2006

LOLO NATIONAL FOREST

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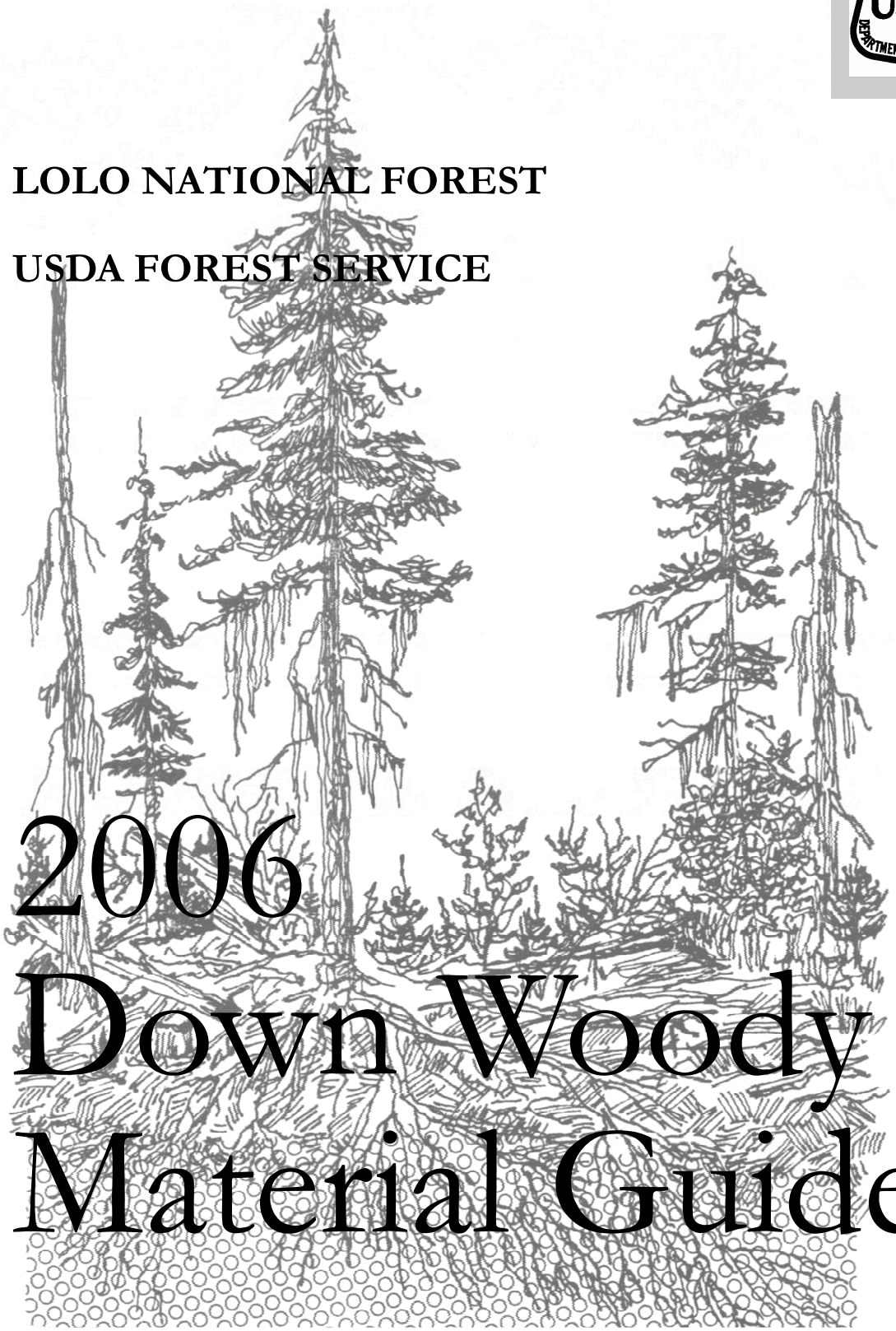

2006 Down Woody Material Guide

LOLO NATIONAL FOREST

Down Woody Material Guide

2006

Revision prepared by:

Cathy Stewart, fire ecologist
Vick Applegate, silviculturist
Brian Riggers, fisheries biologist
John Casselli, watershed forester
Barb Beckes, forest planner/reviewer
Carol Evans, illustrator

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Chapter 1

Introduction

Woody Material as a Resource

Woody material is defined as the woody remains of trees and shrubs scattered on the forest floor. The term is used in this paper with the word *resource* as a reminder that woody material is something useful and necessary. Woody material has also been termed *dead & downed material, decayed wood,* and *coarse woody material*. The Society of American Foresters (1998) defines it as

> "… any piece(s) of dead woody material, *e.g.*, dead boles, limbs, and large root masses, on the ground in forest stands or in streams. Synonyms are large woody debris (LWD), large organic debris (LOD) and down woody debris (DWD) and the type and size of material designated as coarse woody material varies among classification systems."

In 1978, the Lolo National Forest published wildlife and fisheries management guidelines that included woody material (Munther et.al. 1978) which were updated in 1997 (Lolo NF 1997). In 1981 and 1985, scarification guidelines were published to direct activities that in part manage the woody material resource (Barndt et.al.). In 1988, the Coarse Woody Debris Guide was first written, and was revised and updated in 1989, 1991, 1992, and in 1996. Since then, new ideas and methods have emerged, such as technologically advanced harvest systems, increased utilization practices, a perceived need to assume more risk managing fuel hazards, as well as knowledge about the biological significance of woody material, biodiversity and maintaining ecosystem functions.

Purpose & Objectives

A great deal is currently understood about the importance of woody material in our ecosystems and the long-term effects of its absence. The purpose of this paper is to better integrate our current knowledge of woody material resource into land management practices on the forest.

Specifically, the objectives are to:

- Improve our understanding of how significant the woody material resource is to forest productivity and ecosystem stability;
- Insure that vegetation treatments end up with adequate amounts of post-harvest woody material; and
- Improve the woody material resource guidelines.

Relationship to the Forest Plan

Woody material is directly related to four of the eight Lolo Forest Plan (USDA FS, Lolo NF 1986) goals and is further discussed in the forest plan section about desired future conditions.

1. *"Provide a sustained yield of timber and other outputs…"*

   Soil and timber productivity both depend on the amount of woody material incorporated over time into the forest soil.

2. *"Provide habitat for viable populations of all indigenous wildlife species…"*

   Many Lolo species depend on woody material as their primary habitat.

3. *"Provide a pleasing and healthy environment, including clear air, clean water, and diverse ecosystems."*

   Diverse ecosystems contain many different processes, and woody material drives many of them.

4. *"Emphasize the conservation of energy resources."*

   Wise use of woody material as fuel, timber and wildlife habitat is necessary for sustaining the energy needs of ecosystems.

Woody material is also listed in several of the Lolo Forest Plan Standards. Examples include:

- #13. Sufficient amounts of woody debris will be left to maintain soil fertility.
- #25. In portions of the Forest more than 200 feet from all system roads, sufficient snags and dead debris will be provided to maintain 80 percent of the populations of snag-using species found in an unmanaged forest. See Appendix C of this document, which is Appendix N of the 1986 Lolo Forest Plan, *Procedures to Implement the Forest Snag Standard.* This is how we attempt to meet this standard.
- #20 of Management Area (MA) 16 and other timber suitable MAs, contain this wording: *"Dead and down trees may be salvaged as constrained by habitat needs for cavity nesting wildlife species."*

These forest plan goals and standards reinforce that the Lolo recognizes the importance of woody material as a resource. They emphasize the need to manage woody material to benefit a multitude of resources.

Landscape & Stand Management Relationships

Woody material retention should be considered at multiple spatial scales and in relation to overarching resource objectives. Some woody material is needed on all forested acres for soil productivity, but for other resources, woody material is better if distributed over only portions of the landscape. For instance, concentrations of large woody material are desirable as habitat for wide ranging fur-bearers, but in other places, little downed woody material is desirable adjacent to scenic corridors or in areas of high fire risk.

- *Landscape assessments* consider historical conditions and processes. They compare historic conditions and existing conditions with desired future conditions.
- *Stand management* deals with the specifics of a site to work toward the desired conditions for the landscape as a whole.

National Policy

The *National Fire Plan* directed the Secretaries of Agriculture and the Interior to develop a strategy to respond to severe wildland fires, to reduce their impacts on rural communities, and to assure sufficient firefighting capacity in the future. It told federal agencies to take action to reduce immediate hazards to communities in the wildland-urban interface area. Specifically it called for hazardous fuel reduction, expanding the treatment of overly dense forest vegetation through a variety of methods, reducing the level of fire risk and maintaining acceptable levels of risk, with a focus on wildland-urban interface areas.

The *Healthy Forest Restoration Act* directs the Secretaries to conduct hazardous fuels reduction projects aimed at protecting communities, watersheds, and certain other at-risk lands from catastrophic wildfire, to enhance efforts to protect watersheds and address threats to forest and rangeland health (including catastrophic wildfire) across the landscape, and for other purposes. This direction has the potential to mandate treating some sites outside the range of historic variability for woody material levels. In all cases, woody material potentially would be affected.

Ecosystem Classification

Woody material management is often based on ecological classification systems. Habitat types (Pfister & others 1977) classify ecosystems based on successional development and productivity, both of which affect woody material. Habitat types were further grouped into fire groups by Fischer and Bradley (1987) and Davis & others (1980) to reflect how ecosystems affect and respond to fire. For analysis, vegetation is currently grouped into five broad *Vegetation Response Units,* or VRUs, by a combination of habitat types of similar vegetative components, productivity and fire groups of similar fire regimes (fire frequency and severity) (Fischer and Bradley 1987). Plant communities within a given VRU respond similarly to disturbances and have similar ecological functions and environmental conditions. The relationship of these groups is shown in Table 1.

Table 1. VRU cross-over table

Lolo habitat type group	Habitat type description	Fire group	Fire group description	R1 snag VRU
0	Non-forest	0	Misc. special habitats	
1	Warm & dry	2	Warm/dry PP habitats	1 (110-230, 320-370) Warm Dry PP, DF
2	Moderately warm & dry	4	Warm/dry DF habitats	2 & 3 (250-319, 505, 506) Cool DF, warm GF
3	Moderately cool & dry	5 6	Cool/dry DF habitats Moist DF habitats	2 & 3 (250-319, 505, 506) Cool DF, warm GF
4d	Moderately cool & somewhat wet	6 11	Moist DF habitats Warm/moist GF, C, WH habitats	4 (410-480, 510-529, 565-674) Cool, wet dry ES, GF, WH&SAF

Lolo habitat type group	Habitat type description	Fire group	Fire group description	R1 snag VRU
4b 4c	Cool/moist Very wet	9	Moist lower SAF habitats	4 (410-480, 510-529, 565-674) Cool, wet dry Sp, GF,WH&SAF
4a	Warm/moist	11	Warm/moist GF, C, WH habitats	4 & 5 (410-480, 510-529, 565-674) Cool, wet dry Sp, GF, H, SAF (530-560) Low elev C, WH
5	Cool & moderately wet	7 8	Cool, LP-dominated habitats Dry/lower SAF habitats	6 & 4 (675-790, 920, 930, 940, 950) High elev S, SAF, LP
6	Cold	10	Cold/moist upper SAF & timberline habitats	7 (810-871, 91, 910, 92) WBP, Limber Pine

Fire groups relate to the National Fire Regimes (Hann & others 2003, Schmidt & others 2000) as listed below in Table 2. Fire Regime II is minimally present on the Lolo National Forest; discussion will involve primarily regimes I, III, IV and V. See Chapter 2 for more discussion on fire regimes and related condition classes.

Table 2. Historic natural fire regimes and fire groups (Hann & others 2003)

Lolo VRU	Fire regime	Frequency (fire return interval)	Severity	Fire groups
2	I	0-35 years - High frequency	Low	2 & 4
	II	0-35 years - High frequency	Stand replacement	Minimal presence on Lolo
2	III	35-100+ years - Moderate freq	Mixed	5 & 6, some 10
3 & 4	IV	35-100+ years - Moderate freq	Stand replacement	7, 8, 9 & 11
5	V	More than 200 years - Low freq	Stand replacement	10

The National Fire Regimes were created as part of the *Cohesive Strategy*. The Cohesive Strategy report of 2000 responded to Congressional direction to provide a strategic plan to reduce wildfire risk, to restore and maintain health in fire-adapted ecosystems, to improve the resilience and sustainability of forests and grasslands at risk, to conserve species and biodiversity, to reduce wildfire costs, losses and damages, and to better ensure public and firefighter safety. All aspects can affect woody material. Fire regimes and fire groups will be referenced throughout this document as a way to classify systems based on their productivity and fire disturbance history – both reflect coarse woody material.

Chapter 2

Distribution & Dynamics of Woody Material

Woody Material Accumulation & Decay

Although the physical, chemical and biological effects of decaying wood are complex and often subtle, a basic understanding and appreciation of wood decay is essential to sound forest management. An indication of long-term stability and site quality following treatment can be evaluated by measuring the amount and distribution of woody material available for cycling through later rotations or treatments.

Residue accumulates as trees self-prune, become infected or damaged, and die. As trees die, become snags and eventually fall to the forest floor, they go through decay processes that cycle the nutrients bound up in them. Harvey & others (1981) found a lag of about 100 to 300 years between the time wood is produced and when it becomes incorporated again into the soil's organic mantle. Woody material of various sizes and stages of decay is an important ecological component of the forest biota. It significantly influences microclimate, and affects mineral and nutrient cycling, microbial habitat, nitrogen fixing, fungal distribution, stream stability, fire potential and wildlife habitat. Throughout these processes, logs fill important functional roles.

Decay varies considerably between stands, both in process and over time. On drier sites, fire may be a more frequent cycling agent. Fire compresses the oxidation action of decay into a very short time span (Harvey & others 1976). On wetter sites, micro-organisms, fungi and insects are the primary agents interacting to break down and cycle woody material in between longer fire cycles. Throughout decomposition, many vertebrate and invertebrate species use woody material to fill a variety of habitat requirements. These species may further accelerate decay, either directly or indirectly.

