SOILS

Introduction

Soil is the backbone of ecosystem integrity yet remains difficult to quantify when assessing impacts of human and natural disturbance. A general lack of long-term data on management and difficulty in obtaining true reference conditions complicate interpretations. Evidence of short-term impacts to soils from management activities is readily available (Harvey et al. 1994; Perry et al. 1989, Megahan 1992, Prietikäinen and Fitz 1995, Fisher and Binkley 2000) though inherent soil variability can confound results (Fisher and Binkley 2000).

Therefore, assessments on management impacts rely on theoretical assumptions for preserving soil as a life source. Much of this theory centers on preserving soil life attributes: soil aeration, adequate moisture, and organic substrate for sustained soil microbial and fungal communities along with plant communities.

As soil is the ecosystem backbone, it is not surprising soil houses roughly 98% of the diversity of species (Neher 1999). This diversity includes microbes and fungi on up to higher order invertebrates and mammals (Perry and Amaranthus 1997; Stevenson and Cole 1999). The impact of our management actions may select for certain species or orders of organisms. In comparing clearcuts with undisturbed sites in the greater Yellowstone region, clearcuts had 55 identified mycorrhizal species compared to 66 in the undisturbed areas (Byrd et al 2000, p. 156). This shift in mycorrhizal diversity may also impact plant community composition.

This analysis will focus on impacts of timber harvest and road building in the context of soil recovery after the 2002 Sheep Creek Fire. Analysis will focus on identifying sensitive areas that may be hindered from recovery after fire (see Beschta et al. 1995). Also, the impact of different logging systems will be contrasted. Finally, the cumulative impact of past disturbance in addition to proposed treatments will be assessed.

Proposed timber units define the activity area (see FSM 2554, R1 Supplement 2500-99-1, 1999, p. 6) for direct and indirect effects. Cumulative effects are analyzed two ways. First, residual effects from past events such as the Sheep Creek Fire, timber harvest, and cattle grazing are addressed with respect to their cumulative impact on proposed units. Second, a watershed scale approach assesses residual impacts including all forms of disturbance from permanent roads to past harvest.

Field Surveys/Resource Contacts

The data and analysis contained in this report relied heavily on input from Beaverhead-Deerlodge resource staff. Soils expertise was provided from Soil Scientists Dave Ruppert and Dan Svoboda. Soil resource data was obtained using the Land System Inventory (Poff and Svoboda 1981), draft updated Soil Survey, and soil modeling using digital elevation models (30m). Supplementary GIS layers included timber stands attributed from the timber stand database, road and trails, weed risk derived from the Satellite Image Land Cover Classification (SILC), vegetation habitat derived from SILC, and historical vegetation and soil plot data.

Information on the site existing condition was gathered through interviews with resource staff and soil field data gathered in summer 2002 in many of the proposed timber salvage units. Sampling documented soil strength and downed wood distribution in proposed tractor units 2, 3, 5 and 6 along with one cable unit (12; see Figure 2 for unit layout). Sampling did not cover known previously harvested areas. A static cone penetrometer (ELE International Model #29-3739) was used for surface and subsurface estimates of soil strength (Dan Svoboda, personal communication 2003). Soil strength is defined as the resistance of soil structure against the impact of forces such as downward pressure from vehicles. At each transect point soil was assigned qualitative values according to soil disturbance (Howes 2000).

Forest Plan Direction/Other Direction

Forest Plan direction specifies the following goal for soil:

> *"Soil productivity will be maintained and soil erosion will be minimized through the application of BMPs developed through project design and analysis, careful riparian area management, and appropriate mitigation measures. If soil productivity or erosion approach unacceptable levels, project design will be modified, more restrictive mitigation measures will be applied, or projects will be dropped or rescheduled.*" (USDA FS1986, p. II-5)

Below is a forestwide standard:

> *"Coarse woody debris* [*> 3 in diameter*] *maintained at 10-15 tons/acre."* (USDA FS 1986, p. II-29, II-31)

For Management Areas 16 and 20, the following standards contain soil-specific language:

> *"Road construction will be to the minimum standard and density needed to achieve Management Area goals and protect soil and water resources."* (USDA FS 1986, p. III-49, III-65)

Regional guidance for maintaining soil productivity as directed by the National Forest Management Act of 1976 is outlined in the Forest Service Manual (FSM 2554, R1 Supplement 2500-99-1, USDA 1999). Soil productivity is maintained by limiting detrimental impacts of compaction, displacement, rutting, severe burning, and loss of organic matter to less than 15% over an activity area, (i.e. project unit). Detrimental soil disturbance beyond 15% is considered deleterious to soil productivity. In addition, the guidelines specify management activities not cause soil erosion more than one to two tons/acre/year. For areas previously disturbed, the cumulative detrimental effect of prior and planned activities must not exceed 15%.

In addition, the Beaverhead-Deerlodge National Forest scales up these standards to the watershed scale incorporating the 15% threshold to detrimental soil impacts in a 6th code HUC watershed (USDA FS 2003c, p. 3.242). Based on communication with the former regional soil scientist, John Nesser, this interpretation includes analysis of permanent roads within the watershed (Dan Svoboda, personal communication 2003). This interpretation differs from activity area analysis, which excludes permanent roads from analysis (FSM 2554, R1 Supplement 2500-99-1, USDA 1999, p. 3).

Affected Environment

Soils in the project area are derived from frost-churned landforms in a montane setting. Soils range from moderately deep Sandy-skeletal, mixed Typic Eutrocryepts to Loamy-skeletal, mixed superactive Andic Eutrocryepts (Greene 2003). Forest staff observations indicate ash is not very abundant and has scattered distribution; therefore, Andic Eutrocyept is not prominent in the study area (Dave Ruppert, personal communication 2004; Dan Svoboda, personal communication 2003). The landscape is stream-dissected with upper elevation ridges having moderate frost churning. The parent rock is Tertiary age grano-diorite with evidence of glacial till deposits (Poff and Svoboda 1981; Dave Ruppert, personal communication 2004).

The climate is quite cold with minimum temperatures averaging 3° F during January (Prism Climate Model, Disturbed WEPP, and USDA FS 2003b). The combination of cold temperature along with infertile granitic parent rock creates limitations for soil development.

Based on the photo interpreted Land Systems Inventory (Poff and Svoboda 1981), coniferous habitat ranges from Douglas-fir to lodgepole pine with subalpine fir. The mapping shows drier, lower elevation Douglas-fir habitat grading up to higher cooler aspect and more mesic lodgepole and subalpine fir habitat (Landtypes 46B, 58C).

These soils are moderately deep and may actually be deeper than lower elevation soils. The frost-churning action breaks up parent rock and adds to the bedrock decomposition. This in turn adds to soil formation. This frost action complements the limiting soil development factors of climate and relatively infertile granitic parent rock. The cold climate and drier south facing aspect reduces plant productivity. Thus, these soils are mapped as moderately developed inceptisols, with sandy soil texture and prominent rock fragments as indicated by the sandy-skeletal family name.

