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TRAIL DETERIORATION IN THE SELWAY-BITTERROOT WILDERNESS

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ABSTRACT

The relationship of environmental factors to trail deterioration in the Selway-Bitterroot Wilderness of Idaho and Montana was studied from June through November of 1972. Trail erosion was quantified by using a cross-sectional area loss index. Landform, vegetative habitat type, and trail grade have a greater effect on erosion and bog formation than elevation, aspect, parent material, sideslope, soil horizon depths, or amount of use. Landslides or mass failure of trails were most related to side slope, landform, and vegetative habitat type. Biophysical units that combine important landform and vegetative habitat types are proposed as the basis for planning trail construction and maintenance. Trail location, construction, and maintenance standards are described for several sample biophysical units. Tentative management guidelines are suggested.

OXFORD: *686.3; 116.6*
KEYWORDS: *trails; erosion control*

Covering more than 1-1/4 million acres in Idaho and Montana (fig. 1), the Selway-Bitterroot Wilderness is one of the largest areas of wilderness in the Nation. There are nearly 2,000 miles of trail in the Wilderness, largely inherited from a different era. Most trails were built in the 1920's and 1930's, primarily for forest fire control, before the Selway-Bitterroot Primitive area was established in 1936. Utility and convenience, not recreational use or protection of natural conditions, were the principal design criteria. Horses were the main method of travel and dominated trail

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[1]The author was a Cooperator and a Recreation Resource Technician, Intermountain Forest and Range Experiment Station. She is now a Research Associate, University of Alaska. The M.S. thesis based on this study, on which Professor Richard Shew served as advisor, is titled "Selway-Bitterroot Wilderness Trail Deterioration Study." Copies are available from the Department of Forestry and Range Management, Washington State University, Pullman, Washington 99163. Field notes and raw data are on file in the Department of Forestry and Range Management.

Figure 1.--Selway-Bitterroot Wilderness; shading delineates study area.

layout. Many sections of trail have deteriorated badly (fig. 2), a change in the natural environment that conflicts with the purpose and philosophy of the Wilderness Act. (In this report "trail deterioration" refers to changes in the trail tread, such as deep erosion, not to windfalls or brush encroachment.) Deteriorated trails are costly to maintain and detract from the visitor's wilderness experience.

The objective of this study was to determine the factors (environmental and use) that had an important influence on trail deterioration, particularly erosion, and try to relate this knowledge to trail management.

STUDY AREA

The study area covered most of the northern part of the Selway-Bitterroot Wilderness within Idaho, primarily the lower Selway River and Moose Creek drainages. There are nearly 1,000 miles of trail in the study area. This area is geologically more recent than the Rocky Mountain Sedimentaries and consists primarily of highly erosive igneous Idaho Batholith (Ross and Forrester 1958; Thomson and Ballard 1924). Higher peaks of the northeastern portion of the Wilderness have been relatively recently covered by a stagnant ice cap. Loess covers some of these peaks and ridges. The deep Selway Canyon was formed by an actively eroding river. The Moose Creek valley was extensively modified by a valley glacier.

Environments are highly varied. Elevations range from about 2,000 to over 10,000 feet, and precipitation and growing seasons have wide ranges. As a result, vegetative communities also are varied, ranging from the relatively dry ponderosa pine (*Pinus ponderosa*) communities to moist western redcedar (*Thuja plicata*) communities to cool subalpine fir (*Abies lasiocarpa*) communities. These communities are in all successional stages as a result of past wildfires.

Figure 2.--Deteriorating trails are a serious problem in the Selway-Bitterroot Wilderness and on other wildlands.

FACTORS AFFECTING EROSION

Vegetation, soil, climate, and topography are known to affect erosion (Baver and others 1972; Farmer and Haveren 1971; Yamamoto and Anderson 1967). The relationship of these environmental factors to trail erosion, a major cause of trail deterioration, can be evaluated by methods such as laboratory measurements of moisture-holding capacity, bulk density, particle size, infiltration rates, permeability, detachability, and transportability of soil material, etc. However, such methods require sophisticated measurements and facilities unavailable or impracticable for wilderness field personnel. Wilderness managers needed a reliable yet relatively simple field method to determine potentially erosive trail sites. Results of this study point toward such a field method.