Generally, logs remain intact longer in streams than on land. In the Northwest, dendro-chronology dating estimates logs submerged in water have remained intact for more than 100 years (Harmon 1986). On land, logs begin to fragment in times ranging from a few years to a couple of decades. Generally larger pieces decay more slowly than smaller pieces, although exceptions do exist.

Because biomass accumulates and decays relative to the growth potential and the climatic influences of a site, habitat types provide a way to describe or categorize the woody material resource that reflects site variability. While data specific to the Lolo NF is lacking, a wide sampling of woody material through fuel profiles for the Northern Region is available through the Photo Fuel Guides (Fisher 1981a-d). Fuel loads can be arranged by habitat type groups or VRU – see Table 3.

Table 3. Distribution of fuel loading by habitat group

VRU	Habitat group	Frequency on Lolo	Samples	Avg LT 3"	Avg GT 3"	Total range	Total average
1	0	9.42%	0	---	---	---	
2	1	2.27%	2	2.1 tons/ac	3.1 tons/ac	3.8-6.6"	5.2"
2	2	17.31%	24	3.6 tons/ac	8.9 tons/ac	1.4-32.3"	12.5"
2	3	17.73%	9	5.1 tons/ac	14.5 tons/ac	7.8-33.3"	19.6"
3	4	28.07%	28	6.1 tons/ac	27.0 tons/ac	6.5-62.8"	33.1"
4	5	19.61%	5	6.1 tons/ac	7.7 tons/ac	3.5-23.9"	13.8"
5	6	6.22%	0	---	---	---	---

Data from stands not recently disturbed, in tons/acre (Fisher 1981)

A similar description focusing on duff depth can be made using other data available from Fisher's Photo Fuel Guides, as below.

Table 4. Distribution of duff depth by habitat group

VRU	Fire group	Habitat group	# Observations	Range	Average
1	0	0	0	---	---
2	2	1	2	0.6-0.9"	0.75"
2	4	2	25	0.3-2.7"	1.79"
2	6	3	10	1.1-3.0"	2.05"
3	9, 11	4	53	0.9-4.9"	2.68"
4	7, 8	5	21	0.5-4.6"	2.00"
5	10	6	0	---	---

Data from stands not recently disturbed (Fisher 1981)

The above tables confirm what is intuitively assumed: On warm dry sites, total fuel loading and duff depth is limited by the relative lack of total available biomass. Historically, loadings were maintained at low levels by frequent ground fires.

The highest fuel loadings and duff depths are associated with the most productive habitat types, such as the moderately-cool-and-moist habitat group 4. As sites become progressively cooler and drier (habitat

groups 5 and 6), climatic and edaphic features again limit the total biomass produced, and subsequently limit the dead and down material available to be recruited. This is at the extreme in the cold, upper elevations of whitebark pine communities.

Habitat type also has a major influence on decay processes and their effect on woody material accumulation (Harvey & others 1981): Cooler climate slows the decay process and results in high rates of biomass accumulation during long intervals between fires.

Samples of fuel loadings for the fire groups in western Montana are summarized in Table 5. These are averages from stands measured by Fischer and Bradley (1987) and provide more information. Table 6 has fuel loads for the Bitterroot and Lolo National Forests from Brown and See (1981). These quantities probably reflect the high end of pre-settlement fuel levels because reduced fire frequencies and associated fuel consumption have resulted in higher than historic levels (Brown & others 2003).

Table 5. Average fuel loadings in tons per acre for all fire groups

VRU	Fire group	Duff depth	Size Class (inches)							
			0 - .25”	.25 - 1”	1 - 3”	3 - 6”	6 - 10”	10 - 20”	20+”	Total
2	2	.12	1.40	2.40	2.72	1.15	1.05	8.79		17.63
2	4	---	0.68	1.48	2.56	2.13	2.35	2.56	0.93	12.06
2	6	1.97	0.48	1.39	2.28	2.98	6.83	6.18	3.05	25.16
4	7	---	0.70	0.90	3.80	5.83	1.38	1.58	5.53	19.72
4	8	2.37	0.44	1.61	2.80	7.18	16.12	5.04	1.64	37.20
3	9	2.50	0.47	1.64	2.95	5.53	8.83	11.14	2.12	35.18
5	10	0.17	0.53	0.57	1.00	4.10	6.23	2.30	14.60	29.5
3	11	3.01	0.50	1.58	2.09	3.58	6.17	5.71	3.86	26.5

From Fischer and Bradley 1987

Table 6. Average quantities in tons per acre of large woody fuel

Survey type	Bitterroot NF			Lolo NF		
	PP	DF	LP	PP	DF	LP
Forest surveys	5.3	9.2	12.2	4.8	11.5	13.3
# Plots	218	1,056	203	120	1,000	768
Stand exams	11.3	21.1	25.9	10.4	11.9	15.8
# Plots	1,685	7,158	1,152	665	4,233	1,591

Data from the Bitterroot and Lolo NFs inventoried by forest survey & stand exam programs (Brown and See 1981).

Disturbance Agents & Woody Material Dynamics

The primary disturbance agents common in historic periods, that is before European settlement and fire control, were wildfire, pathogens and insect attack. Other agents, such as wind and snow storms, also contributed to woody material accumulations by adding dead trees and consumption (recycling).

Table 7. Fire regime groups

Group	Frequency	Severity
I	0-35 years	Low & Mixed
II	0-35 years	Replacement
III	35-100+ years	Mixed & Low
IV	35-100+ years	Replacement
V	200+ years	Replacement & other fires occurring within this frequency range

Fire Regime Groups are a categorization of historical fire regimes to describe the frequency and intensity of fires, taken from National Fire Regime Condition Class methods and based on Heinselman 1978.

Table 8. Fire severity

Severity class	Effects
No fire effects	Less than 5% replacement (may not be lethal) or surface fire
Surface or low	Less than 25% replacement Surface – Greater than 50% surface burned Low – Less than 50% surface burned
Mixed	Greater than 5% replacement or surface & less than 75% replacement (burns surface fuels and occasionally torch individual or patches of overstory trees)
Replacement	Greater than 75% replacement (burn through the overstory and constitute stand replacement with high mortality in trees, replacement in shrubs or grasses)

For FRCC methodology (www.frcc.gov), *fire severity* is the effect of fire within the fire perimeter of replacing/removing the upper layer vegetation and burning the surface. Replacement/removal may or may not cause a lethal effect on the plants. For example, replacement fire in grassland removes the leaves, but leaves resprout from the basal crown, whereas replacement fire in most conifers causes mortality of the plant. A fire must affect 5 percent or more of the fire perimeter to be counted. Table 2 shows how the Lolo NF generally fits into these broad National Fire Regimes.

Regime I - Frequency is from 0-35 years and low (surface fires most common) to mixed severity (less than 75 percent of the dominant overstory vegetation replaced). These low-intensity fires result in periodic underburning where few overstory trees are killed. This regime mainly includes Fire Groups 2 and 4, which correlates with Lolo habitat type groups 0, 1 & 2. *Low severity* or *cool fires* have minimal impact on the site consuming mainly herbaceous fuels, litter and twigs. They yield light and periodic

woody material recruitment over time. These fires also consume existing woody material under dry conditions.

Regime III - Frequency is from 35-100+ years and *mixed severity* (less than 75 percent of the dominant overstory vegetation replaced). This results in some underburning mixed with stand or patch replacement, where partial mortality occurs or patches of trees are killed. This regime mainly includes Fire Groups 5, 6 and some 10, or Lolo habitat groups 3 and 6. The mixed severity or moderate fires yield pulses of woody material in combinations like those described above. They burn in surface fuels and consume litter, upper duff and understory vegetation; individual or groups of overstory trees may torch out if ladder fuels exist. An understanding of this historic pulsing role of woody material is an important consideration for resource management.

Regime IV - Frequency is from 35-100+ years and high (stand replacement) severity where more than 75 percent of the dominant overstory vegetation is replaced. This includes Fire Groups 7, 8, 9, 11 and some 10, or Lolo habitat group 5 and parts of 4. *High severity fires* burn through the overstory and can consume large woody surface fuel or the duff layer. They can yield a great pulse of woody material lasting decades. Occasionally, as dead fire-killed trees fall, another high intensity fire (a *reburn*) will result, consuming large quantities of these fallen trees. More discussion of the implication of high fire pulses on fire severity is found in Chapter 4.

Regime V - 200+ year frequency and high severity (stand replacement where more than 75 percent of the dominant overstory vegetation is replaced). This regime includes Fire Groups 10 and some 9 and 11, or Lolo habitat group 6 and part of 4. *High severity fires* burn through the overstory and can consume large woody surface fuel or the duff layer. They can yield a great pulse of woody material lasting decades. A reburn can occur consuming large quantities of these fallen trees. More discussion of the implication of high fire pulses on fire severity is found in Chapter 4.

Fire Regime Condition Class is a classification of the amount of departure at a given time from the ecological reference conditions that typically result in alterations of native ecosystem components. The ecosystem components include attributes such as species composition, structural stage, stand age, canopy closure and fuel loadings. Historical conditions are commonly used as a best estimate for the reference conditions. It was assumed to include native anthropogenic influences that may have contributed to development of native species fire adaptations. One or more of the following activities may have caused departures: fire suppression, timber harvesting, livestock grazing, introduction and establishment of exotic plant species, introduced insects or diseases, or other management activities. There are field methods to classify stands into Fire Regime Condition Classes available at www.frcc.gov. There are three classes:

1. Fire regimes are within the *natural or historical range* and risk of losing key ecosystem components is low. Vegetation attributes, such as composition and structure, are intact and functioning.
2. Fire regimes have been *moderately altered*. Risk of losing key ecosystem components is moderate. Fire frequencies may have departed by one or more return intervals, either increased or decreased. This may result in moderate changes in fire and vegetation attributes.
3. Fire regimes have been *substantially altered*. Risk of losing key ecosystem components is high. Fire frequencies may have departed by multiple return intervals. This may result in dramatic changes in fire size, intensity and severity, and landscape patterns. Vegetation attributes have been substantially altered.

Post-Fire Fuel Loads on the Lolo NF

Results of plot sampling done (with photo field guides) in the 2000 Ninemile and Flat Creek Fires are displayed in Table 9, below. The plot estimates of tons-per-acre of fuel loads were averaged for fire groups by severity. Not all fire groups were sampled. Most stands had highly variable fuel loads and burn severities. Low severity was 1 to 20 percent mortality of the overstory trees, moderate 20 to 60, moderately high 60 to 90, and high 90+ percent mortality. When compared to averages measured by Fischer and Bradley, shown in Table 5, one can see that post-fire fuels are currently much lower, especially in the smaller size classes. These results support the general observations of field personnel that fuels, especially in the less than 3-inch size class, were reduced in burned areas. With low levels of fine fuels, the probability that fire will start and spread is low in the short term. This will be a temporary situation, until standing dead trees begin to fall down during the next 10 to 30 years and fine fuels develop again with vegetative growth.

Table 9. Post-burn fuel loads by fire severity from Lolo 2000 burn data (tons/acre)

Fire Group	Severity	0 - .25"	.25" – 1"	1" - 3"	3" +	Total
4	Low	0.1	0.3	0.2	1.4	2.0
4	Mod	0.2	0.2	0.3	2.0	2.7
4	Mod/High	0.1	0.4	0.3	11.6	12.4
4	High	0.1	0.1	0.1	1.8	2.1
6	Low	0.1	0.2	0.4	6.5	7.2
6	Mod/High	0.2	0.2	0.3	7.3	7.9
6	High	0.1	0.1	0.1	2.0	2.3
7	Mod/High	0.2	0.1	0.2	8.0	8.5
7	High	0.1	0.1	0.1	8.0	8.3
8	Mod	0.2	0.2	0.2	5.0	5.6
8	Mod/High	0.1	0.2	0.2	8.8	9.3
8	Unburned	0.5	0.4	0.3	12.8	14.0
9	High	0.0	0.0	0.0	0.3	0.4
11	Low	0.0	0.0	0.0	0.0	0.0
11	Mod	0.3	0.5	1.0	8.0	9.8
11	High	0.1	0.1	0.2	7.0	7.5

Snag Fall Rates

After a moderate to severe fire, snags begin to fall. The majority will be on the ground in 10 to 30 years. A study on the Wenatchee National Forest in eastern Washington (Hadfield and Magelssen 2000) rated snag durability (based on number of snags standing intact) by species group as follows:

- Most durable: western larch, subalpine fir, lodgepole pine, Engelmann spruce
- Moderately durable: Douglas-fir
- Least durable: ponderosa pine, grand fir

Table 10 shows snag fall rates.

Lyon (1977) measured annual fall rates of different size classes of lodgepole pine for 13 years following a fire on the Bitterroot National Forest in Montana. Snags less than 3 inches dbh fell at the highest rate. Snags over 3 inches dbh fell at an average of 8 percent per year, with a marked distinction in that snags over 8 inches dbh fell at a much more sporadic rate as opposed to the relatively constant rate of snags less than 8 inches dbh. Most trees were projected to be down by 40 years after the fire.

Harrington (1996) found that young ponderosa pine (80 to 95 years old) 2 to 16 inches in diameter with greater than 80 percent crown scorch had an 80 percent probability of falling within 10 years on the San Juan National Forest in southwestern Colorado. Trees with less than 80 percent crown scorch had a 75 percent probability of falling if they died within one year of a fire, but only 27 percent probability of falling if they lived 2 or 3 years after the fire.

Older ponderosa pine snags (greater than 200 years) are known to remain standing longer than 10 years after fire (Smith 1999).