These young granitic derived soils have properties that affect erosion potential. Soils are generally well drained with sandy loam texture and skeletal family classification. Observations have found a large distribution of coarse rock throughout the soils, with greater than 15% surface coarse fragments (Dave Ruppert, personal communication 2004). Glacial till deposits along with colluvial deposits of frost-heaved rock may increase soil depth and add resistance against erosive overland water flows. However, road cut areas may be problematic since impermeable granite bedrock forms perched water tables that concentrate water. Therefore, headcutting can occur with more resistant topsoil undermined by structurally weaker subsoil.

Within the project area, these erosion-buffering properties are more prominent on ridge tops correlating to map unit 108Sa (Table 39). Lower elevation and steeper sloped soils, though mapped with similar soil series, occur in map unit 538Sa (Table 39). Just based on overall soil properties, montane ridges would have “moderate to slight” erosion risk and montane slopes have “high to moderate” erosion risk (Dave Ruppert, personal communication 2004). More detailed assessments of slope steepness and ground cover found in the Environmental Effects section provide finer estimates for erosion risk.

The orientation in the landscape and the soil types create low mass erosion potential. Upper hillslope/ridgetop areas do not have as high a potential for slumping. The variables of shallow bedrock, well drained soils, and low clay content lower the risk of positive soil pore pressures that can activate mass movement. In these granite bedrock dominated areas, a deep-seated plane is not present for rotation.

To establish baseline information on soil strength for monitoring harvest impacts to soils, soil condition surveys were done in summer 2002. Proposed treatment units 2, 3, 5, 6 and 12 along with two control areas nearby were surveyed. Proposed timber units differed significantly ($P<0.0001$) when comparing average strength scores using a one-way analysis of variance, though none were found to have root-limiting soil resistance (Figure 27). All results were below known threshold values of roughly 290 pounds (about two Mega Pascals (M Pa)), assuming dry soils.

Baseline soil strength is important for interpreting future soil impacts. Horn and Baumgarle (2000, p. A-22) reported two MPa soil resistance impedes root growth roughly 50% (also see Allmaras et al. 1994, p. 21; Powers 2002, p. 17), while three MPa soil resistance (roughly 435 pounds) completely limits root growth in cropping systems. Brady and Weil (2002, p. 146) showed similar findings when comparing compacted and uncompacted soils.

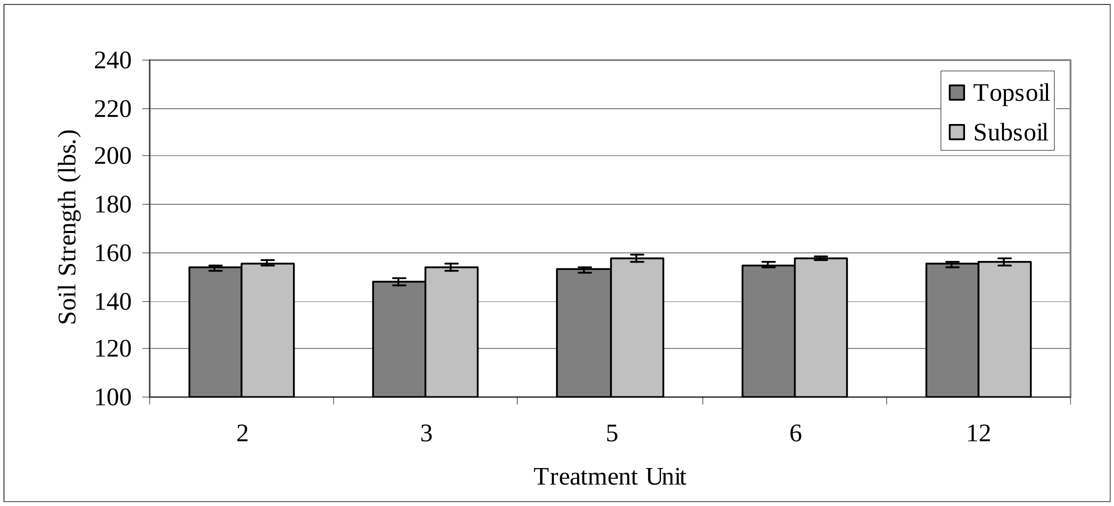
Table 39 - Treatment unit by soil map unit, landtype, slope, and area (Greene 2003).

Treatment Unit*	Map Unit	Landtype	Slope (%)	Area (acres)
1T alt2	108Sa	Ridge	20	104
1T alt2	538Sa	Slope	28	66
1T alt3	108Sa	Ridge	20	38
1T alt3	538Sa	Slope	28	11
2T	538Sa	Slope	28	49
3T	538Sa	Slope	20-35	40
4T	538Sa	Slope	40	22
5T	538Sa	Slope	28-40	41
6T	538Sa	Slope	35	36
7T	108Sa	Ridge	15	49
7T	538Sa	Slope	25	17
8T	108Sa	Ridge	25	44
8T	538Sa	Slope	35	12
9T	108Sa	Ridge	15	82
9T	538Sa	Slope	28	15
10C	538Sa	Slope	40	69
11C	538Sa	Slope	35	45
12C	538Sa	Slope	28-40	67
13T	538Sa	Slope	28	11
14C	538Sa	Slope	40	2
15C	538Sa	Slope	40	3

*T stands for planned tractor-yarding units and C represents cable-yarding units.

The findings indicate none of the proposed units has substantial past harvest impacts and show that site differences do exist for interpreting future readings. Looking at the treatment map (Figure 2), treatment unit 3 is west facing while all other sampled sites are south. Possibly, unit 3 has lower average soil strength due to greater soil development from wetter conditions on this west aspect.

Information on site recovery following wildfire and state of downed wood was gathered from specialists for summer 2002 and 2003. Downed wood measurements were taken with penetrometer data. Intercepted downed wood is available in Table 40. All units had large logs (greater than nine-inch diameter) sampled, except unit 5. This unit had nine downed pieces within the range of three- to nine-inch diameter. Overall, the current downed wood appears in the low range of the forest standard of 10-15 tons/acre. Downed wood recruitment from fallen burned trees will increase these levels.



Data range from 123 to 169. The bars in the figure represent averages (Error bars = standard error).

Figure 27. Average soil strength data by treatment from summer 2002 (representing existing condition).

Existing condition of groundcover was based on photos and assessments from the Burned Area Emergency Rehabilitation Report (BAER) (USDA, 2002b). Figure 28 shows an example of site conditions at the project area. Groundcover is good, with beargrass (*Xerophyllum tenax* (Pursh) Nutt.) cover at roughly 40% and downed wood throughout the site. Beargrass is important because its matted roots secure soil from erosion. Observations by the BAER team indicated ground-spreading shrubs grouse whortleberry (*Vaccinium scoparium* Leib.) and dwarf bilberry (*Vaccinium caespitosum* Michx.) are common at the project area. Kinnikinnick (*Arctostaphylos uva-ursi* (L.) Spreng) is another important shrub adding stabilization that may occur in the project area.

Table 40 - Coarse woody debris intercepted along treatment unit transects by diameter class.

