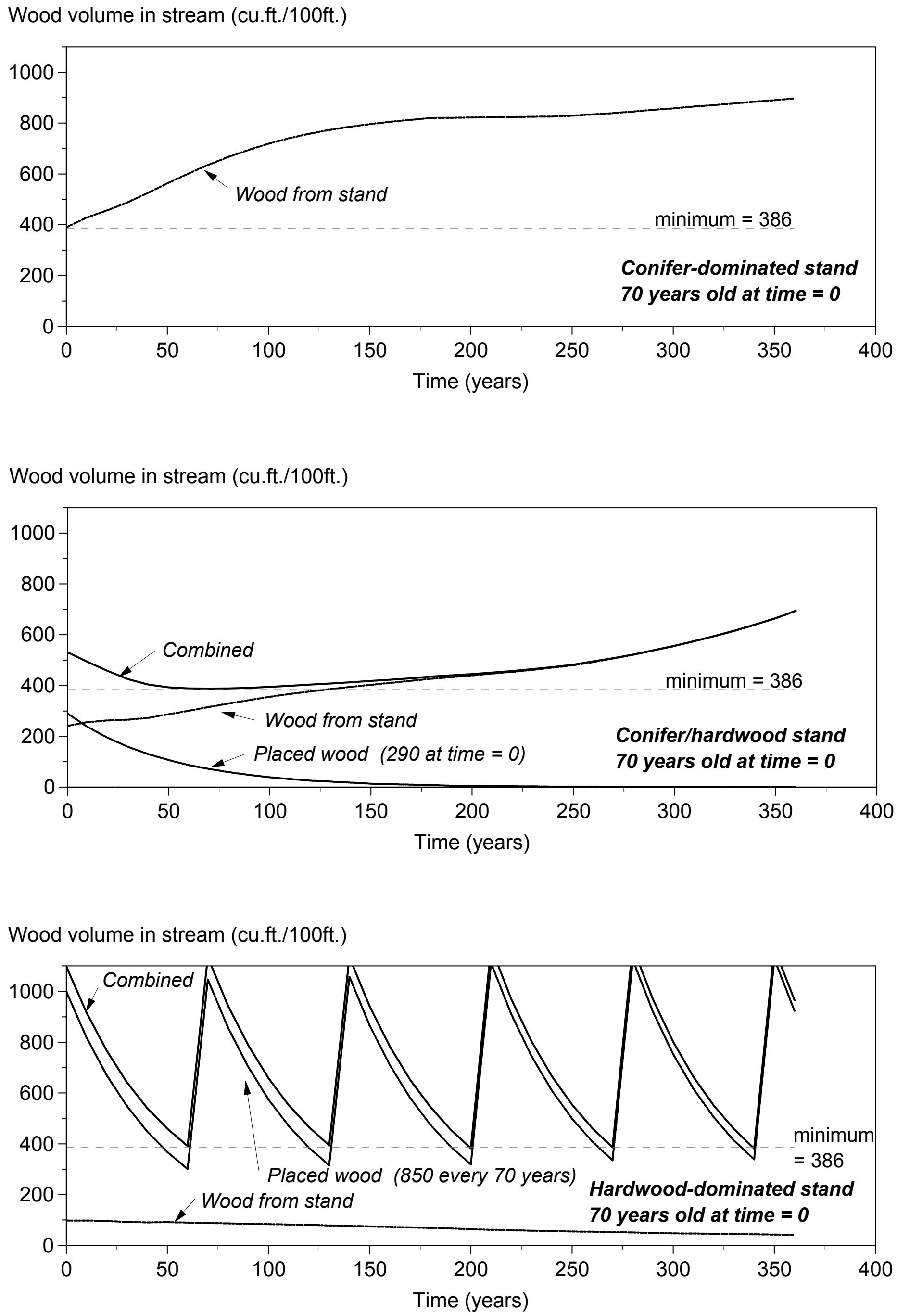
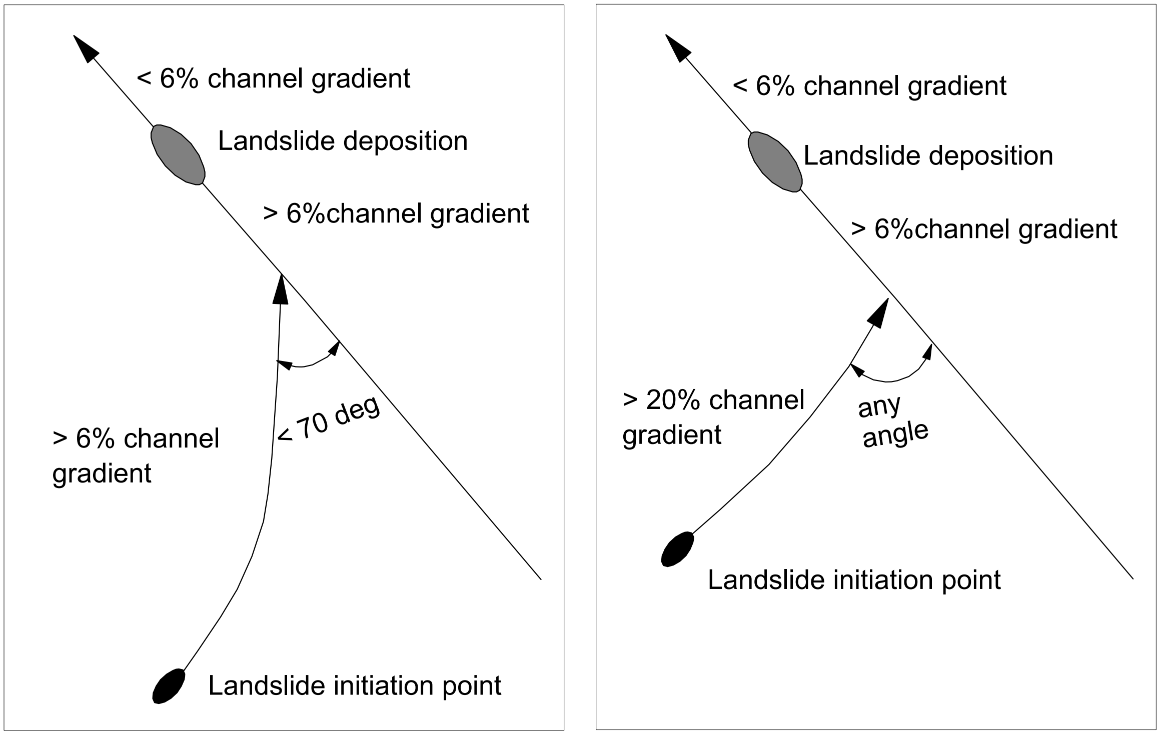