Table 10. Snag decay and fall rates

Species	Snag Decay Five Years After Fire[1]			Other Studies – Snag Fall Rate	
	Percent of Sawlog Size Trees That:				
	Fell Down	Broke Top	Lost >50% of Coarse Branches (>0.5 in dia)	Size Class	Rate
Douglas-fir	**26**	**37**	**53**		
Grand fir	**35**	**47**	**70**		
Subalpine fir	**-**	**5**	**38**		
Western larch	**-**	**7**	**27**		
Lodgepole pine	**3**	**-**	**10**	<3"dbh 3-8" dbh >8" dbh	28%/yr[2] 8%/yr 8%/yr
				Avg 12" dbh	2%/yr[2] for 17 yrs
ponderosa pine	**70**	**75**	**60**	2-16" dbh Death is: 1 yr…. 2-3 yrs…. postfire	 75-80%[3] 27% after 10 yr
Engelmann spruce	**3**	**-**	**58**	3-7" dbh >8" dbh All	0.9%/yr[2] 0.7%/yr 16% total in 25 yrs.
				>5" dbh	0.6 – 2.5% per yr for 23 yrs[2].

[1] Hadfield and Magelssen 2000
[2] Lyon 1977 and referenced studies
[3] Harrington 1997

Desirable woody material loads are listed in Chapter 6, under "Guidelines for Implementation and Fire Management."

Chapter 3

Resource & Woody Material Relationships

Soils & Nutrient Recycling

Research data suggests that woody material plays an important role in the forest ecosystem (Graham & others 1994; Harvey & others, 1987; Harvey & others 1979) and that its wholesale removal will, over time, have an adverse effect on the land (Stark 1982). Benefits of on-site course woody material include:

- Reduced soil erosion;
- Increased nutrient cycling, cation exchange capacity and storage;
- Decreased soil-air temperature on site; and
- Increased moisture storage.

Soil Erosion

Woody material helps reduce soil erosion several ways.

1. Material provides barriers that can reduce the distance water travels before being diverted or trapped, which is beneficial because:
   a) The slower the water moves, the less sediment the water can carry;
   b) The material can trap and store sediment, keeping it on site;
   c) It increases the ability for water infiltration and plant uptake from a reduction in overland flow velocities; and
   d) The traps are excellent spots for tree seedlings because they contain extra moisture and nutrients.
2. Material especially helps reduce soil erosion on skid trails and travelways, which are typically bared during harvest. It also helps reduce the effects of raindrop impact on unprotected mineral soil (Lang & others 1983). Different intensities of the same amount of rain can change the erosion rate by thousands of percents. Adequate amounts of woody material greatly reduce the effective rain intensity.
3. Logs and other woody material can store sediment and reduce sediment transport distances, especially below a road on a hillslope (Ketcheson and Megahan 1996).

Nutrient Cycling

Nutrient cycling is an important concern for forest management. Amaranthus (1992) states that protection or enhancement of organic soil components is a primary factor in maintaining long-term forest growth. Woody material, once on the ground interacts with the biotic components of soil and litter in the processes of litterfall, canopy throughfall, nitrogen fixation and nutrient uptake (Maser and Trappe 1984).

Carbon, nitrogen and the cation exchange capacity are important components of organic matter (Page-Dumroese & others 2000). The rates and quantities of nitrogen fixed in decaying woody residues are important components of the nitrogen cycle in the Intermountain regions of western North America (Larsen & others 1978). The persistence of decaying woody material allows small increments of nitrogen to accrue over many decades (Maser and Trappe 1984). In addition to nitrogen, sulfur and phosphorous are released as coarse woody material decays or is burned, providing additional soil nutrients (Graham & others 1994). Decayed wood also has a much higher cation exchange capacity than other soil components (Harvey & others 1979). If woody material is completely removed, this nutrient source is removed from the site and can affect future site productivity (Stark 1982).

The nutrients in green needles and branches (slash) are available in years 1 through 10, while the nutrients in the larger pieces are available over the long term, from 11 to 70 years. Early research suggested that up to 54 percent of the potential nutrients on a site are locked up in slash and needles that remain on-site after using conventional harvest methods (Rennie 1955). Kolb (2002) stated that research indicates up to 90 percent of nutrients incorporated in tree biomass are located in smaller-diameter structures including twigs and needles. Large downed logs may require from 20 to 200 years, depending on habitat type, to reach advanced stages of decomposition.

Whole-tree utilization procedures may lead to significant nutrient losses after many harvest removals (Boyle & others 1973, White 1974). Continuous cropping and intensive utilization can decrease site productivity (Pierovich and Smith 1973, White 1974). In ponderosa pine habitats of the Inland West, Harvey & others (1988) found that reducing compaction and managing large and small woody residue provides a good opportunity to protect and improve many forest soils.

In ecologically sensitive areas, residues, which are substrates for specific fungi, may have to be managed as intensively as the trees themselves if productivity is to be maintained (Harvey & others 1976, 1987). In the best situation for regeneration units, multi-sized pieces of woody material with patches of bare mineral soil are scattered across the site, so seeds can germinate rapidly and seedlings can readily access nutrients, moisture and mycorrhizae in decaying wood and humus (Harvey & others 1979). Ectomycorrhizae in the soil can help woody plants take up food and nutrients and are essential in forest ecosystems. Down woody material can be an indicator of ectomycorrhizae as well as associated forest soil health (Graham & others 1994).

Temperature Change

Woody material provides ground cover, helping keep the soil surface from reaching extremely high temperatures, which can cause moisture stress in plants, especially young tree seedlings. High temperatures at the soil surface increase evapotranspiration from the soil and from vegetation in the area, bringing on drought earlier than would otherwise occur (Day 1963, Day and Duffy 1963). Reduced soil temperatures reduce plant stress and increase survivability, especially in seedlings. In burned areas, surface soil temperatures can exceed 150º F. Logs that are horizontal and close to the soil surface have a greater shade and cooling effect (Kolb 2002).

Moisture Storage

Fallen trees and down woody material in various conditions of decay can provide a long-term reservoir of moisture, especially significant in times of prolonged drought or after wildfire (Amaranthus 1992). Woody material provides barriers that trap snow and increase water infiltration, increasing the amount of water available to the site and to the watershed as a whole over the course of the year. Maser and Trappe (1984) found the water content in whole fallen trees increased with time and stage of decay on the forest floor. When decaying logs are incorporated into the soil they create pockets of organic matter that can be highly permeable to water. These pockets store and transport water throughout the upper soil horizons (Harvey & others 1988). Amaranthus (1992) found that wood becomes more porous as decay advances and can retain more water, including larger amounts during the winter. As water-holding capacity increases with stage of decay, so do seasonal fluctuations in the water content of woody material.

Wildlife

Dead wood contributes to biological richness in many ways: as substrate, cavity sites, foraging sites, nesting or denning sites, food storage sites, runways and cover or shelter (Bull & others 1997). The relationships of wildlife to woody material are extremely complex, and are best explained by analyzing individual wildlife species or species groups.

Big Game

The relationship of big game to woody material is more indirect than for other species groups. Burning or regeneration timber harvest can provide forage, particularly on winter range, if openings are interspersed with adequate cover. However, benefits from logging occur only if the site receives enough stimulation or scarification to make sure forage plants respond favorably. The way logging slash and soils are handled during this process can significantly affect how deer or elk use the site after logging. Four general rules are:

1. Continuous slash greater than 1½ feet high will prevent most deer and elk from using an area regardless of the forage availability.
2. Long windrows of slash, particularly where incompletely burned, act as barriers significantly reducing the effectiveness of adjacent security cover.
3. Over-scarification significantly inhibits forage response, because existing plants are destroyed rather than stimulated. Generally, over-scarification is defined as anything in excess of 60 percent of a treatment area.
4. Female deer and elk often select large downed logs for birthing and for hiding newborn young.

Woodpeckers & Other Snag Users

This group uses everything from live cull trees to totally rotten downed logs. The dead and down is just as important to them as standing material, since it provides another spectrum of feeding opportunities – see Figure 1 on the next page. Woodpeckers and other snag-users feed primarily on insects. Studies have shown that carpenter ants are the primary prey of pileated woodpeckers. The logs they most prefer are greater than 15 inches in diameter and in advanced stages of decay (Bull & others 1997). Since invertebrates are available at different times of the year, a wide range of decay classes enhances a site's productivity for woodpeckers.

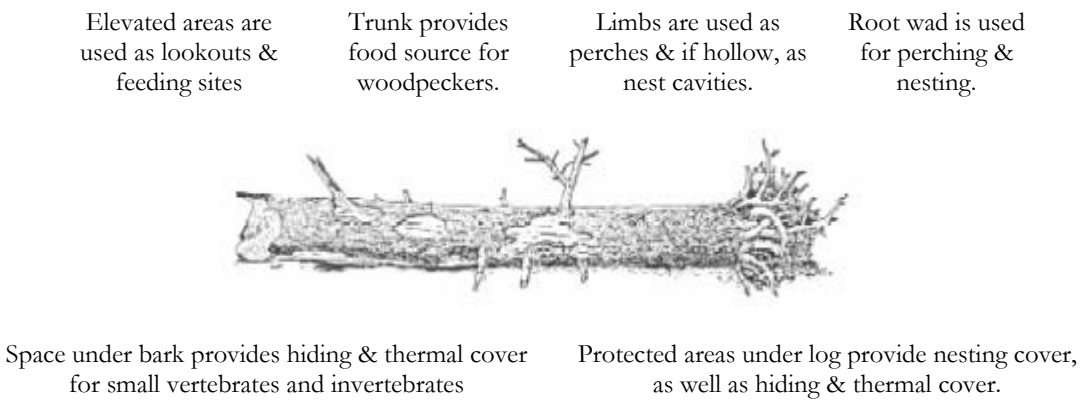

Figure 1. A log showing structural features important to wildlife

Some snag-users, like the winter wren, actually depend more on down than on standing material. The winter wren spends most of its foraging time beneath large suspended woody material.

Inappropriate salvage logging of fire-killed stands can reduce the availability of fire-killed trees and woody material, with adverse impacts on obligate species such as black-backed woodpeckers. High-intensity fires provide habitat for black-backed woodpeckers (Caton 1996, Hitchcox 1996, Hutto 1995, Hejl and McFadzen 2000). The black-backed woodpecker, like most woodpeckers, eats the beetles that come in after a fire, and creates the cavities in standing dead trees that provide homes for the mountain bluebirds (and other species)that follow. Black-backs typically move into burns in high numbers, forage, and reproduce very successfully for up to six years (Caton 1996). Where salvage logging takes place, black-backs nest at much lower densities, even when some of the fire-killed trees are retained (O'Connor and Hillis 2001, Hejl and McFadzen 2000, Hitchcox 1996).

Raptors

Suspended woody material provides accipiters (goshawks, and sharp-shinned and Cooper's hawks) with "plucking logs," where they can consume prey. Such a log provides a secure perch where prey can be handled easily, and serves as a lookout so the accipiter can avoid larger predators. Large diameter snags are important nest structures for bald eagles and osprey as well as owls such as the great grey, great horned and spotted owl. These owls may utilize cavities or hollows in broken tops for nesting.

Forest Grouse & Songbirds

Down wood can provide display or lookout posts for birds (Bunnell & others 2002) as well as cover. It's well understood how ruffed grouse depend on "drumming logs." Ground-nesting birds such as juncos, towhees, nighthawks and hermit thrushes generally select nesting sites with scattered woody material. The material provides additional security by hiding the nest from predators.

Small Mammals

Rodents and other small mammals have a complex interaction with woody material. It can provide runways, cover from predators, sunning places, look-out and food storage sites, as well as shelter for reproduction (Bunnell & others 2002). It also can be used for resting and as a substrate for food such as fungi (Bull 2002). Down wood was within 3 feet of sites where great gray owls captured prey almost 80 percent of the time (Bull & others 1997). A site with all classes of woody material decay represented and arranged in a highly diverse manner, will have the maximum number of species. Inversely, a site with no

woody material, like an over-scarified clearcut, may have the same number of individuals but only two or three species.

Figure 2 shows a diverse site, with small jackpiles hosting hares, scattered logs hosting chipmunks and shrews, and grassy areas hosting meadow mice, gophers and ground squirrels. Generally, such diversity can be achieved with from 12 to 20 tons of woody material per acre, depending on habitat type.

Figure 2. Woody material arranged by size, decay class & spatially, to provide optimal habitat and prey species diversity

A site deficient in woody material typically has less than 6 tons of material per acre, depending on habitat type. Prey species in such sites are limited to meadow mice, gophers and ground squirrels. Maguire (2002) found that species richness of taxonomic groups of small mammals, insectivores and amphibians correlated positively with the volume of woody material; richness of rodents showed no significant relationship with woody material. A site with sufficient woody material may host no more biomass of prey than a woody material-deficient site, but since more prey species are present, a site like Figure 2 would support more predator species as well. In other words, if prey species diversity becomes limited because too much woody material is removed, fewer predator species will be able to successfully exploit those prey. In the Pacific Northwest, 47 vertebrate species responded positively to down wood (Bunnell & others 2002).

Within 10 to 30 years of a stand-replacing fire, most standing dead trees fall, depending on species (Denitto & others 2000, Lyon 1977). This results in a huge concentration of down woody material. Red-backed voles occur in high densities whenever heavy concentrations of woody material occur (Pearson 1994). Red-backed voles are the primary prey for pine martens and fishers (Ruggiero & others 1994). Short-tailed weasels used piles of logging material more than areas without piles, due to greater abundance of red-backed vole (Lisgo & others 2002). In an assessment of fisher habitat in Region 1, Hillis and Lockman (2003) inferred that down woody material as a component of fisher microhabitat in mature forests at low to mid-elevations, likely is at historically normal or higher than normal levels. As with woodpeckers, salvage logging fire-killed stands might reduce the availability of fire-killed trees and woody material, with adverse impacts on these obligate species.