Units	3-6" Diameter	6-9" Diameter	9-12" Diameter	>12" Diameter
2	1	7	5	0
3	2	5	1	1
5	3	6	0	0
6	1	3	1	1
12	3	4	2	0

The effect of fire on soils largely depends on how severely the fire burned. The BAER report indicated most of the project area had low-severity burn and that severity followed patterns of burn intensity (USDA FS 2002b, p. 2). Burn severity represents heat penetrating deep into soil while intensity has ties to flame length above the soil surface (DeBano et al. 1998, p.63). For some crown fires, thermocouple measures showed no heating effects below five cm in soil (Hartford and Frandsen 1992, p. 143). However, under slash piles temperatures may reach upwards of 1000° F and “chink” the soil, baking the soil like a brick (Glassy and Svalberg (date unknown), p.2; Debano et al 1998, p. 63).

The fire burned in a mosaic pattern with rapid revegetation likely. Vegetation recovery was estimated at 5 to 20 years (USDA FS 2002b, p.2). The weakly dissected landforms found in the project area had far less effect on burn patterns than did fuel concentrations, wind speed and direction (ibid. 2002b). Thus, slope and aspect did not strongly drive burn severity on soils.

This analysis follows the logic of the BAER report and assumes fire severity matches mapped fire intensity. Units with large areas of moderate burn severity include units 1, 2, 3, 7, 9, and 12 (see Table 41) and therefore will be slower to revegetate.

Table 41 - Proposed harvest unit by burn severity (USDA 2002b).

Unit	Burn	Acres
1	low	62
1	moderate	100
2	low	36
2	moderate	18
3	moderate	40
4	low	22
5	low	24
6	low	36
7	low	29
7	moderate	22
7	unburned	12
8	low	39
8	unburned	16
9	low	16
9	moderate	77
10	low	69
11	low	46
12	low	27
12	moderate	37
13	low	3
13	moderate	6
14	low	2
15	low	3

Disturbance History

Prior to the recent wildfire in 2002, no evidence was found for wildfire in the project area for the past 40 years (TSMRS database query, Beaverhead-Deerlodge National Forest). Most fire incidence was associated with site preparation activities at timber harvest sites. These areas can experience high fire severity where slash is piled.

Fire severity paralleled fire intensity in the Sheep Creek Fire (USDA FS 2002b, p. 3). Within the proposed units, roughly 415 acres had low burn severity, 301 acres had moderate severity, and 28 acres were unburned. With this classification, low burn areas would have light ground char and partially consumed wood debris accumulations with undamaged root crowns to shrubs and grasses (DeBano et al. 1998, p. 63; FSH 2509.13, USDA FS 1995) (Figure 28). Moderately burned areas experienced moderate soil heating leaving light colored ash on the ground after consuming all litter, charring duff, and deeply charring wood debris (DeBano et al. 1998).

Soil response following fire depends heavily on this fire severity. In low- to moderate-severity fire, microbial populations may be less impacted since heat does not penetrate deep into the soil. In contrast, a high-severity burn may be lethal in the topsoil area. However, even in severely burned areas some biological activity remains, though functional diversity does not resemble pre-burn levels. Jimenez-Esquilin and Stromberger (2003) showed how some microbial taxa were returning one year after fire, postulating refuge was found deeper in soil during the burn.

The long-term soil response depends on the soil site condition following the fire (Zouhar and Deluca 1999, p. 40). Prietikäinen and Fitz (1995) found large reductions in more severely burned harvest/burn scenarios with reduced microbial biomass four years after treatment. For wildfire with mixed severity, nutrient dynamics usually show a short-term flush, and then taper as fire killed substrate lessens (Choromanska and Deluca 2001, p. 234). Notably, microbial biomass was twice as high in a wildfire burned area where a prescribed burn took place three months prior than in the wildfire burned areas without a prescribed burn two years after the wildfire (ibid. p. 237). Thus, the modified site condition had direct implications on microbial biomass with resultant changes to nutrient availability.

Figure 28. Photo illustrates low to moderate fire severity area for soils. Beargrass appears to cover about 40% of the ground.

Historical timber harvest in this watershed (6th code HUC 100200040407) has occurred at a constant rate over the past 40 years, tapering off in the late 1990s. Harvest ranged from a low of 315 acres clearcut during the 1990s to a high of 466 acres clearcut in the 1980s (Table 42).

Research found residual soil impacts from ground-based harvest systems average 30% detrimental disturbance across the timber harvest unit (Block et al 2002, McIver and Star 2000, Clayton 1990). Soil monitoring in the nearby Grasshopper valley found soil compaction evident following 10 to 20 years of recovery following harvest. A t-test was used to compare harvest impacts for cut and no-cut areas. Significant differences were found between harvested and unharvested ground ($P<0.001$) for penetrometer derived soil strength values (see Grasshopper soil data in project file). Less than 1% of these values exceeded known root limiting soil strength values.

Table 42 - Historic disturbance in watershed (6th HUC 100200040407 @ 18,595 acres) for planned salvage. All values are acres.

100200040407 6th code HUC Watershed	Decade	Clearcut	Select	Thin	Total
	1960	377	0	0	
	1970	3127	72	0	
	1980	5651	32	350	
	1990	320	767	563	
Harvest Total		4389	871		5260
Adjusted with 30% detrimental disturbance		1317	261		1578
Severe and Moderate Burn*					130
Road Total					214
Total Disturb Acres					1922
				% Watershed =	10

*Severe and moderate burn estimates from Sheep Creek BAER Report (USDA FS 2002b, p. 3).

Residual harvest impacts from the Lewis & Clark National Forest in northeastern Montana found some 1970s era clearcuts had very good intact understories with no compaction detected. Others of the same era had missing topsoil from extensive soil mixing and very few native species present. Expected impacts depend on operator care, season of harvest and weather conditions during harvest for both re-growth and erosion hazard.

Based on literature and monitoring data, old harvest units in the Sheep Creek project watershed were assumed to have 30% detrimental soil disturbance, regardless of age. For roads, 100% was considered detrimental soil disturbance.

The Sheep Creek project area watershed has timber harvest concentrated on the north side of Highway 43 with disturbance of roughly 12%, including roads. Disturbance over the 6th code HUC watershed area (18,595) acres was 10%. The north-facing slope of the watershed has little harvest activity and currently is designated inventoried roadless.

For context, 3,992 acres of harvest at 30 percent detrimental soil disturbance, 177 acres road disturbance and 130 acres of severe burn exists on the north half of watershed (12,310 acres) resulting in 12 percent disturbance.

Disturbance from recreation and grazing occurs in the project area though the impacts are unclear. Motorized use has seasonal restrictions and some dispersed camping may occur during hunting season. Potential impacts from these activities would be confined to areas of compaction and displacement, and a broader risk of spreading noxious weeds.

Observations from the BAER team found presence of spotted knapweed, oxeye daisy (*Leucanthemum vulgare* Lam.), common tansy (*Tanacetum vulgare* L.), musk thistle (*Circium spp.*) and common mullein (*Verbascum thapsus* L.) along travel corridors. The extent of weed infestations may not be known for up to three years following disturbance (USDA FS 2002b, p. 10).

Noxious weed presence may lead to physical and biological changes in soil. Organic matter distribution and nutrient flux may change dramatically with noxious weed invasion. Spotted knapweed (*Centaurea biebersteinii D.C.*) impacts phosphorus levels at sites (LeJeune and Seastedt, 2001) and can hinder growth of other species with allelopathic mechanism. Specific to spotted knapweed, these traits can ultimately limit native species' ability to compete and can have direct impacts on species diversity (Tyser and Key 1988, Ridenour and Callaway 2001).