Figure 7-24. Rule-of-thumb proposed by Benda and Cundy (1990) for estimating the downstream extent of landslide travel.



The analysis team tested these findings against results from the 1996 landslide study (Robison et al. 1999) and found that this rule-of-thumb (Benda and Cundy 1990) underestimated the gradient at which landslide deposition occurred; landslides tended to deposit in channels once the gradient dropped to 8%, rather than at 6% as suggested. Therefore, the analysis team adopted the 8% gradient limit. The analysis team then considered the information available to ODF staff for applying this revised rule-of-thumb across the Forest and made the following conclusions:

- The 20-foot contours derived from the orthophotos used by the Forest did a reasonable job of delineating depressions in hillslopes that were the paths of actual landslides. About three-quarters of the landslide paths from the Robison et al. (1999) study coincided with depressions or draws that could be discerned from the 20-foot contours. The remaining one-quarter of landslide paths was shown as uniform slopes by the contours. Consequently, the analysis team used the contour coverage to delineate all draws on the Forest that were not already marked by a stream course line in the stream coverage. A draw was defined as any depression on the hillslope that suggested a channel. The draw was extended upstream until the terrain fanned out to a uniform slope. About 85% of the draws discernable from the contour maps had not been previously included in the existing stream course coverage. Forest-wide, a total of 5,764 draws were added.