Too much woody material also can limit wildlife populations. Figure 3 on the next page shows an area with no scarification or slash treatment, which can lead to high populations of deer mice. The absence of the open grassy areas used by hares, meadow mice and ground squirrels limits the variety of prey species. Such sites provide little opportunity for some predators, since such an abundance of cover exists that predation can be ineffective.

Figure 3. An excess of woody material (more than 30 tons/acre) limits prey availability to predators & habitat diversity

Carnivores

Most black bear dens in the Pacific Northwest are associated with wooden structures such as trees, logs and stumps (Bunnell & others 2002). Large logs can provide cover at diurnal bed sites and natal den sites for mountain lions (Bull 2002). Wolverines, fisher and lynx utilize woody material for denning or security and thermal cover (Bull 2002, Bull & others 1997). Snow-free spaces and runways under suspended woody material provide winter habitat protection and foraging for martens, fishers and small mammals (Bull & others 1997).

Invertebrates

Woody material makes the greatest contribution to biological richness as a substrate or moist, thermally stable environment for the invertebrates, fungi, protozoa, roots and cryptograms upon which a wide variety of amphibians, reptiles, bird and mammals species depend for food (Bunnell & others 2002). The relationships between invertebrates and woody material are much like those of vertebrates, only much more complex. This "little world" has the same kinds of prey/predator/scavenger interrelationships, but at a vastly greater scale because of the numbers of species and individuals. In early stages of decay, primary and secondary bark beetles and wood borers were found to be more abundant (Koenigs & others 2002). In later stages of decay, weevils become more prevalent. Many other orders of insects, such as ants and species of diptera, followed further decay (Koenigs & others 2002). Wood is the preferred nest substrate for the majority of ant species studied in British Columbia (Lindgren and MacIsaac 2002). An excellent discussion of these multiple relationships can be found in *The Seen and Unseen World of the Fallen Tree,* by Maser and Trappe (1984).

Regeneration & Tree Growth

Woody material is important for the survival and growth of trees. Harvey (1982) described decayed wood as providing "either the environment or the energy source of microorganisms critical to the survival and growth of conifers in the relatively infertile and frequently droughty soils of the central and northern Rocky Mountains." Graham & others (1994) state that coarse woody material performs many physical,

chemical and biological functions in forest ecosystems. Many plant nutrients are released from coarse woody material during burning.

Large woody material may provide a favorable environment that enhances seedling survival by shading a seedling's root collar near the ground line where solar radiation can raise the temperatures to lethal levels. Damage and mortality can occur at temperatures higher than 130º F. A study by Dick Smith (1983) of droughty sites of the Idaho Panhandle National Forest showed heat girdling to be a leading cause of death to recently planted seedlings. Soil surface temperatures in excess of 130º F were measured on all of his study sites. A similar study on the Helena National Forest (1987) also found tree mortality occurring before soil moisture stress. Soil surface temperatures there measured in excess of 140º F. Figure 4 is a photograph of a heat-damaged seedling.

Figure 4. Heat girdling of western larch seedling – note the bole shrinkage near the root collar, where the stem necks down (just below the pencil point)

Woody material can prevent heat-induced mortality and protect young seedlings. Reforestation by natural regeneration is often the most successful on harsh sites behind the north or east sides of material or live vegetation – this can be attributed to the fact that shade reduces temperatures and helps retain moisture. Woody material also protects seedlings from wind, blowing snow, temperature extremes, trampling by animals (Graham & others 1992) and it stores water (Harvey & others 1987).

Woody material and organic matter act as mulch, retaining subsurface moisture and improving soil nutrient levels (Page-Dumroese & others 1986). More water is available and is retained longer inside down and rotten woody material, which increases tree survival and growth. Seedling roots often follow along or grow inside of buried and decaying logs, probably due to the greater concentrations of water and nutrients.

The fungus-root association, mycorrhizae, is necessary for trees to grow and survive. The fungus helps trees absorb more mineral nutrients and water. Conifer plantation failures have occurred on sites lacking this fungus (Mikola 1973). The fungus depends on decaying woody material for its survival, especially during dry periods or on dry sites (Harvey 1982, 1979). It is rational to use ectomycorrhizal activity as a primary indicator of a healthy forest soil (Graham & others 1994).

When nitrogen and other nutrients necessary for the growth and survival of trees are more available, healthier seedlings are produced. Nitrogen is usually the most limiting nutrient in our forest ecosystems (Harvey & others 1979), and woody material helps retain nitrogen on sites lacking nitrogen-producing plants.

It's possible for woody material to become detrimental to seedlings. Very high levels of woody material can impede or deform seedlings; an excess of woody material can shelter and protect animals that feed on tree seedlings. A discussion of these relationships was covered in the wildlife section, above.

Although trees can become established and grow on sites without woody material, they grow poorly and will not survive on some sites. Added to the needs of other resources, such results tell us to manage the woody material resource to insure a healthy and productive forest.

Riparian & Floodplain Habitat

The quality of water and fish habitat in aquatic systems is inseparably related to the integrity of both upland and riparian areas within watersheds (Naiman and others 2002, Berg and others 2002, Kershner 1997, Minshall and other 1997, Young 1994, Malanson and Kupfer 1993, Harmon and others 1987). In most forested riparian environments, woody material is a defining structural feature that influences water flow and stream habitat quality, and is critically important in regulating geomorphic, hydrologic, and biologic processes (Dollof and Warren 2003, Fausch and Northcote 1992, Bilby 1981, Bilby and Likens 1980). Current practices and laws largely ensure that trees in streams and along stream banks remain to provide woody material to stream channels (Lolo National Forest Plan 1986, Inland Native Fish Strategy 1995). However, as we begin to more effectively manage woody material as an ecological resource in riparian zones, we should consider areas outside the stream channel and stream banks and include the entire valley bottom landform, extending consideration to the entire area that affects and is affected by the stream network.

Timber harvest and road construction adjacent to streams has reduced the woody component from many streamside areas (Bilby and Ward 1991), and recovery is slow, taking at least 60 years after harvest before riparian areas begin to contribute wood to the stream system (Grette 1985). Often, woody material in these systems is smaller and highly mobile compared to down wood in streams from unharvested areas (Evans and others 1993, McHenry and others 1998). Within riparian habitats and floodplains, restoration and maintenance of down woody material at levels more characteristic of natural ranges is critical in providing physical and biological templates for future stream channel processes. Today, land managers are recognizing the important ecological role of woody material in these areas, and are seeking ways to leave more down wood to help reverse past trends.

The *100-year floodplain* is the area along a stream channel that is covered with water during a 100-year runoff event (FEMA 1994, Dunne and Leopold 1978). This definition provides for easy interpretation and allows for site-specific variances in the width according to local features that affect flow patterns. The 100-year floodplain can generally be identified as the first major, continuous landform slope break outside the stream bank, on either side of the channel (Figures 5 & 6). It can vary in width from less than 10 feet in small, highly confined headwaters, to more than several hundred feet in larger, unconfined valley bottoms. Because inundation of the entire 100-year floodplain is rare (by definition only a 1 percent chance in any given year), this feature may not support riparian vegetation for its entire width, so vegetative communities cannot be used to define it. Many 100-year floodplain boundaries have been mapped by the Federal Emergency Management Agency on Flood Rate Insurance Maps and are available online at http://www.fema.gov/fhm/.

The *floodplain influence zone* is an area adjacent to the 100-year floodplain that contributes woody material or products associated with woody material to the floodplain. As the stream channel migrates across the floodplain, this zone becomes important in providing trees that can fall into or influence the new channel and riparian zone (O'Connor and others 2003, Rosgen 1996, Schumm 1977). This zone usually does not

contain typical riparian vegetation, but supports more typical upland forest types (Figures 5 & 6). It can range from a relatively flat area, like an abandoned river terrace, to an extremely steep area, like a highly confined, avalanche-prone headwater reach. In steep, landslide prone areas such as the Oregon Coast Range and the Cascades, the floodplain influence zone can extend thousands of feet from the stream channel and can be responsible for 10 to over 50 percent of the woody material that reaches the floodplain and stream channel (Naiman and others 2002). However, in more stable areas where large landslides or avalanches are rare, trees growing adjacent to the floodplain and stream channel generate nearly all wood delivered to the stream (Murphy and Koski 1989). Across the Lolo National Forest, large landslides and avalanches are not common, and therefore the extent of the floodplain influence zone in most cases can be defined as a band including approximately one tree width beyond the 100 year floodplain. Identification of this area for managing coarse woody material is consistent with guidelines in INFISH (1995).

The footprint of a channel can be expressed as a percent of the total floodplain area in plan view (May 2002), and as the channel migrates, the composite of these footprints occupies an increasing percentage of the floodplain (Maser and Sedell 1994). At some point in the past, the stream channel has migrated through every part of the valley floor (Dunne and Leopold 1978). In contrast to the concept of managing woody material in stream channels and Streamside Management Zones, which depends strictly on the current location of the stream, the *floodplain influence zone* recognizes the dynamic nature of stream channels and valley bottoms as streams change location over time, as Figure 7 illustrates.

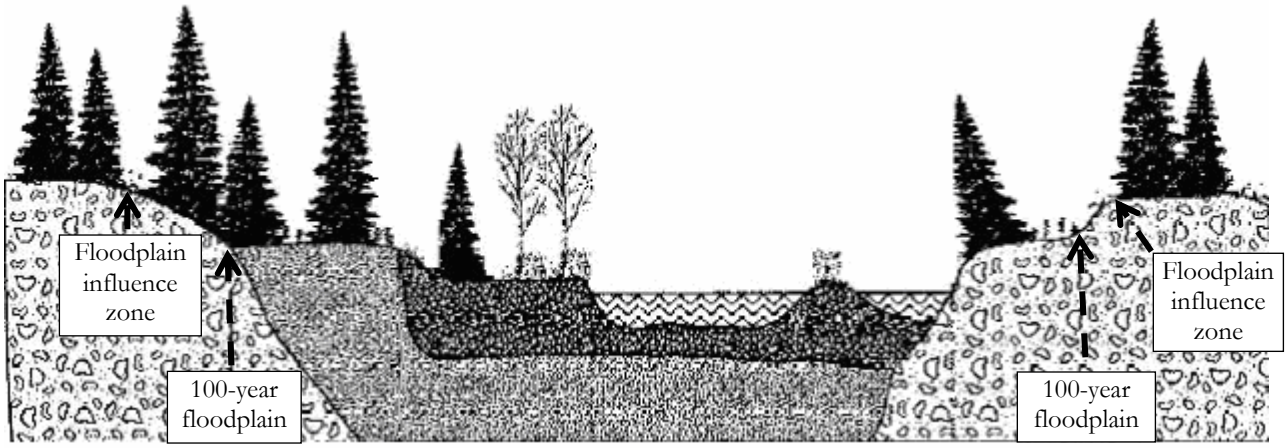

Figure 5. 100-year floodplain zone, flatter terrain. Modified illustration from Hansen, P. L., et. al., *Classification and Management of* *Montana's Riparian and Wetland Sites*, 1995

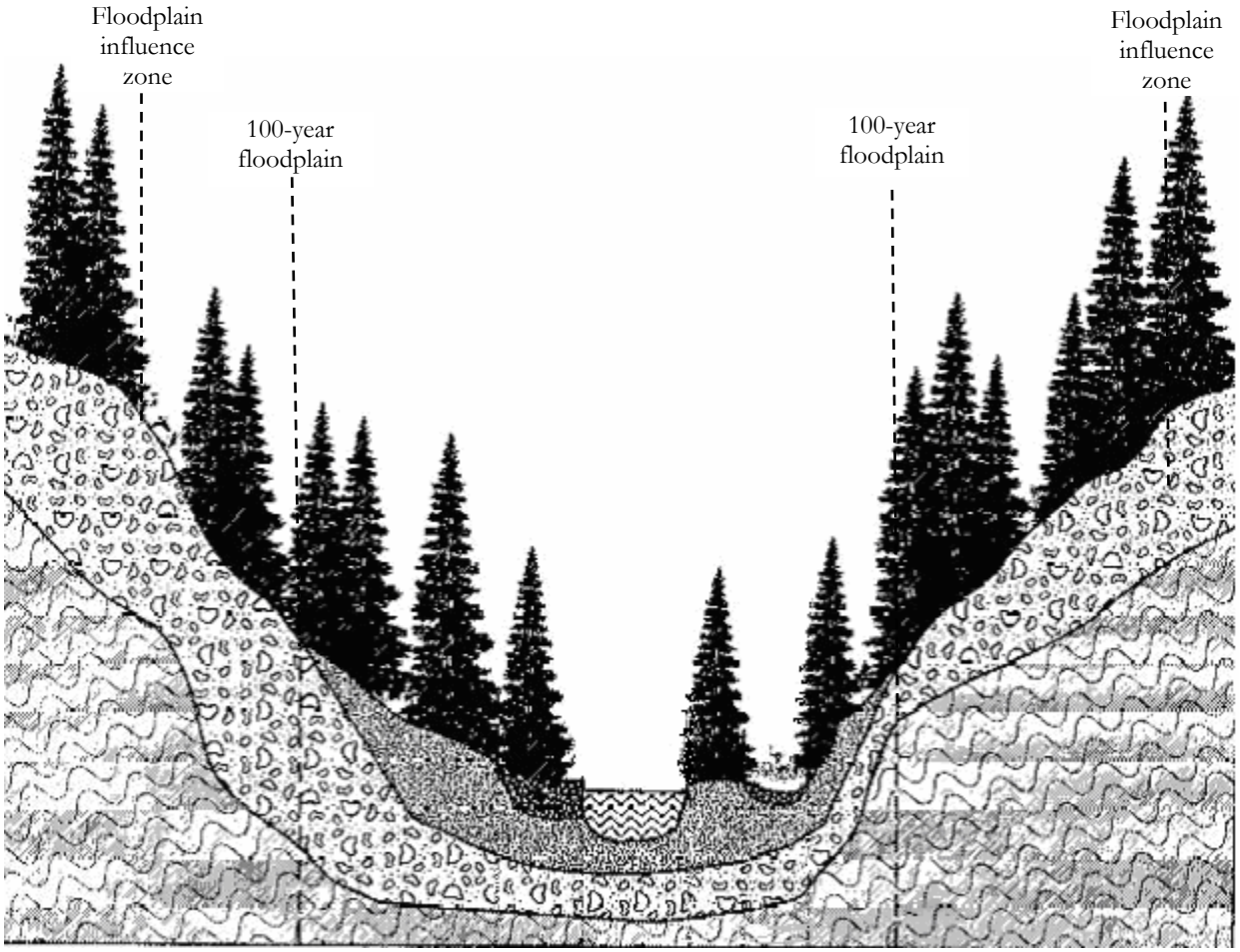

Figure 6. 100-year floodplain zone, steep mountainous terrain (note the width of approximately one tree length). Modified illustration from Hansen, P. L., et. al., *Classification and* *Management of Montana's Riparian and Wetland Sites*, 1995

Significance of Woody Material to the Aquatic Community

Woody material in the *100-year floodplain* is important for several reasons. In addition to the many ecological roles it plays on upland sites, in floodplains woody material moderates flow velocities, reduces stream bank and floodplain erosion, traps sediment by creating low velocity areas, provides structural complexity and refugia for fish, invertebrates and riparian-dependent wildlife, stores and recycles nutrients, moderates temperature and moisture fluctuations, and regulates other ecological processes (Naiman and others 2000, Maser and Seddel 1994, Bisson and others 1987).