Environmental Effects

Executive Summary

The action alternatives would not exceed regional soil guidelines for soil quality (USDA FS 1999) with mitigation for proposed treatment units and hazard tree removal areas. Soil guidelines would also be met for two acres where old skid trails would be used outside units 3 and 8. Restoration activities would be implemented to ensure continued recovery beyond pretreatment levels as mandated by the soil guidelines (USDA FS 1999, p 2). By meeting soil quality guidelines, these proposed actions would likely not impact soil productivity significantly. Table 43 outlines the projected percentages of detrimental disturbance for the action alternatives. The sensitive site condition following wildfire on erosion-prone, granitic substrate necessitates special soil considerations. Risks of soil displacement and accelerated soil erosion have the greatest potential to affect soil productivity. These risks are directly tied to the amount of groundcover remaining following treatment.

Table 43 - Detrimental soil disturbance by harvest unit for action alternatives.

Unit	Alternative 2	Alternative 3
1	14.3	13.0
2	13.0	13.0
3	13.0	13.0
4	13.0	13.0
5	14.0	13.0
6	13.0	13.0
7	14.3	13.0
8	13.5	13.0
9	13.0	13.0
10	6.1	
11	5.0	
12	5.0	
13	13.0	13.0
14	13.0	13.0
15	5.0	

Mitigation options are offered to maintain soil productivity. These include: 1) operating during winter conditions; 2) through coarse woody debris management; and 3) preserving groundcover. The highest disturbance areas, log landings and temporary roads, would be reclaimed to aid soil re-development. Vegetation regrowth would continue and lower incidence of accelerated erosion following wildfire disturbance. Soil guidelines apply only to management actions and thereby do not restrict the No Action Alternative.

Background for Effects on Soil Productivity

This analysis considered impacts to soil productivity from proposed treatment activities by focusing on key indicators. These include impacts to soil biology from compaction, soil displacement, and erosion. These indicators largely relate to soil quality and function as surrogates for assessing productivity.

As mandated by the National Forest Management Act, management shall avoid permanent impairment to site productivity with special attention to soil and water resources (36 CFR 219.27(b)). Since soil productivity is important to ensure *site* productivity, Forest Service standards were set. These standards focused on a minimum detectable difference for assessing impairment to soil productivity (see USDA FS 1999). Most measures involve a 15% threshold. The measures largely use soil quality indicators as surrogates for productivity. The assumption is that if soil is compacted, then the reduced soil functional attributes of holding water, supporting microbes/macrofauna, and aeration would also be reduced.

Soil productivity is closely linked to soil biology since many of the essential nutrients used by plants are the results of biological processes. Since soil is habitat, soil biology is sensitive to changes in site condition such as alterations to heat and moisture from canopy removal (Jones et al. 2003, p. 411; Powers 2002, p. 72). Impacts from ground-based logging systems can alter site condition through soil displacement, compaction, and erosion (Harvey et al. 1994, p. 11; Powers 2002, p. 71). Compacted soil leads to less air for soil respiration and alters soil water status. Displacement removes carbon substrate and topsoil, which is rich in biological activity. For burned areas, slope steepness and slope length are strong erosion indicators that relate to effects of logging equipment. Torque from tracked vehicles would be greater on steep grades, causing increased displacement and compaction (Hillel 1998). Greater slope length increases energy for eroding soil.

To reduce logging impacts to soil biological processes, ground cover should be preserved and plant species diversity and abundance should be maintained. Site ground cover and recovering plant species increase colonization potential for microbes. Native shrubs may act as “refuge plants” for ectomycorrhizae recolonization (Jones et al. 2003, p. 422). While severely burned fire zones may have reduced ectomycorrhizal formation, inoculum persists in deeper soil layers for colonization as native vegetation is reestablished (ibid., p. 407) Plant diversity can aid in the recovery following disturbance by stabilizing belowground mutualists (Perry et al. 1989, p.4; Harvey et al. 1994, p. 14).

Leaving dead and downed wood on the site also moderates impacts from logging activities. The temperature and moisture modifications of downed wood on the forest floor create zones for increased soil biological activity with greater mycorrhizal fungal activity and concentrated bacterial populations (Graham et al. 1994, Perry and Amaranthus 1997, p. 44).

Based on the Northern Region Snag Management Protocol (USDA FS 2000, p. 12), leaving 5 to 10 snags per acre is recommended with emphasis on the largest diameter trees, and Douglas-fir where it occurs. Large diameter Douglas-fir may stand longer and provide benefits to soil productivity (Perry et al. 1989, Evers 2002, p. 18). Leaving snags may reduce logging impacts on soil biology because standing snags offer some shade, reducing solar radiation, and may moderate soil temperatures by altering wind dynamics (Fisher and Binkley 2000, p. 72). Snags also become woody debris. Decomposition rates will differ between standing snags and downed wood. As snags fall, they offer different levels of physical and chemical structure. By leaving some snags either in clusters or as individuals, the beneficial soil properties of this forest standard will extend longer term. Treatments are proposed to leave 10 to15 tons per acre in compliance with the Forest Plan standard (USDA FS1986, p. II-29, II-31).

The timing of timber harvest can greatly influence soil impacts. For instance, winter harvest can offer added protection if done when soils are frozen or a snow buffer exists. Though not as effective, logging during dry months can minimize compaction since soil strength is maximized when moistures are generally lower than 6% (Craig 1983, p. 33). Above a six percent threshold, soils are more prone to compaction (ibid.). While dry soils offer some protection against compaction, the method of mechanized harvest operation can largely affect the degree of compaction.

Amaranthus and Steinfeld (1997, p. 5) point out soil compaction results from the first few passes with mechanized equipment. Low pressure tracked or wheeled equipment may have low stationary or static ground pressures as low as 7 psi. Once in operation, torque from pulling heavy loads, turning or forward motion greatly increase ground pressures and thus compaction potential (Hillel 1998). In comparing rubber tire with tracked skidders, Clayton (1990) reported tracked vehicles had 50% greater dynamic pressure even though both had equal static pressures. Therefore, effects will depend largely on equipment used and methods. Skidding downhill versus uphill reduces torque and thus reduces pressure on soils.

Soil erosion caused by logging may result in loss of fertile topsoil. Natural replacement of topsoil in these granitic soils is slow due to inherently infertile mineral composition and resistant mineral structure for soil formation (Dan Svodboda, Beaverhead Forest Soil Scientist, personal communication 2003). Megahan (1992, p. 28) found added erosion risk on south-facing slopes for areas with hot dry summers in the Idaho batholith region. The proposed project area has similar south-facing aspects, though a moderate mean maximum July temperature of 78 °F (Prism climate model, WEPP, USDA FS 2003a).

Erosion forces include overland water flow (Ritter et al 2002, p. 145) which can be increased by roads and skid trails. Bare soil is less cohesive with loss of ground cover, which intercepts raindrop splash and overland flow. Accelerated erosion occurs when weakly bound soil is exposed to channelized flow, especially in steep areas where gravity increases water overland flow.