- The large number of draws for evaluation (estimated to be about 6,800) presented a problem for conducting a Forest-wide determination of which draws were most likely to supply fish-bearing streams with wood and boulders when a landslide occurred. Although automated calculations of channel gradient using the available DEM were considered, the DEM was too coarse to discern small differences in channel gradient. The inability to discern the difference between a 6% and 8% channel gradient, for example, can result in a one-quarter to one-half mile difference in landslide travel distance for typical Forest streams.
- Because of the lack of automated methods for analysis, the analysis team decided that determining the location of landslide deposits would best be handled for small areas during the planning stages for timber harvest units using manual mapping methods. The steps to accomplish this and an example are provided below.

Steps for prioritizing stream segments according to their likelihood of delivering large wood and boulders to streams when shallow landslides occur are as follows.

1. Number the draws and stream channels without fish into segments, similarly to what is shown in Figure 6-14. A stream segment downstream of the confluence of two other segments gets its own stream segment number.
2. Note which segments flow directly into a fish-bearing stream.
3. Determine which segments have a gradient less than 20% at their downstream ends.
4. At the intersection of two segments, note if the confluence angle is less than 70 degrees.
5. On the map, note where the channel gradient is less than 8%.
6. Using information from items 2-5, indicate which segments are likely to deliver large wood and boulders to fish-bearing waters, based on the following criteria:
   - ⇒ Landslides will deposit their load once the channel gradient becomes less than 8%.
   - ⇒ Irrespective of the confluence angle, landslides traveling through a stream segment will continue downstream as long as the gradient of the contributing channel is greater than 20%.
   - ⇒ If the gradient of the contributing channel is between 8% and 20%, the landslide will continue downstream only if the confluence angle is 70 degrees or less.
7. A further refinement of this method is possible by noting the percentage of segment length bordered by side slopes greater than 70%. Segments bordered by steep slopes have more landslide initiation sites. Furthermore, large wood and boulders are more likely to be produced by steep, unstable side slopes than by gentle side slopes. Therefore, stream segments with a higher frequency of landslides and with abundant accumulations of logs and boulders are more likely to benefit downstream fish-bearing streams.
8. Combining information from items 6 and 7, priority categories can be established to rate the relative importance of stream segments relative to the likelihood of a landslide reaching a fish-bearing stream plus the likely abundance of wood and boulders available for transport by a landslide. The following categories are recommended by the analysis team but other categories could be developed to further refine the process.
   - ⇒ *High.* Landslide expected to reach fish-bearing stream and 70% or more of the segment length is bordered by slopes 70% or greater.
   - ⇒ *Moderately high.* Landslide expected to reach fish-bearing stream and 30% to 70% of the segment length is bordered by slopes 70% or greater.

⇒ *Moderate.* Landslide expected to reach fish-bearing stream and less than 30% of the segment length is bordered by slopes 70% or greater.

⇒ *Low.* Landslide is not expected to reach fish-bearing stream.

An example of this method is illustrated for a tributary basin of Cougar Creek (Table 7-10, Figure 7-25). Fish use this stream up to the junction with stream segment #9. Because all stream segments but #6 have a gradient at the lower end that is greater than 20%, any landslides would be expected to continue downstream in the receiving channel, even where the confluence angle is greater than 70 degrees. For stream segment #6, since the confluence angle is less than 70 degrees, landslides from this segment also would be expected to continue downstream.