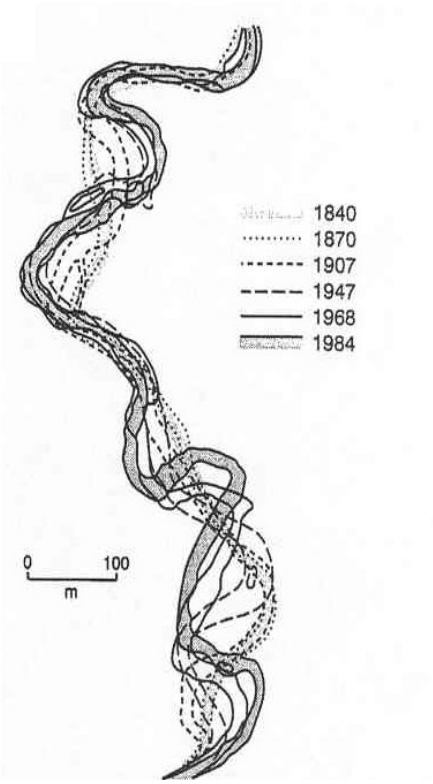

Figure 7. Example of a meander pattern through a floodplain over time. Original illustration from Knighton, D., *Fluvial Forms & Processes – A New Perspective,* 1998.

Woody material in the *floodplain influence zone* is important in providing structure, shade, and nutrients to floodplains (Harmon and others 1986, Keller and Swanson 1979). It also serves as a final filter for runoff from upslope areas, and provides wildlife habitat and corridors for movement. Perhaps most important is the role that the floodplain influence zone plays as a source of down-slope recruitment of wood into the floodplain. On steep slopes, pulses of woody material loading that result from disturbances like fire and windthrow can create significant structural features (Andrus 1998, Swanson and others 1982). These structural features support critical physical, biological, and chemical processes in valley bottoms and stream channels.

Table 11 contains woody material load samples from primarily undeveloped watersheds across the Lolo National Forest over the past 15 years. The data include two survey efforts. Lolo National Forest DFC data (Riggers and others 1998) includes down large (>12") woody material loading rates from riparian areas adjacent to stream survey reaches, and is a direct measure, converted to tons/acre. PIBO monitoring data (Heitke and others 2005) includes instream woody material measurements, which are an indirect measurement of riparian down woody material used as a surrogate, converted to tons/acre, and includes all woody material greater than 4 inches in diameter. Numbers from the PIBO data may differ from actual riparian down woody material amounts due to the higher patchiness associated with instream woody material accumulation as compared to riparian zones. In a recent study on the Lolo and Bitterroot National Forests, Young et al (2006) measured down woody material in riparian areas adjacent to stream survey reaches, and found numbers similar to those observed in the Lolo DFC effort.

Table 11. Average loading densities (tons/acre) of down woody material in floodplains by fire group from three studies on the Lolo National Forest

Fire group	LOLO DFC[1] Mean volume (tons/acre) of down woody material GT 12" in 100-yr floodplain (# of samples in parentheses)	PIBO[2] Mean volume (tons/acre) down woody material GT 4" in stream channel (# of samples in parentheses)	
2	30 (5)	28 (3)	
4	30 (5)	28 (3)	
5	1 (2)	28 (3)	
6	12 (12)	114 (3)	
7	37 (7)	29 (2)	
8	38 (9)	29 (2)	
9	18 (27)	5 (1)	
10	53 (7)	29 (2)	
11	18 (33)	5 (1)	

[1] Riggers et al 1998
[2] Heitke et al 2005

Chapter 4

Fire Management Considerations

Fuel Loads

Dead and down woody material has long been considered a fire hazard. However, to manage all residue on all sites as potentially dangerous because it can threaten resource values and fails to consider the complete range of factors contributing to risk definitions.

According to the *Glossary of the Wildland Fire Terminology* (National Wildfire Coordinating Group 1996):

- *Fire risk* is the chance of fire starting as determined by the presence and activity of causative agents, namely, environmental conditions and ignition source.
- *Fire* or *fuel hazard* is a fuel complex defined by volume, type condition, arrangement and location, which determines how difficult it is to ignite and control.

The resources at risk are also an important consideration in determining overall fire risk. Fire risk and fuel hazard are typically greater concerns in the *WUI* (Wildland Urban Interface).

- The WUI, according to the Glossary of the Wildland Fire Terminology, is the line, area or zone where structures or other human development meet or intermingle with undeveloped wildland or vegetative fuel.

When fires occur in the WUI, resources of human value can be at risk. Life, property, and infrastructure are the primary values, however, the "viewshed" of private homes or a community, and a pleasing forest environment with aesthetic appeal, can carry significant property value. Reducing fire risk in the WUI, where fire suppression forces are often concentrated, can increase firefighter safety.

Fire risk assessments are based on climatic influences and topography, and influenced by the probability of ignition. Even with relatively high fuel loads, sites are not necessarily hazardous if they are wet habitats with a low probability of ignition.

Assessments must evaluate fuel loads by size class to gain a clear indication of potential effects – gross tons per acre carries little meaning. Relatively low fuel loads are hazardous on warm, dry sites when fuels are continuous and if most fuels are *fine*, less than 3 inches in diameter. Hazard ratings go up more when the area has a high incidence of fire starts, such as in the WUI.

Fine fuels have the most dangerous rate of spread. Just how dangerous depends on the fuel's continuity, the probability of ignition (based on fuel moisture and weather conditions), and the proximity to other valuable resources. Based on undisturbed stands, desired loadings for fine fuels vary from 2 to 6 tons per acre, depending on habitat group – see Table 12.

Table 12. Range of desired fuel loadings in the less-than 3" size class for acceptable fire hazard. (Note: Lower ends of ranges are from Table 9 (Post-burn fuel loads) and upper ends of ranges are averages from Table 3 (Existing fuel loads from stands not recently disturbed).

Fire groups	VRU	Habitat group	Material loading LT 3"
0	1	0	N/A
2	2	1	up to 2 tons/acre
4	2	2	0.6 to 3 tons/acre
6	2	3	0.5 to 5 tons/acre
9 & 11	3	4	0.6 to 6 tons/acre
7 & 8	4	5	0.6 to 6 tons/acre
10	5	6	NA

The bigger the piece, the longer it will persist, particularly if it's not in contact with the ground. Normally, for pieces greater than 3 inches in diameter, fuel loads should be kept below 20 tons per acre for warmer, drier habitat types, assuming most fuels are greater than 6 inches in diameter. With such fuel loads, on a typical 50-foot transect (based on methods listed in Chapter 7) there would be six 3-inch pieces (5 tons/acre) and four 6-inch pieces (15 tons/acre). Again, hazards vary with habitat group, fuel arrangement, expected line production rates and values at risk. If fuels are large and well scattered, heavier loads are acceptable.

For areas that have experienced moderate to severe fires, such as in 2000, there are future fuel considerations. It may take more than 30 years for a duff layer to establish in areas that burned with moderate to high severity (Brown & others 2003). Fine fuels increase as shrubs and grasses resprout and new seedlings become established. Because of western Montana's dry climate, the large fuels remaining in burned areas decay slowly and likely would remain on the landscape until it burned again.

The possibility of a reburn is small on any site but high over the landscape. Fire hazard and resistance-to-control reach high ratings when large woody fuels exceed 25 to 30 tons per acre combined with small woody fuels of five or more tons per acre (Brown & others 2003). Accumulations of large woody fuels can hold a smoldering fire on a site for extended periods (Brown & others 2003). Potential for spotting and crown fires is greater where large woody fuels have accumulated (Brown & others 2003). A severe fire occurrence in the next several decades will depend on the amount of fuels present, vegetation development, point of ignition and weather. Based on Brown's 2003 paper, the effects of a future reburn during high to extreme burning conditions in areas that previously burned at moderate to high severity are as follows.

- *0-10 years after fire* – Severe fire unlikely because large woody fuels still accumulating and not enough decay to support prolonged smoldering combustion.
- *10-30 years after fire* – Most large woody fuels have fallen down, with some decay to support prolonged burning. Duff layer not well established. High-severity burn would occur primarily where large woody material lying on or close to ground. High-severity burn could be substantial where large portion of soil surface directly overlain by large woody pieces.

- *30-60 years after fire* – Large woody fuels have considerable rot; duff layer may be well established depending on amount of overstory conifer. More severe burning possible, depending on how much soil covered by large woody pieces. If conifer overstory present, crowning and duff burnout could amplify burn severity.

This increase in the *duration* (how long smoldering combustion remains on site, increasing soil damage) of future burns (because of the presence of large down woody material), historically did not occur in lower-elevation habitat types because the snags and down woody material did not occur. Instead, they were slowly consumed over time during frequent fires. The increase in burning durations at lower elevations could cause soil damage outside the range of historic variability and prevent regeneration.

Chapter
5

Down Woody Material Resource Standards & Direction

Forest Plan Standards

Forest plan Standard #13, under the timber heading, states in part that sufficient amounts of woody material will be left to maintain soil fertility.

Forest plan Standard #25, under wildlife and fish, provides snags and dead material for snag-dependent species. It further refers to Appendix N, which contains snag retention prescriptions for forest habitat groups.

In MAs 13 & 14, Standard #9 includes riparian areas and says, "Riparian vegetation, including overstory tree cover, will be left along water bodies as needed to provide shade, maintain streambank stability, desirable pool quality and quantity for aquatic organisms, and promote filtering of overland flows."

MA 13 Standard #5 says to "Maintain natural habitat or restore conditions for indigenous aquatic organisms, including fish, by management of vegetative conditions, channel structure, and limiting those activities of developments that are adverse to these organisms of the aquatic ecosystem."

MA 16, as well as other timber-suitable MAs, contains Standard #20 that says, "Dead and down trees may be salvaged as constrained by habitat needs for cavity-nesting wildlife species."

Taken together, these standards reinforce the fact that the Lolo recognizes the importance of woody material as a resource for a multitude of resource values. It also emphasizes the need to manage woody material.

Lolo Best Management Practices (BMPs)

The Lolo National Forest BMPs set guidelines for managing impacts to soil and water. They are based on FSH 2509.22, the Soil and Water Conservation Practices Handbook (1993).

Lolo National Forest Snag Recommendations

Hillis and OConnor (1997) developed recommendations for snag retention on the Lolo. These recommendations have not been formally amended to the Forest Plan, however, they provide useful direction in managing this resource. Overall recommendations are provided below, along with a table defining retention objectives by fire group:

1. Protect high value snags wherever they occur;
2. Recruit high value snags from the existing mix of live trees when available;
3. When desired seral species are unavailable, be willing to trade off the recruitment of less desirable climax snags if retaining those trees conflicts with the long-term recruitment of desired snags (i.e., don't worry about losing live grand fir if it allows for larch re-establishment);
4. Such decisions should be made over large landscapes. When all things are equal, managing snag recruitment in the long run to desired species probably should take precedence over simply retaining high numbers of snag recruitment trees of a marginally valuable species.

Lolo Dead & Down Habitat Components Guidelines

Table 13. Snag retention needs per acre

Habitat feature	Fire groups			
	2,4,5	6	7,8 ‡	9,11
Total snags or substitutes*	1-2	1-12 †	only risk type 2	4-12
Live replacements**	8-12	8-12	- -	8-12
Dead and down in ton/acre (greater than or equal to 6"in diameter x 6' long)	5-12	12-20	12-20	12-20
Fire created habitats - D&D recruitment, groups of trees/acre from identified needs	3-15	3-15	16-60	16-60

* Snag substitutes - Live, defective trees that function as snags
** Replacements - Live trees left to provide long-term recruitment
†Snag density-should reflect past stand & fire history - If stands result from frequent, low-intensity fires, retain 1-2 snags/acre; if stands originate with severe fire, retain 4-12 snags/acre
‡ Only pure lodgepole - If other species present, retain snags as prescribed in fire group 9, 11

Worker safety needs to be considered in the planning stages. OSHA Danger Tree (Snag) Regulations (29 CFR 1910.266(h)(1)(vi) say "Each danger tree shall be felled, removed or avoided. Each danger tree, including lodged trees and snags, shall be felled or removed using mechanical or other techniques that minimize employee exposure before work is commenced in the area of the danger tree. If the danger tree is not felled or removed, it shall be marked and no work shall be conducted within two tree lengths of the danger tree unless the employer demonstrates that a shorter distance will not create a hazard for an employee."