1. Vegetation

Vegetation affects erosion in numerous ways. First, it provides a protective cover from raindrop splash (Farmer and Haveren 1971). Organic matter in the soil is associated with erosion (Meeuwig 1971; Baver and others 1972). Soil structure is protected by a well-rooted turf in alpine areas (Root and Knapik 1972). Root channels increase porosity, and therefore permeability of the soil. The result is less surface runoff and less erosion. Root systems also help provide the microirregularities on the surface that decrease water velocity and therefore erosion. Revegetation at varying rates in different vegetative types affects the extent of trail deterioration (Dale 1973).

2. Soil Properties

The primary soil properties affecting erosion are texture, structure, and the slope on which the soil has developed. The ability of a soil to disperse, or to be brought into suspension and to aggregate, is as important an indicator of erosive potential as is particle size or texture (Baver and others 1972). Structural type, grade, and cobble content are also important (Long 1972; Dale 1973).

3. Climate

The amount and timing of precipitation will affect the erosive potential of the site. In addition to biological relationships, climate also affects the season during which a trail is used.

4. Landforms

Baver and others (1972) considered slope to be the most important factor in predicting the amount of erosion on a site. Steepness of slope and length of slope are closely associated with landform. Certain landforms such as concave and convex slopes erode at different rates and in different parts of the slope (Young 1960; Schumm 1956). Landform was related to trail deterioration in the Canadian Rockies, where alluvial plains were considered the most erosive landforms (Root and Knapik 1972).

5. Use

In addition to the four environmental factors, disturbance by people, animals, or machines can contribute to erosion. Wilderness trails are used by varying numbers of people traveling on foot and with horses, mules, or burros. Cattle and sheep also use some wilderness trails, but not in the study area since earlier in this century. Trail use has often been blamed as the cause of trail deterioration (Snyder 1966; USDI Bureau of Outdoor Recreation 1966).

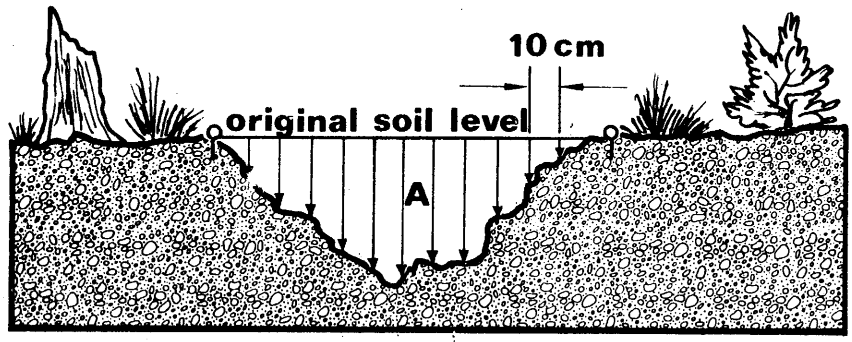
METHODS

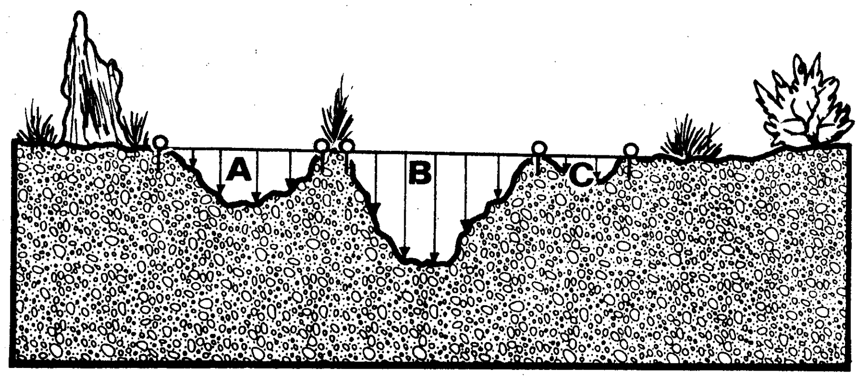
Field data were collected from June through November 1972. Seventy sample sites were selected after Forest Service personnel, commercial outfitters, and public groups identified general areas of deteriorated trails. The trails were walked over three times and then the worst sites were selected. The deliberate selection of badly deteriorated sites seemed reasonable for an initial reconnaissance study, but results must be interpreted with caution.