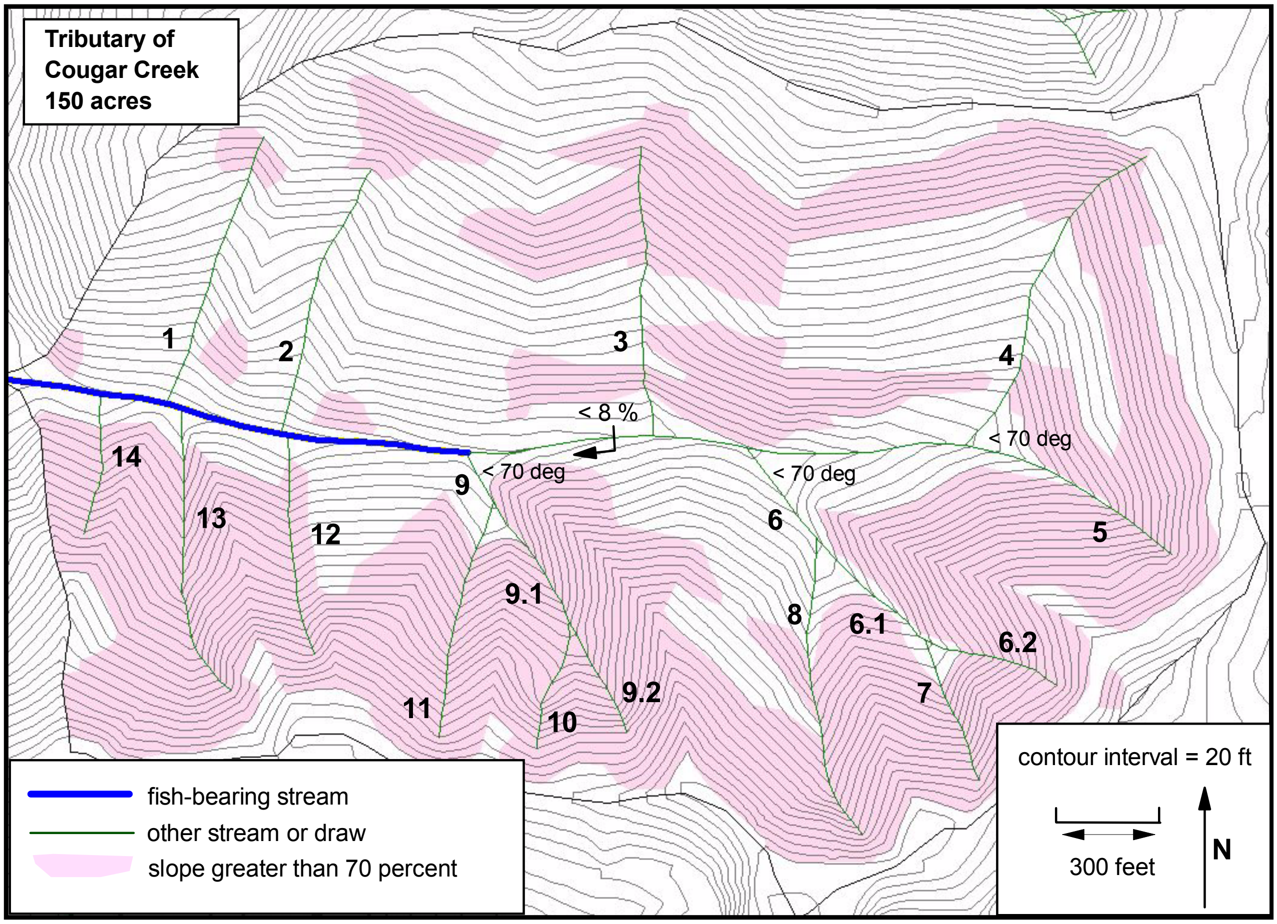
Table 7-10. Information on stream segments within a tributary drainage of Cougar Creek and ranking according to the likelihood that landslides reach fish-bearing streams and expected abundance of large wood and boulders in the contributing stream segment.

A Stream Segment Number	B Empties directly into fish-bearing stream?	C Greater than 20% gradient on downstream end?	D Confluence angle less than 70 degrees?	E Landslide deposit in fish-bearing stream?	F Percent length bordered by slopes greater than 70%?	G Priority for retaining trees for wood delivery to stream*
1	Yes	Yes	No	Yes	10	Mod. high
2	Yes	Yes	No	Yes	0	Mod. high
3	No	Yes	No	No	60	Low
4	No	Yes	Yes	No	40	Low
5	No	Yes	Yes	No	30	Low
6	No	No	Yes	No	0	Low
6.1	No	Yes	N.A.	No	0	Low
6.2	No	Yes	Yes	No	70	Low
7	No	Yes	Yes	No	70	Low
8	No	Yes	Yes	No	60	Low
9	Yes	Yes	Yes	Yes	10	Mod.
9.1	Yes	Yes	N.A.	Yes	100	High
9.2	Yes	Yes	Yes	Yes	100	High
10	Yes	Yes	Yes	Yes	100	High
11	Yes	Yes	Yes	Yes	80	High
12	Yes	Yes	No	Yes	90	High
13	Yes	Yes	No	Yes	90	High
14	Yes	Yes	No	Yes	90	High

N.A. = not applicable.
* Priority rating system (Column G):

High: Column E = Yes and Column F ≥ 70%.
Moderately high: Column E = Yes and Column F between 30% - 70%.
Moderate: Column E = Yes and Column F ≤ 30%.
Low: Column E = No.