The return of groundcover, which is important to minimize erosion, depends on the site growth characteristics such as available seed source, soil moisture and how much vegetation survived the fire (Elliot et al. 1999; Megahan 1992, p. 14; Clayton and Megahan 1997, p. 693; Robichaud et al. 2000, p. 48). Addressing burned area rehabilitation, Robichaud et al. (2000, p. 48) cite 30% cover reduces erosion by half and 60% cover reduces erosion rates to insignificant levels.

The project area has some increased susceptibility to erosion based on the stream-dissected nature of the landscape and granitic parent material, and because the fire exposed bare soil by consuming groundcover. Abundance of rock fragment and naturally high infiltration rates may counteract this erosion potential. Cobble and stone-sized rock fragments lessen the erosive energy of overland flows while the high infiltration reduces the volume of flows. Erosion following fire can vary with low figures of 18 Mg/ha (8 tons/acre) from low intensity fire, to higher figures of 85 Mg/ha (38 tons/acre) associated with high-intensity fire (Baird et al. 1999, p 239; Amaranthus and Trappe 1993, p. 45). For management activities, erosion thresholds are set at two tons/acre/year (USDA FS1999). Erosion following fire largely depends on rainfall intensity (ibid. p. 45). Soil sampling in the project vicinity indicated large sediment dumps with much buried charred wood (Beaverhead-Deerlodge National Forest Ecodata). This data indicates there are historical sediment flushes following large wildfires. The impacts of management given this historical context are difficult to gauge. The issue remains complex and debatable (Moore et al. 1999, p. 1274).

For assessing the impacts of logging on areas with recent wildfire, additional erosion resulting from these activities may impair recovery. On one hand, fire is a natural disturbance mechanism for this ecosystem with resultant accelerated erosion. On the other hand, burned areas represent sensitive sites for soil recovery (Beschta et al. 1995). Regional guidance suggests no more than two tons/acre/year soil erosion occur as a result of management activities (USDA FS 1999). Also, soil productivity is to be maintained as stipulated in the Forest Plan (USDA FS 1986). Therefore, management activities are assessed as to their effects on the *current* soil condition.

Direct and Indirect Effects

Alternative 1 – No Action

This alternative maintains the existing condition of the project area. Soils are stabilizing after the wildfire disturbance with groundcover returning. Taking no action preserves these processes, though a reburn could affect soil productivity at the site.

In a paper on balancing hazardous fuel loads with benefits of coarse wood, Brown et al. (2001, p. 8) recommended 10 to 30 tons/acre of coarse wood for cool Douglas-fir and lodgepole cover types. At 40 tons/acre detrimental soil heating (275 °C) that kills soil microbes could penetrate two centimeter into mineral soil (ibid., p. 5), though larger downed wood (> six inch diameter) would extend this threshold higher. In assessing risk for severe burning, Brown et al. (ibid., p. 9) found the greatest likelihood 30 to 60 years following the initial burn since adequate ground fuels would exist to carry fire and greater amounts of wood material would be in contact with the soil. Therefore, during years 30 to 60 (assuming the predicted fuel increase of 70 tons/acre detailed in the purpose and need (Chapter 1)), risk of severe burning would be elevated with fuel loads greater than the upper threshold of 40 tons/acre for detrimental soil heating.

Risk of accelerated erosion would remain in some areas. Proposed treatment units 12 and 13 have greater risk for erosion than other areas due to site circumstances (Figure 29). Habitats in these areas have less probability of root binding shrubs in combination with steep slopes and moderate burn severity.

When comparing the alternatives, the No Action Alternative would likely have less deleterious impacts to soil productivity. Some risk of higher burn severity and higher postburn erosion does exist if a reburn were to occur within the 30- to 60-year timeframe. In addition, the erosion risk at units 12 and 13 is lower than predicted erosion from the action alternatives (Figure 29).

Alternative 2 – Proposed Action

This alternative would have the greatest risk for direct and indirect effects on the soil resource. Disturbance from timber harvest operations would cover more area than Alternative 3 with activities in all proposed treatment units (1-15). Soil disturbance from road building would occur along 2.6 miles traversing unit 1, 5, 7, 10 and a clearcut harvest unit from 1991. The risk of mass failure of soils was not found.

<u>Tractor Logging</u>

The general risk of erosion, compaction, and displacement applies to all proposed ground-based treatment units (1-9, and 13; see Figure 2). Alternative 2 presents the greatest risk since more area is proposed for treatment by tractor logging than Alternative 3.

Harvest operations during winter, when soil is either frozen to a depth of four inches, or under settled 24-inch snow cover, will minimize compaction and displacement from harvest activities. In comparing levels of severe soil disturbance from postfire logging, McIver and Star (2000, p.15) cite tractor skidding 36% disturbance, followed by cable skidding (32%). Tractor skidding over snow created 9.9% disturbance. Even though this study was conducted on a site substantially different from the proposed project area, it demonstrates the dramatic reduction in effects between harvesting in winter versus non-winter conditions. Thus, for this analysis, skidding operations over snow or frozen ground are analyzed assuming 10% detrimental disturbance. An additional 1 to 3% disturbance may result from pile and burn activities following burning.

Incidental slash that exceeds the forest standard would be piled and burned for all tractor units.

The excavator would have the same seasonal and slope restrictions as for harvesting equipment. Mitigations would lower impacts overall, though the concentrated severe burning at slash piles complicates soils recovery following the recent wildfire (Ken McBride, personal communication 2004).

Incidental slash that exceeds 20 tons per acre on would be excavator piled and burned for all tractor units. The projected amount of slash may be 10 to 15 piles per acre. Piles are limited to a 15-foot diameter size to reduce heat concentration and promote biotic reestablishment from areas not severely burned. This amounts to 10-15 tons per acre removal assuming piles stack one ton of downed wood. Coincidentally, a remaining 10-15 tons per acre coarse wood would be maintained after slash piling.

Forest soil scientists prefer that pile burning occur at landings. However, if outside the landing, then smaller piles are preferred over larger piles (Sue Farley, personal communication 2004; Dave Ruppert, personal communication 2004; Ken McBride, personal communication 2004).

Since tractor-units may reach up to 14% detrimental disturbance with a combination of harvesting, temporary road construction and fuels treatments, regional guidelines would be met within planned treatment units. Correct use of mitigations and operator care could reduce this disturbance dramatically. Given this compliance, the impacts would not likely significantly impact soil productivity (Table 43).

The planned use of old skid trails in past harvest units next to units 3 and 8 would meet soil guidelines as long as these areas are left in better condition than prior to treatment. Residual disturbance is currently 30%, mainly due to old skid trails. The old skid trails planned for use amount to two acres. Since restoration techniques may have mixed success, recommended restorative treatments would be assessed and implemented through consultation with the Forest soil scientist. Treatments would include: (1) installing erosion control measures, (2) decompacting only detrimentally compacted areas with a disc or subsoiler, (3) seeding/transplanting native grasses/shrubs only in viable planting areas, (4) placing coarse wood debris at 10-15 tons/acre, and/or (5) recontouring skid trails to the existing slope. These restorative treatments would likely improve soil functional attributes to conditions above pretreatment levels and thereby maintain direction of regional guidelines (USDA FS 1999). Erosion risk would be diminished using winter harvest operations. Detached sediment should not exceed the 1 to 2 tons/acre/year as long as ground cover is preserved and water energy is dissipated for units 1, 5, 8, 10, 11, 14 and 15. However, a 10 to 20% probability of generating sediment over the regional standard may occur for units 2, 3, 4, 6, 7, 9, 12 and 13. Units 9, 12 and 13 have existing erosion risk from the Sheep Creek wildfire and steep slope setting above the regional standard.