More information on the Lolo's *Dead & Down Woody Debris Guidelines* can be found in Appendix C.

Guidelines for Implementation

Different-sized pieces of fuel represent a variety of values. Woody material decays and releases nutrients at different rates, depending on the size and circumstance. Often, one size-class has value and is best left on a site, while another size-class is less desirable and may be removed. The left side of Figure 8 shows what Brown & others (2003) found to be the optimum ranges of woody material for soil productivity, soil protection and wildlife needs for warm dry forest types, and the right side of Figure 8 shows their results for cooler and lower-subalpine forest types, while still providing acceptable risks of fire hazard and fire severity. The dotted lines show the ranges they found best meets most resource needs: 5 to 20 tons/acre for the warm dry types and 10 to 30 tons/acre for other types. Stream and riparian values are not included in this table, but would be similar to the upper levels for soil resources.

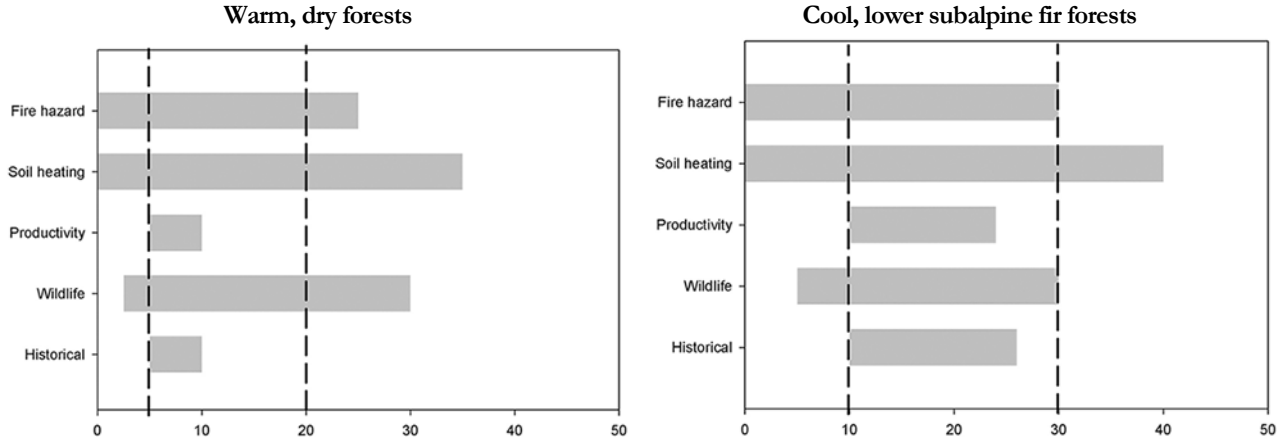

Figure 8. Optimum levels of coarse woody material (tons/acre) for various resources for warm, dry forest types on the left & cool, lower subalpine forest types on the right (Brown & others 2003)

Using current woody material research and the woody material loadings found in undisturbed natural systems as a benchmark, we have approximated a general range of acceptable loadings by habitat group for the Lolo National Forest. While many factors need to be considered in determining potential risks, this approach nevertheless provides an ecologically based starting point. Where fire hazard is determined to be low and other resource needs are compatible, relatively higher fuel loadings may be acceptable.

Table 14 on the next page contains Lolo NF recommendations for a general range of acceptable woody material loadings by habitat type or fire group. Woody material loads are broken down into size classes. They are *not* absolutes, but rather serve as a guide to use in the absence of better information. The table is comparative, showing that not all resources find the same range beneficial. Some may be limiting or contradicting. This is where interdisciplinary team assessments need to be reviewed and line officer decisions are needed. Detailed site-specific, stand-specific woody material loading-per-acre

recommendations generally are developed after interdisciplinary landscape assessments and strategies are identified to achieve desired future conditions.

Table 14. Summary of general range of acceptable woody material loading (tons/acre)[4] (LT = Less Than, GT = Greater Than)

Resource		LT 3"	GT 3"	GT 6"	GT 12"
Wildlife (USDA 1996)	Fire groups				
	FG 2, 4, 5			5-12	Included within GT 6"
	FG 6, 7, 8			12-20	Included within GT 6"
	FG 9, 11			15-30	Included within GT 6"
Tree planting micro-site & tree productivity	Aspects SE to W		5-15	Included within GT 3"	Included within GT 3"
	Aspects NW to E		11-24	Included within GT 3"	Included within GT 3"
Soil productivity (Graham 1994)	Habitat & fire groups				
	HG 2/3 FG 4-6		4-13 [1]	Included within GT 3"	Included within GT 3"
	HG 4 & 6 FG 9, 10, 11		7-24	Included within GT 3"	Included within GT 3"
	HG 5 FG 7, 8		7-22	Included within GT 3"	Included within GT 3"
Fire hazard	Habitat & fire groups				
	HG 2 FG 4	0 - 3	LT 20	Included within GT 3"	Included within GT 3"
	HG 3 FG 6	0 – 5	LT 20	Included within GT 3"	Included within GT 3"
	HG 4-6 FG 7, 8, 9, 10, 11	0 - 6	LT 40	Included within GT 3"	Included within GT 3"
Fish/stream stability Flood plain zone Flood plain influence zone	Fire Groups				
	Flood plain FG 2, 4, 5		4-13 [2]	Included within GT 3"	6-30 [3]
	Flood plain FG 6, 7, 8		7-22	Included within GT 3"	12-38
	Flood plain FG 9, 10, 11		7-24	Included within GT 3"	18-53
	Influence zone FG 2, 4, 5		4-13	Included within GT 3"	Included within GT 3"
	Influence zone FG 6, 7, 8		7-22	Included within GT 3"	Included within GT 3"
	Influence zone FG 9, 10, 11		7-24	Included within GT 3"	Included within GT 3"

[1] Use Idaho DF/Caru for Lolo

[2] From Soil Productivity numbers

[3] Upper levels from stream survey info, lower levels from Graham et al. 1994

[4] There are guidelines that may not be achievable if worker safety is compromised at a specific site.

Whenever fuel loading or woody material is an issue, appropriate levels will have to be determined. The interdisciplinary team is responsible for bringing together the various resource objectives and concerns and developing a range of suitable harvest, post-harvest or fuel treatment alternatives in stands that may be deficient in total loading. The line officer will select an alternative for implementation in the context of biological, social and economic consequences. These loadings will be detailed in a site-specific silvicultural prescription along with monitoring needs.

Several approaches may be used to predict future or find existing fuel loadings. Predictive models and methods that may be used to more accurately gauge the weight of fuels and material are outlined in Chapter 7 - Monitoring and Evaluation.

Floodplain & Floodplain Influence Zone Management Considerations

Recent management strategy and direction, such as INFISH, promote standards and guides that reflect increased sensitivity and a commitment to ecosystem management (INFISH 1995). Using the 100-year floodplain in this Guide does not replace INFISH; instead, it provides guidance for managing woody material in valley bottoms to meet INFISH Riparian Management Objectives (RMOs). It should be noted that the standard widths defining interim INFISH Riparian Habitat Conservation Areas (RHCAs) include reference to "the outer edges of the 100-year floodplain" for *Category 1 (fish-bearing)* and *Category 2 (perennial, non fish-bearing)* waters, but not for *Categories 3 (standing, or lentic)* water bodies and *Category 4 (intermittent)* waters. The following considerations provide information to manage woody material for the long-term structural integrity of riparian zones and the streams they support. They do not discount or eliminate the need to address other aquatic issues such as sediment filtering and temperature regulation that are also associated with healthy riparian zones.

In the 100-year floodplain, the overriding role of vegetation (alive and on the forest floor) is to promote functional, resilient fluvial processes. These values were recognized in the 1986 Lolo Forest Plan (1986), with special management area designation (MA 13) and guidelines. As a result, current vegetation management practices are typically designed to avoid these areas or should be specifically designed to improve riparian and fluvial processes.

Management and restoration of these sites to recover from past activities and cumulative anthropogenic effects in the watershed critically depends on leaving periodic pulses of woody material on site (Naiman and others 2002, Maser 1994). These relatively infrequent occurrences provide ecological complexity and richness across the floodplain, allowing natural fluvial processes to restore functional balance to the riparian ecosystem (Bisson and others 2003, Beschta and others 2003). Table 11 contains levels of woody material measured in streams across the Lolo National Forest, and emphasizes the wide range of values characteristic of riparian sites.

A range of values for Flood Plain Zones was listed in Table 14 so the sampled values from Table 11 would not be viewed as "thresholds" or minimum levels that must be left following timber harvest, burning, or other planned activities. Rather, they should be used as guidelines that illustrate what we are trying to achieve over large scales, realizing that much variability is typically associated with riparian habitats. Table 14 uses the Lolo DFC (Riggers and others 1998) sampled levels as the upper level and upland site information for the lower limits. In many cases, woody material levels at a site-specific scale may far exceed those in Table 14, but may be limited in much of the rest of the stream. In cases like this, it is important to understand the importance of maintaining levels higher than the guidelines suggest to compensate for other areas that are lacking. Likewise, a site with woody material levels below those shown in the table, but located among others with more than enough woody material, would not necessarily indicate a need for restoration. The potential future recruitment of woody material from

standing trees should be considered in terms of how it will affect the woody material resource in the future.

In cases where past or emergency actions (such as fireline construction) have affected down woody material in the floodplain, and *direct restoration activities* are proposed, the objectives should attempt to achieve densities and sizes listed in Table 11 in Chapter 3. It should be noted that objectives for down woody material should be patchy, rather than evenly spaced throughout the floodplain, attempting to represent the more diverse suite of disturbances and natural site conditions as closely as possible (Lisle 2002, Gregory 1997).

In the floodplain influence zone (see Chapter 3 for description and Table 14 for sample loadings) on both sides of the 100-year floodplain, woody material should be considered by project interdisciplinary teams to provide the resources needed to contribute to the floodplain. Since these sites indirectly influence the woody material resource in floodplains, they are less critical in terms of retaining all down woody material on sites, and should represent a general transition between upland sites and riparian floodplain sites (Gregory 1997).

The overall objective in each of the habitat types in the *100-year floodplain* and *floodplain influence zone* is two-fold:

1. To maintain the woody structural material that is responsible for riparian dependent ecological processes, and
2. To maintain the long-term recruitment of this material.

Chapter 7

Monitoring & Evaluation

The need to monitor the effects of our management activities is growing. Public groups expect it and many government policy documents direct it. NEPA suggests that monitoring and evaluation be conducted to mitigate human actions that alter landscape or environments. Forest plan direction requires monitoring for many resource areas. The Lolo Forest Plan requires monitoring in item 3-3, "*Assure silvicultural prescriptions meet multiple use goals*;" and item 4-3, *"Monitor the effect of soil disturbance/displacement of land productivity."* Direction is also mentioned in the silvicultural practices handbook (R-1 Supplement 2409.17-94-1): "*Silvicultural practices will be monitored and evaluated for biological and ecological soundness and for effectiveness in meeting resource needs*." Each silvicultural prescription generally lists monitoring as a function of successful implementation. All vegetation treatments should speak to woody material. Specific guidance is also stated in Chapter 2 of FSH 2509.18, Soil Quality Monitoring Handbook (R-1 Supplement No. 2500-99-1). "Organic Matter Guidelines," including coarse woody material and soil productivity monitoring, are outlined.

Manual direction under FSM 5140.42 (fire section) encourages adequate monitoring of all prescribed or wildland fire use at the forest level. The Implementation Procedures Reference Guide of the Prescribed Fire Management Policy (1998) directs monitoring for short term and long-term fire effects. The 2001 National Fire Plan and the 2002 10-Year Comprehensive Strategy Implementation Plan both stress accountability and monitoring to evaluate the effectiveness of treatments. The 2003 amendment to the Fire Management Planning Handbook (FSH 5109.19) calls for implementation monitoring, effectiveness monitoring and validation monitoring. The Healthy Forest Restoration Act of 2003 (Section 601.a) states that the Secretary of Agriculture shall carry out a comprehensive program to inventory, monitor, characterize, assess and identify forest stands.

Methods

Several methods are readily available to approximate existing or predicted future fuel loadings. These include:

Existing Fuel Load

- *Fuel Transect* (Brown 1974). Methods are included in *Firemon* (www.fire.org or www.frames.gov), *FSVeg* (NRIS corporate date base available at http://fsweb.ftcol.wo.fs.fed.us/fsveg/index.shtml), *FEAT (Fire Ecology Assessment Tools*, new National Park Service software) or in the new *Lolo Fuels Spreadsheet* (Appendix A)
- *Photo Fuel Guide Series* (Fischer 1981 a-d, Maxwell and Ward 1976), may be updated by Roger Ottmar (PNW)
- *Lolo Spreadsheet* for live tree weights by species (Appendix D)

- *Table Guides* for tons per acre (See Table 13 and Table 14, Appendixes A and B)
- *Logarithmic derivations* (Anderson 1978)
- *Forest Inventory and Analysis (FIA) data (http://fsweb.ogden.rmrs.fs.fed.us/)*

Future Fuel Loads

- *FVS - FFE* (Forest Vegetation Simulator - Fire and Fuels Extension by Beukema, Reinhardt, Kurz and Crookston 2000). Effects of timber harvest, fuel treatment, and fire on subsequent fuel dynamics, stand development, and potential fire intensity can be simulated for a period of decades. Available on web at http://www.fs.fed.us/fmsc/fvs/index.php or at http://www.frames.gov/tools/
- *FOFEM - First Order Fire Effects Model* (Reinhardt 1996) – A program for predicting tree mortality and fuel consumption (does not predict snag fall rates, in-growth or future down fuel loads like FVS). At http://fire.org/ at http://www.frames.gov/tools/
- *SnagPop* - A matrix population model that plots the number of live trees and number of snags per unit area over time and can determine recruitment level. Go to http://fsweb.r1.fs.fed.us/wildlife/wildlife_ecology/snagpop/snagmain.html
- *FSVeg Material Prediction Model* - To be included in FSVeg from stand exam data, at http://fsweb.ftcol.wo.fs.fed.us/fsveg/index.shtml or at http://fsweb.r6.fs.fed.us/nrisnet/fsveg/
- *NEXUS* is a spreadsheet application that allows you to build custom surface fuel models and test them for torching and crown fire potential

Making decisions about planned loading is a central consideration in choosing among the methods available. For most purposes, it's adequate to use ocular estimates using the fuel photos series to calibrate results. The Photo Fuel Guides are widely used, but may be limited in their ability to distinguish loadings by size class. A forest-specific photo series is being developed by several district fuel management officers.