Trail erosion at each selected site was quantified using a cross-sectional area loss index. A taut tape was strung across the trail tread at right angles at the original soil level (fig. 3). The depth of the tread from the tape was then measured at 10-centimeter intervals. The total cross-sectional area was calculated using the formula for the area of a triangle for the end measurements and the formula for the area of a trapezoid for the internal depth measurements. The cross-sectional area loss index can be converted to a soil volume loss by adding a length measurement. The index expresses the impact of manmade trails on the natural environment. One advantage of this quantifying system, as compared to the single depth measurement used by Ketchledge and Leonard (1970) or Dale's (1973) two measurements of depth and width, is that many different types of trails can be compared such as a single tread trail vs. a multiple tread trail. The data can be easily computerized and quickly analyzed.

At each site, depth of soil horizons, trail grade, side slope, aspect, and elevations were recorded. Microclimate was not directly classified but was represented by aspect and elevation. Aspect and elevation influence formation and melting of snowbanks that supply the moisture that causes trail erosion in many situations (Root and Knapik 1972). Vegetative habitat type (discussed below) also reflects general climatic

Figure 3.--Cross-sectional area loss index = A + B + C. The cross-sectional area loss index is a method by which trail erosion can be quantified. Trails of various configurations (3a, 3b) can be compared using this method.





characteristics. Landforms at each site were classified into four broad categories based on origin: (1) Alluvial Erosional; (2) Alluvial Depositional; (3) Glacial Erosional; and (4) Glacial Depositional. The landform types making up each category are:

Alluvial Erosional

concave slope
streambank
ridgetop
gully
saddle
truncated slope
rock outcrop

Alluvial Depositional

slump toe
colluvial slope
landslide
colluvial cone
alluvial-colluvial fan
alluvial slope
stream terrace
flood plain

Glacial Erosional

nivation cirque
cirque wall
ice steepened wall

Glacial Depositional

lateral moraine
recessional moraine
edge moraine
glacial valley train
compacted (indurated) till
glacially eroded valley slope

Parent material was noted. Soil properties can be predicted through identification of the parent material. Parent material also has been related to the erosiveness of soils. For example, trails placed over loessial soils were found to be more erosive than nonloessial soil in the Canadian Rockies (Root and Knapik 1972). Yamamoto and Anderson (1967) used parent material to predict soil erosiveness in Hawaiian soils.

The Daubenmires' (1968) vegetative habitat type approach was used to classify vegetation at sample sites. The closely related habitat types grand fir-*Pachistima* (*Abies grandis*-*Pachistima myrsinites*) and western redcedar-*Pachistima* (*Thuja plicata*-*Pachistima myrsinites*) were combined. Finally, Ranger District personnel categorized trail use as light, medium, or heavy. In the absence of use records, these classifications were informed judgments. Light use was defined as less than 50 travelers per year; medium, 50 to 125; heavy, over 125.

Sample size was inadequate for linear multiple regression. Instead, the measured variables (for example, elevation, trail grade, etc.) were correlated with the cross-sectional area loss index for the sampled sites within each stratum (for example, for trail slope within landform strata or classes.) Averages were also calculated for each category of the various factors.

RESULTS AND DISCUSSION

Aspect, elevation, and trail grade had variable correlations with trail deterioration (table 1). Deterioration in relation to parent material, landform, vegetative habitat, and use are discussed in more detail in the following sections. Depth of soil horizons had no apparent correlation with trail deterioration. Soils in the Selway-Bitterroot Wilderness were extremely variable; for example, loess and ash have been deposited over a variety of residual soils. More specific data need to be obtained on the relationship of soil horizon to trail degradation.

In addition to entrenchment caused by erosion, two other major types of trail deterioration were identified: bogs caused by perched or high water tables, and landslides caused by trails being constructed on unstable, oversteepened slopes. The area loss index does not represent these last two types of deterioration, and therefore they will be discussed in a qualitative way.

PARENT MATERIAL

Parent material was considered to be the original, weathered aggregates from which the soil formed. Soil material from horneblende gneiss appeared to be subject to more severe trail deterioration than the other parent materials (table 2), although biotite granite is by far the most common parent material for the sample deteriorated sites. Ash and loess were expected to be the most erodible materials, but the actual trail deterioration in these parent materials was relatively low. This could be a result of the trail depth being controlled by the residual soil over which ash and loess were blown. The ash and loess often were observed to have eroded down to the residual soil, which had then eroded to various depths. Trail deterioration in ash appeared to be highly correlated with trail grade. "Accumulation and retention of materials such as loess and ash indicate a very stable, nonerosive surface condition; therefore these sites do not erode as a result of natural site qualities.[2]

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[2]Personal communication with Professor Ray Gilkeson, Department of Soils, Washington State University, Pullman. January 1974.