Overall, almost half of the planned area for tractor harvest occurs on low slope ground (288 acres) (Figure 29). These areas have lower erosion risk. Higher risk is associated with steep ground on 39 acres in the project area. These steep areas have increased risk where groundcover is limited from either higher burn severity or less abundant root matting shrubs (see Table 44).

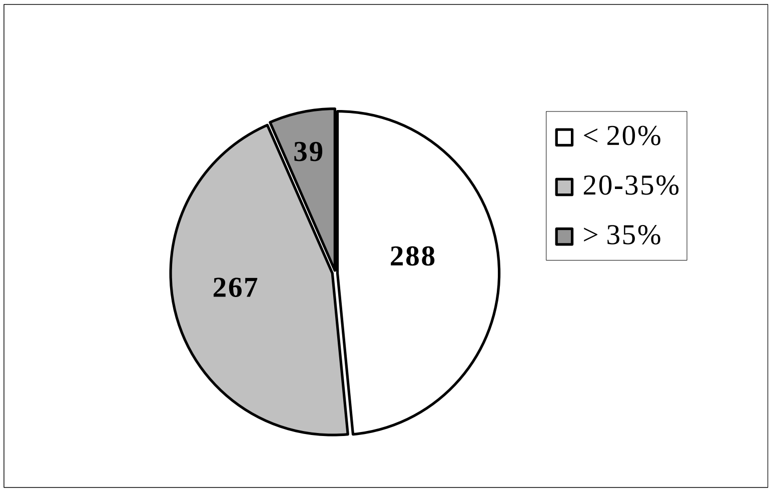
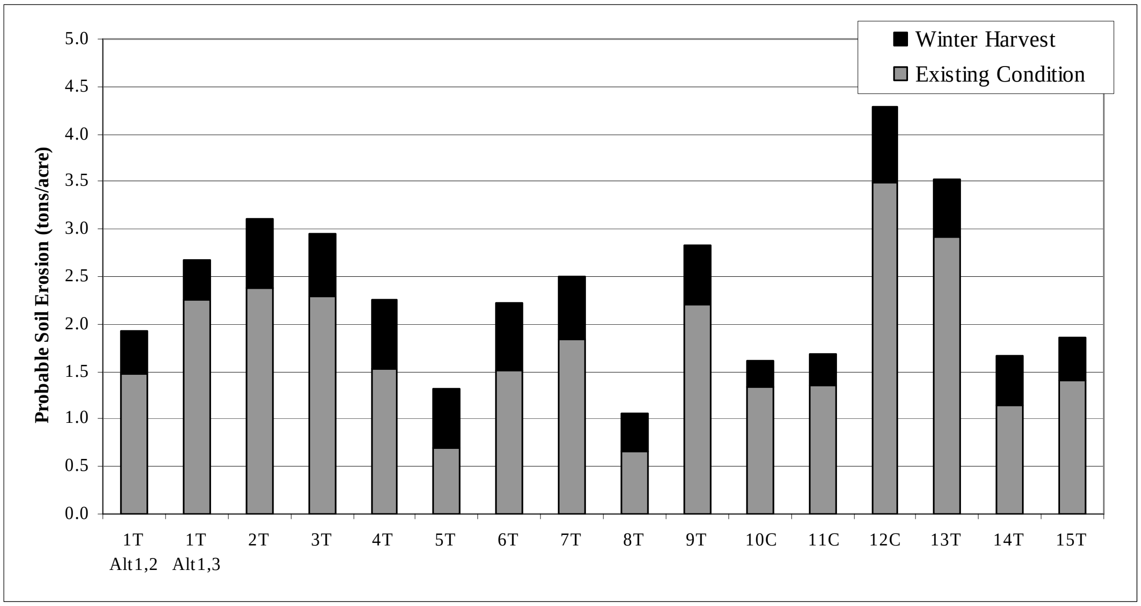


Figure 29. Treatment areas (acres) within different slope class for tractor logged units. Slopes were generated using 30 m. digital elevation models.

To assess erosion risk, the WEPP erosion model was used (USDA FS 2003a). Results are based on the probability a strong enough climatic event triggers soil erosion within two years of project implementation. Tractor units were assumed to increase bare cover by 10% (McIver and Starr 2000), while cable units would increase bare ground by 5% (USDA FS 2003e).

Figure 30 shows the modeled erosion for the action and no action alternatives. Treatment units 2, 3, 4, 6, 7 and 9 have site characteristics where erosion may be problematic. Unit 1 has some small sections with higher erosion risk, though the unit in general has less overall erosion potential. Slope is generally low and the fire burned as a mosaic, thereby breaking up erosive water energy. The extent and type of site variables more prone to erosion are highlighted below (also see Table 44):

- Unit 2: Moderate slopes and long slope length at 54 acres.
- Unit 3: Steep slopes at 14 acres with moderate slopes and moderate-severity burn on 26 acres.
- Unit 4: Moderate slope and moderate-severity burn at 22 acres.
- Unit 5: Steep slope for 17 acres.
- Unit 6: Moderate slopes for 29 acres and steep slopes for 8 acres.
- Unit 7: Moderate slope and moderate-severity burn at 40 acres.
- Unit 9: Moderate slope and moderate-severity fire at 64 acres.



*T= tractor skidding – 10-20% risk for soil erosion   C= cable skidding - 10% risk for soil erosion

Figure 30. Predicted erosion in treatment units for no action and action alternatives.

These erosion-prone areas contribute to the higher erosion rates reported in Table 44 and Figure 30. Unit 13 has the highest modeled erosion amongst the tractor units, though it is not deemed as high risk since it only extends 11 acres.

If a significant storm does not occur, erosion risk will diminish substantially in four years. This estimate is based on a minimum 40% groundcover reported by Robichaud et al. (2000, p. 48) for negligible erosion rates and reported recovery rates from harvested postfire burn studies (McIver and Star 2000, p. 11).

As the project site revegetates following treatment, erosion risk drops. If a big erosion pulse-event does happen, detached sediment would be removed but additional events would not produce as much sediment since loose sediment would already be transported. Once the soil is removed impacts on soil productivity can last for decades since granitic substrate has limited soil development capacity. For overall soil productivity, localized erosion is not as detrimental as gully erosion where soil processes are hindered by channelized water flows.

Considering erosion risk amongst the alternatives, the No Action Alternative would have the least risk since recovery from wildfire would continue. Of the action alternatives, Alternative 3 would pose the least risk by omitting road building and harvesting fewer acres. Winter harvest would lower risk of most erosion concerns from harvest operations. In addition, tractor harvest has mitigations to avoid ground steeper than 35% and designate skid trails. Finally, protecting the roadfill slopes from disturbance would lower erosion since the sediment filter would halt water routing from roads.