The *Brown line transect* method is the most accurate means available for existing fuels but requires intensive sampling and is relatively expensive. It should normally be used only when higher accuracy is required. An Excel spreadsheet has been created that is based on Brown calculations (1974) that will calculate large woody material once log diameter data is entered into it. The transect-intersect information can be based on a 50- or 100-foot transect lengths. Separate spreadsheets exist for fine fuels less than 3" in diameter and large fuels greater than 3". See the spreadsheets in Appendix A. Transects can also be used with the tables in Appendix B.

The Fire Lab produced *Firemon*, a fire monitoring software package (http://fire.org/firemon/) that has the capacity to measure many resources at many levels. It includes the Brown (1974) transects and has a field to accommodate the Photo Fuel Guides by Fischer (1981 a-d). It also includes help and direction to create a sample design. Firemon includes tools to measure existing fuels and tree information to put into FVS - FFE to predict future loads.

SnagPop is a method/model for determining existing snag recruitment levels. Use of the model and its mathematical rationale are described more fully in Appendix 2 of the *Northern Region Snag Management Protocol*. Recruitment rates in the SnagPop model are based on the following variables:

- *Live tree survivorship rates,* or the predicted rate at which trees of a given species die;
- *Snag fall rates,* the predicted rate at which snags of a given species fall, by west side & east side.

SnagPop requires users to enter data based on current stand conditions, such as the initial number of live trees per unit area and the initial number of snags per unit area. It requires a decision on the number of

years to run the simulation. The user also needs to decide whether to use the live tree survival rates, snag fall rates, and stem decay occurrence provided for the four most important snag species, or to use local data if available. The sources of data for the model are described in Appendix 2 of the *Northern Region Snag Management Protocol*. The protocol also discusses methods of recruiting more snags in areas where snags are scarce.

FVS (Forest Vegetation Simulator) with *FFE* (Fire & Fuels Extension) is a computer model that can help predict fuel load after harvest and/or burning. It requires a tree list that can be provided by FSVeg.

The new NRIS (Natural Resource Information System) corporate data base system also includes *FSVeg* (Forest Sampled Vegetation) (http://fsweb.ftcol.wo.fs.fed.us/fsveg/), which replaces R1EDIT with the common stand exam. FSVeg includes Brown fuel transect methods and a field for fire behavior fuel models (Anderson 1982). In the future, it will include a material prediction model from harvested tops and cull pieces. Another part of NRIS is TERRA, which replaces Ecodata, and includes fuel measurement transects as an option. There are future plans to standardize Firemon codes and data to upload it into the FSVeg or TERRA data bases.

The logarithmic charts developed by Anderson (1978) are another quick means to estimate woody material loadings. The process may be applied either to determine gross tonnage or to find the number of intercepts required to meet some specified loading. In this approach, however, only 3-inch and larger diameter material is considered. Nevertheless, this technique may be valuable in predicting or assessing fuels of uniform character, most notably in even-aged lodgepole pine where fuel-loading problems are most often encountered.

For most decisions involving future woody material needs, these systems offer good resolutions. As with any model, the user is cautioned to understand and compensate for the assumptions on which the models are based.

Guides to Determine Woody Material

There are many table guides or charts available to make quick determinations of woody material loads. Tables estimating the weight based on piece size are in Appendix A. Appendix B has charts based on number of pieces encountered in a transect, such as Table 15, which estimates down woody material on a 50-foot transect). These tables were developed by Graham adapted from Brown calculations (1974) for 50-foot and 100-foot transects to determine tons per acre of woody material. See the box inserted in the table for example and instructions for use.

In addition, there is a sample of a Excel spreadsheet to calculate fuel loads in Appendix D. The calculations are based on number of pieces encountered on 50- or 100-foot transects and entered into the proper fields. The spreadsheet can be downloaded from the site link listed in Appendix D.

Table 15. Estimate of tons per acre of down woody material from *50-foot* transects

#	Diameters																	
Logs	3”	4”	5”	6”	7”	8”	9”	10”	12”	14”	16”	18”	20”	22”	24”	26”	28”	30”
1	0.8	1.5	2.3	3.4	4.6	6.0	7.5	9.3	13.4	18.3	23.8	30.2	37.2	45.1	53.6	62.9	73.0	83.8
2	1.7	3.0	4.7	6.7	9.1	11.9	15.1	18.6	26.8	36.5	47.7	60.3	74.5	90.1				
3	2.5	4.5	7.0	10.1	13.7	17.9	22.6	27.9	40.2	54.8	71.5	90.5						
4	3.4	6.0	9.3	13.4	18.3	23.8	30.2	37.2	53.6	73.0	95.4							
5	4.2	7.4	11.6	16.8	22.8	29.8	37.7	46.6	67.0	91.3								
6	5.0	8.9	14.0	20.1	27.4	35.8	45.3	55.9	80.5									
7	5.9	10.4	16.3	23.5	31.9	41.7	52.8	65.2	93.9									
8	6.7	11.9	18.6	26.8	36.5	47.7	60.3	74.5										
9	7.5	13.4	21.0	30.2	41.1	53.6	67.0	83.8										
10	8.4	14.9	23.2	33.5	45.6	59.6	75.4	93.1										
11	9.2	16.4	25.6	36.9	50.2	65.6	83.0											
12	10.1	17.9	27.9	40.2	54.8	71.5	90.5											
13	10.9	19.4	30.3	43.6	59.3	77.5	98.1											
14	11.7	20.9	32.6	46.9	63.9	83.4												
15	12.6	22.3	34.9	50.3	68.4	89.4												
16	13.4	23.8	37.2	53.6	73.0	95.4												
17	14.2	25.3	39.6	57.0	77.6													
18	15.1	26.8	41.9	60.3	82.1													
19	15.9	28.3	44.2	63.7	86.7													
20	16.8	29.8	46.6	67.0	91.3													
21	17.6	31.3	48.9	70.4	95.8													
22	18.4	32.8	51.2	73.8														
23	19.3	34.3	53.5	77.1														
24	20.1	35.8	55.9	8.5														
25	21.0	37.2	58.2	83.8														

Example: Walking a 50-foot transect, you cross two 8” logs (which = 11.9 tons) plus one 4” log (which = 1.5 tons). This represents 11.9 + 1.5 = 13.4 tons per acre of large woody material.

Calculations made by Russ Graham, based on Brown 1974

Fuel Models

When assessing potential fire hazard, several means are available. Fuel managers often use the fire behavior models developed by Anderson (1982). It should be noted that slash fuels vary a great deal depending on the age, structure, and composition of the stand at harvest. Therefore, caution should be exercised in applying the slash models. To illustrate the values in fire behavior modeling, the distribution of loadings by size class is described below.

Table 16. Distribution of loadings for NFFL fire behavior models

Model description		0.25"	0.26-1.0"	1.1-3.0"	Total LT 3"	Average GT 3"
8	Forested, light fuels	1.5 tons/acre	--	--	5.0 tons/acre	--
10	Forested, heavy down fuels	3.0 tons/acre	--	--	12.0 tons/acre	--
11	Light slash	1.5 tons/acre	4.5 tons/acre	5.5 tons/acre	11.5 tons/acre	LT 15.0 tons/acre
12	Medium slash	4.0 tons/acre	14.0 tons/acre	16.5 tons/acre	34.5 tons/ac	36.0 tons/acre
13	Heavy slash	7.0 tons/ac	23.0 tons/ac	28.0 tons/ac	58.0 tons/ac	GT 50.0 tons/acre

Where better resolution may be required, the fuel manager may elect to use the FVS-FFE or one of the other programs listed above. Or, the manager can build a custom fuel model in the BEHAVE system. The values that are derived through modeling are subject to professional interpolation and should not be applied as absolute.

Chapter
8

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Appendix A

Tools & Charts based on Piece Length & Diameter

Table A-1. Number of pieces required to total 10, 15, 20 & 25 tons per acre

Diameter	Piece length				
	10’	20’	30’	40’	50’
Loading 10 tons/acre (number of pieces)					
5”	500	250	170	140	110
10”	130	70	40	30	25
15”	60	30	20	15	10
20”	30	20	10	10	5
Loading 15 tons/acre (number of pieces)					
10”	154	77	51	38	30
20”	39	19	13	10	8
30”	17	9	6	4	3
40”	10	5	3	2	2
Loading 20 tons/acre (number of pieces)					
10”	206	103	68	51	40
20”	52	26	17	13	10
30”	23	11	8	6	5
40”	13	6	4	3	3
Loading 25 tons/acre (number of pieces)					
10”	257	128	85	63	50
20”	64	32	21	16	13
30”	29	14	10	7	6
40”	19	8	5	4	3

Base data from Brown and Johnston (1976)

Weight Estimates of Logs

The following tables are simple cubic-foot calculations multiplied by the average of the weights of four conifer species at 28.5 pounds per cubic foot. The results are rounded. As such, they give good approximations for estimates.

Table A-2. Weight of selected dimensional conifer wood

Piece diameter	Piece length					
	5'	10'	20'	30'	40'	50'
5"	20#	40#	80#	120#	150#	180#
10"	80#	150#	310#	460#	620#	770#
15"	170#	350#	690#	1,040#	1,390#	1,730#
20"	310#	620#	1,230#	1,850#	2,470#	3,080#

Expressed in pounds at dry standard

Applying this information, the number of pieces required to meet a given standard may be determined. For instance, for fuel pieces between 5 and 20 inches in diameter and between 10 and 50 feet in length, 10 tons/acre can be described by the number of pieces as follows:

Table A-3. Number of pieces per acre required to total 10 tons

Piece diameter	Piece length					
	5'	10'	20'	30'	40'	50'
5"	1,000	500	250	170	140	110
10"	250	130	70	40	30	25
15"	120	60	30	20	15	10
20"	60	30	20	10	10	5

Table A-4. Total tree bole weight of wood & bark

DBH	PP	DF	LP
4”	.017 tons	.021 tons	.026 tons
5”	.029 tons	.037 tons	.051 tons
6”	.048 tons	.060 tons	.081 tons
7”	.074 tons	.088 tons	.118 tons
8”	.107 tons	.123 tons	.162 tons
9”	.147 tons	.166 tons	.215 tons
10”	.196 tons	.218 tons	.275 tons
11”	.258 tons	.274 tons	.343 tons
12”	.332 tons	.341 tons	.420 tons
13”	.416 tons	.416 tons	.504 tons
14”	.511 tons	.501 tons	.597 tons
15”	.617 tons	.595 tons	.698 tons
16”	.736 tons	.699 tons	.807 tons
18”	1.009 tons	.938 tons	1.051 tons
20”	1.334 tons	1.220 tons	1.328 tons
22”	1.714 tons	1.546 tons	
24”	2.151 tons	1.921 tons	
26”	2.648 tons	2.344 tons	
28”	3.208 tons	2.819 tons	
30”	3.832 tons	3.346 tons	

Based on whole-tree volume equations[4], wood density, and bark-to-wood ratios[5] for trees from stands of a variety of site indexes and densities, from Brown & others 2003

[4] Equations for 4-inch dbh from Faurot (1977) and for 5- to 30-inch dbh from Brown and Johnston (1976) and Stage (1973)

[5] Wood density and bark ratios from Brown & others (1977)

Table A-5. Loading of standing dead ponderosa pine woody debris

Snags per acre	DBH							
	6”	8”	10”	12”	14”	16”	20”	24”
4	0.2 tons/ acre	0.4 tons/ acre	0.8 tons/ acre	1.3 tons/ acre	2.0 tons/ acre	2.9 tons/ acre	5.3 tons/ acre	8.6 tons/ acre
6	0.3 tons/ acre	0.6 tons/ acre	1.2 tons/ acre	2.0 tons/ acre	3.1 tons/ acre	4.4 tons/ acre	8.0 tons/ acre	12 tons/ acre
8	0.4 tons/ acre	0.9 tons/ acre	1.6 tons/ acre	2.7 tons/ acre	4.1 tons/ acre	5.9 tons/ acre	11 tons/ acre	17 tons/ acre
10	0.5 tons/ acre	1.1 tons/ acre	2.0 tons/ acre	3.3 tons/ acre	5.1 tons/ acre	7.4 tons/ acre	13 tons/ acre	22 tons/ acre
15	0.7 tons/ acre	1.6 tons/ acre	2.9 tons/ acre	5.0 tons/ acre	7.7 tons/ acre	11 tons/ acre	20 tons/ acre	32 tons/ acre
20	1.0 tons/ acre	2.1 tons/ acre	3.9 tons/ acre	6.6 tons/ acre	10 tons/ acre	15 tons/ acre	27 tons/ acre	43 tons/ acre
25	1.2 tons/ acre	2.7 tons/ acre	4.9 tons/ acre	8.3 tons/ acre	13 tons/ acre	18 tons/ acre	33 tons/ acre	54 tons/ acre
30	1.4 tons/ acre	3.2 tons/ acre	5.9 tons/ acre	10 tons/ acre	15 tons/ acre	22 tons/ acre	40 tons/ acre	64 tons/ acre
40	1.9 tons/ acre	4.3 tons/ acre	7.8 tons/ acre	13 tons/ acre	20 tons/ acre	29 tons/ acre	53 tons/ acre	86 tons/ acre
50	2.4 tons/ acre	5.4 tons/ acre	9.8 tons/ acre	17 tons/ acre	26 tons/ acre	37 tons/ acre	67 tons/ acre	
100	4.8 tons/ acre	11 tons/ acre	20 tons/ acre	33 tons/ acre	51 tons/ acre	74 tons/ acre		
200	9.6 tons/ acre	21 tons/ acre	39 tons/ acre	66 tons/ acre	102 tons/ acre			
300	14 tons/ acre	32 tons/ acre	58 tons/ acre	100 tons/ acre				

Loadings computed from Table A-4

Appendix B

Charts to Estimate Tons per Acre based on Transect Length

Tables developed by Graham from Brown (1974) calculations for 50-foot and 100-foot transects to determine tons per acre of woody material. See box inserted in the table for example and instructions on use.