Figure 7-25. Stream segments and draws for a tributary of Cougar Creek with information needed to prioritize draws according to the likelihood of landslides reaching fish-bearing stream segments and the relative amount of large wood and boulders likely to accumulate.



The gradient of the main channel increases with increasing upstream distance and reaches 8% about 100 feet downstream of the junction with stream segment 3. This is the point where landslides originating from stream segments #3 through #8 would be expected to stop, which is about 400 feet short of the downstream fish-bearing segment.

Landslides within segments #1-2 and #9-14 would be expected to reach fish-bearing streams in this drainage. The two segments draining from the north (#1-2) would be considered lower priority than those draining from the south (#9-14) because not much of their length is bordered by steep slopes. Segments draining from the south have at least 80% of their lengths bordered by side slopes of 70% or greater, and therefore rated as higher priority.

ANALYSIS

Current and Future Riparian Conditions

Currently, hardwood-dominated stands are common along fish-bearing streams of the Forest and are likely more widespread now than in the past. While hardwood trees growing next to streams provide abundant shade, nitrogen-rich leaf litter to the aquatic environment, and some structure to the stream channel when trees tip over, the ability of these stands to create the volume of large wood sufficient to match historical levels is very limited. The above modeling reveals that within 200 years, a typical hardwood-dominated stand is expected to result in a large wood volume only one-tenth of what a conifer-dominated riparian stand is expected to produce. Furthermore, the large wood volume in streams surrounded by hardwood-dominated stands is predicted to decline to about one-half the current Forest-wide average within 200 years.

Reasons that hardwood trees are currently abundant along Forest streams include: (1) insufficient control of brush and animals to ensure conifer tree survival in the portion of harvest units closest to streams; (2) natural establishment of hardwoods in areas cleared for roads along streams (most built decades ago); and (3) scouring of streamside areas by landslides. Streamside areas most dominated by conifers today are those that were harvested to the edge of the stream 20-35 years ago, followed by intensive control of mountain beaver and brush near streams.

During the last 15 years, buffer strips of trees have been routinely retained along fish-bearing streams in the Forest. More conifers have been retained in recent buffers (0-7 years ago) than in older buffers. Recent buffers commonly extend 100-150 feet on each side of the stream, which is the zone that contributes nearly all wood to streams. Conifer regeneration in clearcut areas at the edge of buffers is usually very sparse since a no-spray zone is usually maintained next to buffers when herbicides are aerially applied. Conifer regeneration within a buffer is rare since the surrounding clearcut area allows side light to penetrate the buffer, which triggers the development of a dense understory. Consequently, only those trees retained in the buffers at time of harvest are a source of wood to streams for the next several centuries.

Currently, wood volume in Forest streams with an active channel width less than 40 feet averages 28% of the wood volume in nearby reference streams bordered by 88- to 118-year-old timber, and 14% of the wood volume in those reference streams bordered by old-growth timber. This severe scarcity of wood can be attributed to intentional removal of wood from streams during the 1960s and 1970s, removal of streamside trees in areas harvested more than 15 years ago, and the regeneration of hardwoods in streamside areas that once supported conifers. The largest streams on the Forest (West Fork Millicoma River and Mill Creek) have only token amounts of large wood, except where it has been intentionally added to improve fish habitat.

Streamside Forest Management and Future Conditions

Modeling results indicate that trees growing more than 150 feet from streams rarely contribute wood to streams. Therefore, widening buffers along streams to distances of 200 feet or beyond does little to increase the large wood budget of streams. Nevertheless, extra conifers retained along the outer edges of buffers are a relatively inexpensive source of wood when logs are intentionally placed in the stream at a later time. This applies mainly to streams along roads when a small cable yarder is used to pull the logs downstream into the channel.