Table 44 - Site characteristics and probable erosion for existing condition and action alternatives.

Unit	Burn	Slope (%)	Slope Length (ft)	Area (acres)	Existing Cover (%)	Existing Erosion (tons/acre)	Adjusted Existing Erosion (tons/acre)	Probable Cover (%)	Probable Erosion (tons/acre)	Adjusted Probable Erosion (tons/acre)

Unit	Burn	Slope (%)	Slope Length (ft)	Area (acres)	Existing Cover (%)	Existing Erosion (tons/acre)	Adjusted Existing Erosion (tons/acre)	Probable Cover (%)	Probable Erosion (tons/acre)	Adjusted Probable Erosion (tons/acre)
1T alt1,2	mod	15	2800	170	60	1.5		50	1.9	
1T alt3	low	15	1000	49	40	2.3		30	2.7	
2T	low	28	1600	49	65	2.4		55	3.1	
3T	mod	15	600	13	60	1.2	2.3	50	1.7	3
3T	mod	28	750	13	60	2.8		50	3.2	
3T	mod	40	500	13	60	2.8		50	4.0	
4T	low	28	1000	22	75	1.5		65	2.3	
5T	unburn	35	700	25	90	0		80	0.5	
5T	low	35	801	16	75	1.7	0.7	65	2.6	1.3
6T	low	28	2100	29	75	1.6	1.5	65	2.4	2.3
6T	low	40	250	7	75	1.2		65	1.7	
7T	mod	15	1800	26	60	1.5	1.9	50	1.9	2.5
7T	mod	28	500	40	60	2.1		50	2.9	
8T	unburn	25	600	22	100	0		90	0.3	
8T	low	25	1200	44	85	1	0.7	75	1.5	1.1
9T	low	15	1600	32	85	0.6	2.2	75	0.9	2.8
9T	mod	25	800	64	60	3.1		50	3.8	
10C	low	40	800	69	85	1.3		80	1.6	
11C	low	35	1400	46	85	1.4		80	1.7	
12C	mod	28	500	21	40	3.5		35	3.9	
12C	mod	28	1300	21	40	4.2	3.5	35	4.7	4.3
12C	low	40	800	25	65	2.9		60	3.3	
13T	mod	28	500	11	50	2.9		40	3.5	
14T	low	40	200	2	75	1.2		65	1.7	
15T	low	40	300	3	75	1.4		65	1.9	

Using disturbed WEPP model (USDA 2003a).

Cable Logging

Comparing the action alternatives, Alternative 2 would create greater risk for direct and indirect effects because of the temporary road building and additional treatment units (10 and 11) proposed (Table 43).

Regional guidelines for displacement and compaction would remain below regional thresholds with significant effects not likely. Winter skyline operations would likely lead to 5% detrimental disturbance. Soil monitoring of the Maudlow Toston Salvage Project was below 5% for displacement (USDA FS 2003e). Displacement and compaction is concentrated at roadfill slopes or shoulder-slope areas where logs lose suspension and log traffic is concentrated.

Figure 30 shows unit 12 has a much higher risk of soil erosion. The increased risk is a result of the combined site characteristics of moderate burn severity, a lower elevation Douglas-fir habitat (Poff and Svoboda 1981), long slope lengths, and steep portions of the unit (see Table 44). The Douglas-fir habitat has greater erosion potential with less likely root matting vegetation such as beargrass (*Xerophyllum tenax*) and *Vaccinium spp.*

Overall, cable units are predicted to have less erosion risk than tractor units (Figure 30). The probability for soil erosion is 10% given a significant storm event to generate runoff. The predicted difference between existing condition rate and treated rates is consistently smaller with cable systems. This difference rests on the assumption that cable systems preserve more groundcover.

Complications result from cumulative impact of tractor logging and temporary road building upslope from the units (see temporary road building section below). These upslope areas could route erosive overland flow onto cable units. The long-term consequence for these cable units would depend on the competing factors of accelerated runoff and recovering groundcover in sediment filtering areas.

Accelerated runoff from the road surface would depend heavily on the timing of road decommissioning activities and their extent. Restoring full contour, especially in the steep areas between units 7 and 10, would minimize long-term consequences.

Temporary Road Building

Alternative 2 would have direct effects from temporary road construction. These roads would be decommissioned following the same methodology outlined in the Mussigbrod soil/water mitigation (USDA FS 2002a). Since fill would be pulled back and contour restored, slope hydrology would be restored. Soil biological function may be limited from lack of topsoil and the mixing with subsoil.

Direct and indirect impacts from temporary road building would occur at units 1, 5, 7, 10, and 11. Temporary roads are within unit boundaries for unit 1 (0.9 mi) and unit 5 (0.1 mi). For cut slope areas, impacts would be greater, requiring a larger road prism and interrupting subsurface hydrology. These impacts are subtler for units 1 and 5. Unit 1 temporary roads would have cut slopes along roughly 0.3 mile, although the road prism should be small since much of the unit has very shallow slope. For unit 5, temporary road building has fewer impacts with 0.1 mile along a ridge.

Temporary road cutslopes have the greatest impact for units 10 and 11 along with building through a past harvest unit. Moderate slopes occur along 0.7 mile bisecting units 7 and 10 and secondarily for 0.3 mile bisecting units 1 and 11. Erosion may be problematic in these areas since granitic bedrock can form perched water tables and route water. At cutslopes, this can lead to concentrated water flows that lead to headcutting (Megahan 1992, p. 24). Also, concentrated water flows from roads can interfere with soil recovery within harvest units.

Road reclamation activities would greatly reduce erosion concerns if done immediately. If fill slopes remain in place, stabilizing slopes with seed and mulch along with wood debris would help intercept runoff (see Chapter II, Design Features).

Hazard Tree Removal

Compaction and soil displacement would result from hazard tree removal along road 1085. The magnitude of impact depends on the concentration of activities, and whether the area is burned. Harvest along road 1085 may range from 5-100% for any given acre with some unmerchantable cull trees left standing (see

Vegetation Section). The road bisects slopes from 20 to 30% in much of the project area (see Figure 2). Cut and fill slopes may be vulnerable to soil erosion where mechanized equipment enters either side of the road.

Based on the variability of terrain and range of harvest potential, specific mitigation is difficult to outline. Once more, available equipment would depend on the logging contractor selected. Therefore, a performance standard is recommended whereby harvest would comply with regional soil guidelines (USDA FS 1999). Recommendations are for follow-up monitoring by the Beaverhead-Deerlodge soil scientist to document success of methods. An example of hazard tree removal with low impacts to soils is a combination of long boom harvester and winter conditions, which minimized compaction and displacement (Helena National Forest Timber Sale Administrator Dave McCann, personal communication 2004). In the example, fill slope cover was preserved to address erosion concerns from water routed from roads.