Table 1.--*Cross-sectional area loss related to vegetative habitat types*

Habitat type	Number of samples	Mean area loss	Mean trail grade	Correlations with area loss[1]			
				Side-slope	Trail grade	Elevation	Aspect
		Cm^2	*Percent*	- - - - *Correlation Coefficient* - - - -			
Subalpine fir-*Pachistima*	5	7,880	13.4	0.11	0.84*	-0.28	-0.36
Whitebark pine-Subalpine fir	7	6,875	25.0	.25	- .09	- .11	- .66
Ponderosa pine-Bluebunch wheatgrass	5	6,230	25.8	.01	.93*	- .10	.42
Subalpine fir-*Pachistima*--*Menziesia* phase	6	5,855	14.3	- .26	- .71*	- .30	.35
Grand fir (western redcedar-*Pachistima*	13	5,837	13.4	- .23	.25	.01	.51*
Subalpine fir-Beargrass	25	5,158	25.2	.17	.29	.39*	- .01
Douglas-fir--Ninebark	3	4,703	29.0	.70*	.99*	.56*	- .99*

[1] Asterisk (*) indicates a 10 percent level of significance which means that there is only a 10 percent or smaller chance that the correlation in fact does not differ from zero. Similar correlation coefficients are available for tables 2, 3, and 4 in the thesis "Selway-Bitterroot trail deterioration study." A high correlation value means a greater association of that factor with trail deterioration.

Table 2.--*Trail cross-sectional area loss related to parent material*

Parent material	Number of samples	Mean area loss[1]	Mean trails grade	Mean elevation
		Cm^2	*Percent*	*Feet*
Ash	4	4,902	21	6,500
Mica schist	5	5,442	19	2,520
Loess	12	5,448	26	6,300
Biotite granite	29	6,388	16	5,130
Granite gneiss	3	6,463	23	5,180
Horneblende gneiss	7	6,841	28	6,580

[1] 1,000 cm^2 equal about 158 in^2.

Table 3.--*Trail cross-sectional area loss as related to landforms*

Landform type	Number of samples	Mean area loss	Mean trail grade	Mean elevation
		cm^2	*Percent*	*Feet*
Glacial Depositional	15	5,365	12	4,100
Glacial Erosional	8	5,545	30	6,610
Alluvial Depositional	23	5,506	19	4,830
Alluvial Erosional	23	6,450	24	5,350

LANDFORM

Three of the landforms had nearly identical mean area losses. Alluvail Erosional landforms had a greater average area loss than the other three landforms (table 3). Many factors interact to create the total cross-sectional area loss. For example, the Glacial Erosional category had very light use and well-drained soil, but a very steep trail grade (30 percent) caused deterioration. The Glacial Depositional category had a fairly gentle grade (12 percent), but heavy use along with a high water table created an equal amount of trail deterioration.

Field observations suggested that landform categories probably were too generalized, and that some of the types within each class were quite different. For example, the mean trail grade in the Glacial Depositional category was 12 percent, but Glacial Valley Train, a landform in the Glacial Depositional category, began to erode severely at only a 4 percent grade. Glaciated alpine valleys in the Glacial Depositional category were associated with bogs and compacted till. Compacted till occurs when gravel has been compressed into an impermeable hardpan by the weight of a glacier. Trail construction brings subsurface drainage to the surface, which accelerates damage (fig. 4). Each of these landforms is in the Glacial Depositional category, but each has separate trail conditions and management problems and should be managed differently.

Oversteepened concave slopes can occur in both Alluvial Erosional and Glacial Erosional categories. Landslides or mass failure of trails in these landforms present a unique and difficult trail management problem as compared to the usual entrenchment in Alluvial Erosional and Glacial Erosional categories. Steep side slopes (trail affected by landslides examined had sideslope from 78 to 99 percent) appear more critical than trail grade in causing trail deterioration in these landforms.

VEGETATIVE HABITAT

Vegetative habitat type is one of the most promising bases for predicting trail deterioration. Each habitat type can have unique trail deterioration problems such as trail grade, type of deterioration, period of use, or a combination of these factors. For example, there was a high degree of correlation between trail grade and area loss within most habitats (table 1). Yet, each habitat type had a different threshold at which trail grade induced serious erosion.