Table B-1. Estimate of tons per acre of down woody material from *50-foot transects*

#	Diameters																	
Logs	3”	4”	5”	6”	7”	8”	9”	10”	12”	14”	16”	18”	20”	22”	24”	26”	28”	30”
1	0.8	1.5	2.3	3.4	4.6	6.0	7.5	9.3	13.4	18.3	23.8	30.2	37.2	45.1	53.6	62.9	73.0	83.8
2	1.7	3.0	4.7	6.7	9.1	11.9	15.1	18.6	26.8	36.5	47.7	60.3	74.5	90.1				
3	2.5	4.5	7.0	10.1	13.7	17.9	22.6	27.9	40.2	54.8	71.5	90.5						
4	3.4	6.0	9.3	13.4	18.3	23.8	30.2	37.2	53.6	73.0	95.4							
5	4.2	7.4	11.6	16.8	22.8	29.8	37.7	46.6	67.0	91.3								
6	5.0	8.9	14.0	20.1	27.4	35.8	45.3	55.9	80.5									
7	5.9	10.4	16.3	23.5	31.9	41.7	52.8	65.2	93.9									
8	6.7	11.9	18.6	26.8	36.5	47.7	60.3	74.5										
9	7.5	13.4	21.0	30.2	41.1	53.6	67.0	83.8										
10	8.4	14.9	23.2	33.5	45.6	59.6	75.4	93.1										
11	9.2	16.4	25.6	36.9	50.2	65.6	83.0											
12	10.1	17.9	27.9	40.2	54.8	71.5	90.5											
13	10.9	19.4	30.3	43.6	59.3	77.5	98.1											
14	11.7	20.9	32.6	46.9	63.9	83.4												
15	12.6	22.3	34.9	50.3	68.4	89.4												
16	13.4	23.8	37.2	53.6	73.0	95.4												
17	14.2	25.3	39.6	57.0	77.6													
18	15.1	26.8	41.9	60.3	82.1													
19	15.9	28.3	44.2	63.7	86.7													
20	16.8	29.8	46.6	67.0	91.3													
21	17.6	31.3	48.9	70.4	95.8													
22	18.4	32.8	51.2	73.8														
23	19.3	34.3	53.5	77.1														
24	20.1	35.8	55.9	8.5														
25	21.0	37.2	58.2	83.8														

Example: Walking a 50-foot transect, you cross two 8” logs (which = 11.9 tons) plus one 4” log (which = 1.5 tons). This represents 11.9 + 1.5 = 13.4 tons per acre of large woody material.

Calculations made by Russ Graham, based on Brown 1974. Same as Table 13 in Chapter 7.

Table B-2. Estimate of tons per acre of down woody material from *100-foot transects*

#	Diameters																	
Logs	3”	4”	5”	6”	7”	8”	9”	10”	12”	14”	16”	18”	20”	22”	24”	26”	28”	30”
1	0.4	0.7	1.2	1.7	2.3	3.0	3.8	4.7	6.7	9.1	11.9	15.1	18.6	22.5	26.8	31.5	36.5	41.9
2	0.8	1.5	2.3	3.4	4.6	6.0	7.5	9.3	13.4	18.3	23.8	30.2	37.2	45.1	53.6	62.9	73.0	83.8
3	1.3	2.2	3.5	5.0	6.8	8.9	11.3	14.0	20.1	27.4	35.8	45.3	55.9	67.6	80.5	94.4		
4	1.7	3.0	4.7	6.7	9.1	11.9	15.1	18.6	26.8	36.5	47.7	60.3	74.5	90.1				
5	2.1	3.7	5.8	8.4	11.4	14.9	18.9	23.3	33.5	45.6	59.6	75.4	93.1					
6	2.5	4.5	7.0	10.1	13.7	17.9	22.6	27.9	40.2	54.8	71.5	90.5						
7	2.9	5.2	8.1	11.7	16.0	20.9	26.4	32.6	46.9	63.9	83.4							
8	3.4	6.0	9.3	13.4	18.3	23.8	30.2	37.2	53.6	73.0	95.4							
9	3.8	6.7	10.5	15.1	20.5	26.8	33.9	41.9	60.3	82.1								
10	4.2	7.4	11.6	16.8	22.8	29.8	37.7	46.6	67.0	91.3								
11	4.6	8.2	12.8	18.4	25.1	32.8	41.5	51.2	73.8									
12	5.0	8.9	14.0	20.1	27.4	35.8	45.3	55.9	80.5									
13	5.4	9.7	15.1	21.8	29.7	38.7	49.0	60.5	87.2									
14	5.9	10.4	16.3	23.5	31.9	41.7	52.8	65.2	93.9									
15	6.3	11.2	17.5	25.1	34.2	44.7	56.6	69.8										
16	6.7	11.9	18.6	26.8	36.5	47.7	60.3	74.5										
17	7.1	12.7	19.8	28.5	38.8	50.7	64.1	79.2										
18	7.5	13.4	21.0	30.2	41.1	53.6	67.9	83.8										
19	8.0	14.2	22.1	31.8	43.3	56.6	71.7	88.5										
20	8.4	14.9	23.3	33.5	45.6	59.6	75.4	93.1										
21	8.8	15.6	24.4	35.2	47.9	62.6	79.2	97.8										
22	9.2	16.4	25.6	36.9	50.2	65.6	83.0											
23	9.6	17.1	26.8	38.6	52.5	68.5	86.7											
24	10.1	17.9	27.9	40.2	54.8	71.5	90.5											
25	10.5	18.6	29.1	41.9	57.0	74.5	94.3											
26	10.9	19.4	30.3	43.6	59.3	77.5	98.1											
27	11.3	20.1	31.4	45.3	61.6	80.5												
28	11.7	20.9	32.6	46.9	63.9	83.4												
29	12.2	21.6	33.8	48.6	66.2	86.4												

Example: Walking a 100-foot transect, you cross three 6” logs (which = 5.0 tons) plus one 10” log (which = 4.7 tons). This represents 5.0 + 4.7 = 9.7 tons per acre of large woody material.

For rotten logs, reduce these sound weights by 25 percent. Calculations made by Russ Graham, based on Brown 1974.

Appendix C

Lolo Forest Revised Dead & Down Habitat Component Guidelines (Hillis and OConnor 1997)

Snag Retention Needs

Habitat feature	Fire groups			
	2, 4, 5	6	7, 8 ‡	9, 11
Total snags or substitutes per acre*	**1-2**	**1-12 †**	**only Risk Type 2**	**4-12**
Live replacements per acre**	**8-12**	**8-12**	**- -**	**8-12**
Dead and down in ton/acre of pieces greater than or equal to 6" diameter x 6' long	**5-12**	**12-20**	**12-20**	**12-20**
Fire created habitats - dead & down recruitment, groups of trees/acre from identified needs	**3-15**	**3-15**	**16-60**	**16-60**

* Snag substitutes - Live, defective trees that function as snags
** Replacements - Live trees left to provide long-term recruitment
† Snag density should reflect past stand/fire history – if stand originated from frequent, low-intensity fire, retain 1-2 snags/acre; if stand originated from a severe fire, retain 4-12 snags/acre
‡ Only pure lodgepole; if other species present retain snags as prescribed in Fire Group 9, 11

Selection Attributes

Select snags or live trees with the following characteristics:

- *Select largest available,* minimum greater than 10" dbh
- Cull snags or trees, versus merchantable
- ponderosa pine, larch, Douglas-fir, grand fir, subalpine fir, cedar & hemlock (priority order)
- Broken tops, versus top intact
- Nesting holes or cavities present
- Minimal lean, less than 10º
- Heart rot, conks, scars, wounds, etc.
- Dead tops or areas within crown

Disease

Live "snag substitutes" and "replacements" carry some risk of transmitting disease to the understory. Precautions should be taken to minimize the risk, but some risks are acceptable in order to meet the

guidelines. These shall be addressed in the detailed silvicultural prescription. If replacements are girdled to avoid disease transmission, effects on wildlife should be disclosed in the EA.

Protection during Management Activities

Selecting larch and ponderosa pine for retention should minimize impacts during burning. If these species are unavailable, or other factors place snags under special risk, extra replacements should be marked for retention to compensate for anticipated snag losses. Other measures, such as designating snags at the lower two-thirds of the unit or away from roads should minimize snag loss. Retain green leave trees on either side of retention snags to act as 'bumper trees' to protect against yarding or skidding damage.

Administrative Guidelines

Snags in the context used here refer to snags, snag substitutes and replacement trees.

1. Snags or defect trees should be randomly distributed singly or in small clumps (defined as 3-15 trees).
2. Retention snags should be marked in leave-tree units.
3. Retention snags may not be marked in cut-tree marked units. Leave substitutes if these snags are removed for safety.
4. Consider protecting snags within 200' of roads with wildlife tree signs, armoring, or other means.
5. Timber sale contracts should use appropriate 'clauses' to protect retention snags.
6. To achieve the Forest Snag Policy, merchantable trees may be retained.
7. Sale administrators must know marking guides and contract wording to avoid approving removal of retention snags.
8. If the contractor indicates a specific snag constitutes a safety hazard, permission must be granted to remove the snag and a substitute designated (if available).
9. Felling of retention snags should be avoided, if possible, including soft stubs greater than 10" dbh and less than 15' high.
10. Markers and sale administrators should know the document *Risk Assessment for identifying Reserve Trees.* Protect Type 3 & 4 snags with reserve islands where those types are needed to meet the minimum snag density.
11. Snag management strategy and availability will be addressed in EMA analysis. Snag availability and marking guides will be addressed in the detailed silvicultural prescription.

Risk Assessment for Snag Retention

For more information refer to the 11-page booklet *Risk Assessment for Identifying Reserve Trees, a Supplement to Rules Relating to Logging Operations in Montana and Idaho*

Reserve Tree Types (Conifer Only)

Reserve trees for standing dead habitat are divided into four types based on health and morphological conditions.

- *Type 1* - Live trees that are defective or deformed, with sound tops, trunks and roots. They are stable and not generally considered "danger trees." They may have part of the top broken out or have

evidence of other defects, such as "cat face," animal chewing, and equipment, insect or storm damage.

- *Type 2* - A dead tree with sound top, trunk, and roots. May be a snag with no root rot or lean and no top. Normally are not considered danger trees. Ponderosa pine, larch and red cedar may stand a long time as Type 2. Firs, lodgepole pine and spruce deteriorate rapidly. Presence of needles and small twigs/branches may indicate stability. If fire damage to the root system or trunk, consider changing to a more hazardous type.
- *Type 3* - Live or dead trees with tops or upper portions of the trunk that are broken or unstable. Roots and main trunk are sound but have defects in live or dead wood higher on the tree. Logging equipment, wind or other activity may dislodge dangerous portions of the tree. A "hazard area" should be avoided around the tree (see description below).
- *Type 4* - A live or dead tree with unstable trunk or roots, with or without bark. Includes "soft" snags and live trees with roots made unstable by root rot or fire. Consider conks or other signs of stem decay. Root-rot pockets give signs of groups of dead or leaning trees. Burned out trunks and roots indicate danger. The *hazard area* around the tree (the area on the ground that could be reached by any portion of the tree that might collapse) should be avoided.

Hazard Area

Assess direction of lean, if any.

1. Determine length of hazard portion that may fall and double its length.
2. Determine the amount of lean (horizontal distance from where the hazard piece would dislodge relative to the base).
3. The "hazard area" would be the distance determined by adding steps 1 and 2 and 90º on each side of the lean beginning at the base.

The area behind the lean is not a hazard area unless equipment or activity contacts the reserve tree.

Appendix D

Excel Spreadsheet to Calculate Fuel Loads

This spreadsheet can be found on the web at www.fs.fed.gov/rl/lolo/fuel_load_spreadsheet

FINE FUEL PLOT SHEET **100 ft Transect Length Only for Fine Fuels < 3"**

Name _____ Date _____

Contract # or Stand # _____ Unit _____

Transect #	Diameters (D) < 3 in. 0 - .25"	.25 - 1"	1 - 3"	Transect Slope	Comments
				1.08	
				1.08	
Total =	0	0	0		

Do not fill in the shaded column. The shaded columns will automatically be calculated.

	Constant	n	D^2	s	a	c	L	Tons/acre
I. 0 - .25"	11.64	0	0.016	0.48	1.13	1.08	100	0.1435
II. .25 - 1"	11.64	0	0.391	0.48	1.13	1.08	100	0.1472
III. 1 - 3"	11.64	0	4	0.4	1.13	1.08	100	0.1825
						Total = I + II + III =		**0.4732**

11.64 = constant D = diameter of intersecting point

n = sum of # of intersections for each diameter size class

s = specific gravity, (**.48** for 0-.25" & .25-1", **.4** for 1-3")

a = nonhorizontal angle, (**1.13** for 0" to 3")

c = slope correction, (0%-10% = **1.00**, 20% = **1.02**, 30% = **1.04**, 40% = **1.08**)

Formula: Tons per acre =

11.64 X n X d2 X s X a X c

length of transect (L)