Retaining narrow rather than wide buffers of hardwood-dominated timber along streams, combined with intensive conifer regeneration in cleared areas nearest the stream, is a potential tool for increasing the long-term abundance of wood in Forest streams. Modeling results show that by retaining only a 50-foot-wide buffer of hardwoods along streams and establishing a conifer/hardwood stand in the cleared areas results in a 10-fold increase in large wood 300 years in the future as compared to retaining a wide hardwood-dominated buffer. The one difficulty with this strategy is the cost and diligence involved in establishing conifers near buffers. For adequate conifer regeneration, aerial applications of herbicides would be needed up to the boundary of the buffer or expensive backpack spraying would be needed near buffers. Furthermore, intensive control of mountain beaver (trapping) and elk browsing (planting tall seedlings and using protective tubes) would be needed. Discussions with regeneration foresters working for the Forest indicate that these extra measures could easily cost twice that of establishing conifers elsewhere within harvest units.

The intentional placement of conifer logs within streams during harvest of adjacent areas or placement at later times also is a promising tool for increasing wood in streams, especially for the short-term. Large wood has been placed in a number of streams throughout the Forest during the last decade (see Chapter 8, *Aquatic Organisms and Their Habitat*); with the recent emphasis on placing long logs that are naturally stable in the channel during high flows, most have been successful at creating high quality fish habitat. Modeling results indicate that streams bordered by 70-year-old stands dominated by conifers have the least need for supplemental wood placement and wood volume will steadily increase over time, reaching 800 cubic feet per 100 feet within the next 200 years. Conifer/hardwood stands would need 290 cubic feet per 100 feet of wood added to streams at year 0 in order to maintain a goal of twice the current Forest-wide average over the long term. In order to meet this same goal, streams bordered by hardwood-dominated stands would require a wood addition of 850 cubic feet per 100 feet every 70 years for perpetuity. Obviously without the contributions of large wood from surrounding conifers, supplemented by wood from landslides, intentional wood placement would be a very expensive option for maintaining desired levels of large wood for the 161 miles of fish-bearing stream on the Forest.

Large Wood from Steep Draws

A general lack of information on the amount of wood that accumulates in steep draws, and the mechanisms for wood delivery to streams by landslides, prevented the analysis team from providing much information on this topic. Results from the 1996 ODF landslide study (Robison et al. 1999) indicate that landslides contributed minimal amounts of large wood to streams during the 1996 storms. Whether this was due to a general lack of large wood in the draws studied or the result of much of the wood floating far downstream during the high water (or both) is unknown. More site-specific information on wood loads within draws on the Forest is needed to complete the picture.

The analysis team developed a procedure for isolating those draws within planning areas that are most likely to contribute sizable amounts of large wood to fish-bearing streams when landslides occur. The method requires information on slope steepness, channel gradient, and the angle at which two draws or streams intersect.

Recommended Actions and Monitoring

Current and Future Riparian Conditions

The analysis team has no recommended actions on the topic of current and future riparian conditions. The team does recommend that the ODF examine the consistency of the fish habitat condition surveys for the Forest being conducted by the ODFW. The analysis team found large differences in large wood volumes reported within surveys on a number of stream reaches for which two surveys took place within a year or so of each other. Differences in estimating methods among crews are a probable source of error.

Streamside Forest Management and Future Conditions

Forest staff currently does not conduct tree regeneration surveys within harvest units near streams separately from surveys of entire harvest units. Lack of information on conifer regeneration success near streamside buffers, along with the likely success and cost of enhanced conifer regeneration techniques, prevents staff from evaluating scenarios for buffer widths and conifer regeneration in streamside areas now dominated by hardwood trees. Pilot projects on selected harvest units demonstrating the use of alternative conifer regeneration techniques near streams also may be helpful to staff.

Large Wood from Steep Draws

Information is lacking on the abundance of large wood typically found in steep draws surrounded by stands of various ages and management histories. Casual observation of a number of draws by the analysis team suggests that past timber harvest has resulted in a marked reduction in wood. Managing the landscape to provide enough current and future large wood within draws so that future landslides can resupply streams with large wood over time requires some understanding of how wood accumulates in draws over time and of the current wood deficit. In 2001, the ODF contracted with a consultant to create a study plan for acquiring this information through field sampling. The analysis team recommends that the study be conducted so that the information is available for future decision-making on the layout of proposed harvest units and the amount of tree retention along draws.