Alternative 3 – No New Roads

Compared to Alternative 2, direct effects from Alternative 3 would be less deleterious to the project area overall with the elimination of temporary roads. Impacts of compaction and displacement would be reduced for treatment units 1 and 5, and eliminated in treatment units 10 and 11. Within common units, impacts would be similar for compaction and displacement. Cable and tractor logging would meet regional guidelines for proposed treatment units (Table 43). For the proposed treatment units, significant impairment to long-term soil productivity is not evident. Past harvest areas would be utilized for skidding next to units 3 and 8. These units would meet soil guidelines with the combination of added protection from winter conditions and restoration following treatment to further soil recovery beyond pretreatment levels.

Indirect effects of erosion would be much less than Alternative 2 since no new temporary roads would be constructed. McIver and Star (2000, p. 11) cite that 90% of accelerated sediment transport from logging operations can be attributed to road building. Alternative 3 eliminates road-building impacts in the moderately steep area dividing treatment units 7 and 10 and in the recovering old harvest unit directly east of unit 7. A 10 to 20% chance exists that erosion may exceed the regional standard in units 2, 3, 4, 6, 7, 9, 12 and 13 for the first two years following harvest.

Hazard tree removal would have similar impacts to Alternative 2. Regional guidelines (USDA FS 1999) are set as a performance-based standard.

Cumulative Effects

This analysis considers the cumulative impact of action alternatives given the existing postfire condition. Analysis is two tiered with one aspect given to residual effects of past disturbance within the proposed treatment units. Regional guidance suggests cumulative effects of past and present actions not exceed 15% in the activity area, defined as the treatment unit (USDA FS1999, p. 2). This is after project implementation and restoration. The second aspect will consider the impact of past and present actions at the watershed scale using the 6th code HUC watershed.

The cumulative impact of past disturbances to soils in addition to activities proposed in the action alternatives would not likely exceed regional guidelines.

- None of the action alternatives had significant effects from past harvest within proposed treatment areas since harvest occurred outside these areas. However, past harvest units adjacent to units 3 and 8 may be utilized for skidding with mechanized equipment. The cumulative effects of potential skidding disturbance on previously harvested sites is expected to be minor because skidding would occur during winter or under frozen ground conditions.

- Fire intensity and thus, surface damage, in previously harvested units was low in most cases because of the lack of fuel present when the fire passed through.
- The scale of disturbance in units 3 and 8 would be small, likely less than two acres.

To comply with regional guidance (USDA FS 1999), units 3 and 8 would receive restorative treatments to improve conditions above pretreatment levels. These treatments would be focused since traditional restoration methods have mixed results. Thus, the assessment and implementation of this restoration would be under the guidance of the Forest soil scientist. Treatments would focus on improving drainage, decompacting only severely compacted areas, establishing native grasses and shrubs and maintaining coarse wood to improve soil biological and physical functional attributes.

The following are the past, present and reasonably foreseeable actions from the beginning of Chapter 3 that have the potential to have cumulative impacts on soils. Items not listed would not have cumulative effects.

1. In 2002, Sheep Creek fire burned 2,015 acres of the project area. Suppression efforts included 7.9 miles of dozer line and 1.2 miles of handline. Fireline was immediately rehabilitated prior to snowfall, including water bar construction and sod pulled back. Also, road maintenance was performed to ensure proper drainage (USDA 2002a, 2.17; USDAb 2002). The improvements to road drainage will localize road drainage and reduce erosion potential in the study area. The recovery of dozer-line and handline is uncertain, though groundcover is anticipated to have at least two growing seasons to reestablish.

The cumulative impact from the recent wildfire in addition to proposed harvest activities would not likely lead to long-term impairment of soil productivity. The impact of the fire was generally low as indicated from soil quality assessments done in three proposed treatment units, units 2, 3 and 5 (see project file). Soil quality assessments used Howe's technique (2000) to qualitatively rate soil disturbance coupled with a penetrometer for quantitative assessments of soil strength. Qualitative assessments found only slight disturbance while quantitative measures found strength well below root limiting values. Soil strength ranged from 122-169 lbs. for topsoil and 108 to 173 lbs. for subsoil, while root-limiting measures occur at 290 lbs or 2 MPa (Allmaras et al. 1993, p. 21; Horn and Baumgarle 2000, p. A-22; Powers 2002, p. 17). Though not significant, the proposed treatments would influence the natural rate of recovery from wildfire. Amaranthus and Trappe (1993) observed reduced infiltration and flow interception as result of severe wildfire. However, because of the moderate- to low-intensity of the Sheep Creek burn and because the ground will have had two years for disturbance recovery, infiltration and flow interception should be close to normal. Cumulative impacts may be greatest where ground vegetation and ground cover is disturbed. These influences are discussed in detail in the section entitled Direct and Indirect Effects on page 176.

3. The Mussigbrod Post Fire Vegetation and Fuels Record of Decision was issued April 2003 to treat 1,465 acres a post fire burn area. This activity is to occur north of the Sheep Creek project area outside of the 6th code HUC watershed; therefore, the Mussigbrod project is not anticipated to affect soil productivity within the Sheep Creek project area.

6. Extending cumulative effects to the watershed scale (6th code HUC), the existing condition has 10.4% soil disturbance (see Affected Environment). This assumes old harvested acres have 30% detrimental soil disturbance with no recovery from time of harvest and roads have 100% detrimental disturbance. Of the 18,595-acre watershed, old and proposed harvest activities amount to 5,257 acres with approximately a

third of these old areas having detrimental soil disturbance. This harvest dates back to the mid 1960s (also see Soils Affected Environment).

7. Cumulative effects from weed risk are possible with known populations in the area. Spotted knapweed (*Centaurea biebersteinii*) was identified in a1960s era clearcut on the eastern perimeter of the fire. Also, several species of noxious weeds are common along the treatment area access road and along Hwy. 43 (USDA 2002b, p. 10). Given the proximity, weeds may spread into newly disturbed harvest areas.

The threat of weed impacts to soil productivity may also increase from recreational use of travel ways. Snowmobiles and ATV's from the nearby Bitterroot valley, which has a much higher level of noxious weeds, may deposit seeds in transit.

The noxious weed risk may be reduced through a variety of measures. Logging equipment is washed prior to site entry. Winter harvest activities may lower this risk since snow would cover seed and lessen spread. Also, winter activities lower the percentage of disturbed ground. Finally, the Wisdom Ranger District has a very aggressive weed program to control spread.

8. Livestock grazing in the project area has not occurred since the fire and will not likely be reintroduced until 2006. Therefore, direct impacts from grazing would not occur.

9. Roads present one of the greatest impacts to soil productivity with changes to subsurface and overland hydrology and increased soil density (Trombulak and Frissell 2000, p. 21-22). At the watershed scale, 57 miles of road exists with most of these concentrated on the south facing aspect. This amounts to roughly 214 acres of detrimental soil disturbance assuming the road prism is 100% detrimentally disturbed soil.

Comparing the alternatives, Alternative 2 increases total watershed disturbance to 11.1% detrimental disturbance, while Alternative 3 increases total watershed disturbance to 10.9%. The sheep creek fire was factored into these estimates with detrimental disturbance estimates from the BAER report (USDA 2002b). Based on these gross estimates, the project would not exceed the interpretation of no more than 15% detrimental disturbance on a watershed scale. Therefore, significant cumulative impacts to soil productivity are not evident.