Habitat type is an expression of moisture and soil-related factors. The *Menziesia* phase of the subalpine fir-*Pachistima* habitat type had a finer soil texture and was more moist than the *Pachistima* phase of that habitat type. Deep, single-tread entrenchment occurred at sample sites in the *Menziesia* phase; multiple-tread entrenchment

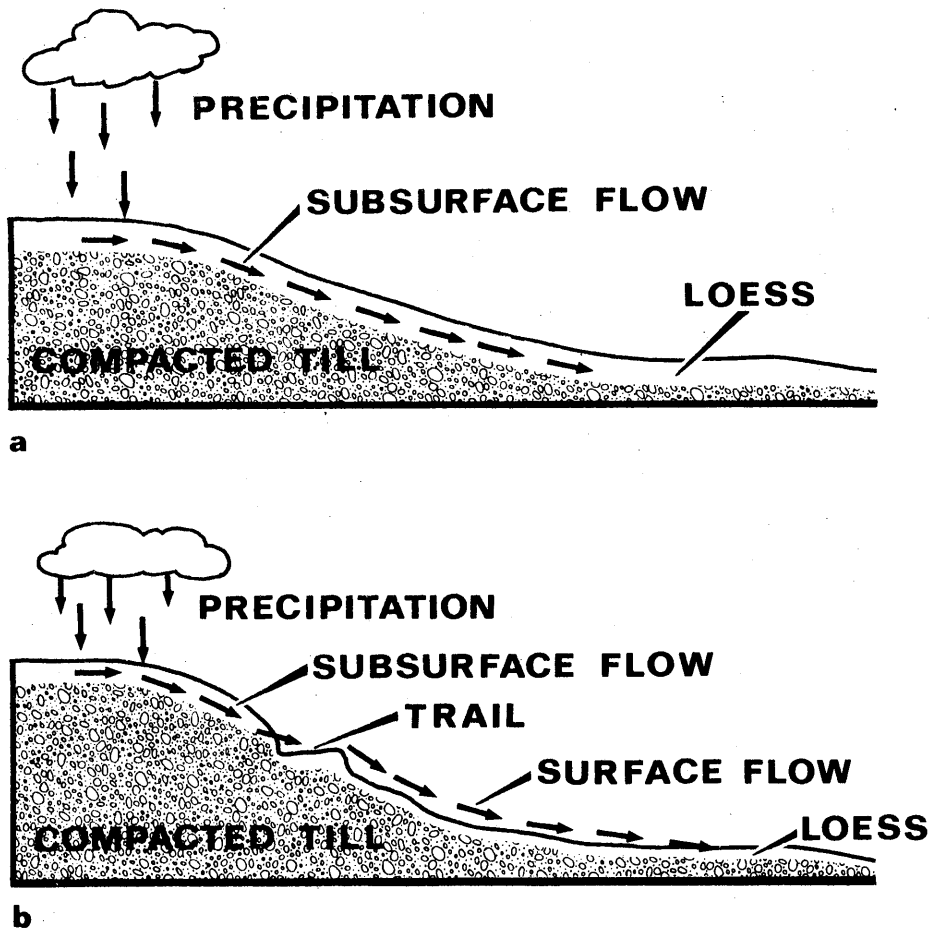

Figure 4.--Building trail on compacted till can interrupt normal subsurface flows (4a) and cause accelerated channel erosion (4b).

occurred in the *Pachistima* phase. High or perched water tables (a factor indicating bog formation) can be associated with the western redcedar habitat types. Field observations suggest that the western redcedar-*Pachistima* habitat type will form bogs while the wetter western redcedar-ladyfern habitat type will form an entrenched trail.

The negative correlation coefficient (table 1), which suggests that as trail grade increases deterioration decreases in the subalpine fir-*Pachistima (Abies lasiocarpa-Pachistima myrsinites)* habitat type, is an anomaly. It may be the result of trail deterioration occurring on areas of compacted till with a loess cap, which have gentle grades compared to the other subalpine fir-*Pachistima* habitat types. In the whitebark pine-subalpine fir type even a gentle slope appeared to be enough to promote active erosion of the ash cap. Sample size in both cases is also small.

TRAIL USE

Amount of use was less strongly and consistently related to deterioration than expected. Table 4 indicates that low-use trails (which were very steep) eroded most severely. High use results in trail damage, especially if perched and high water tables are present. On gentle slopes, little damage would result even with high use on the well-drained sites; poorly drained sites would show greater damage with much less use. Medium use on medium grades has the least cross-sectional area loss. One possible explanation is that medium use may compact the tread enough to inhibit erosion.

Table 4.--*Trail cross-sectional area loss related to use*

Use category	Number of samples	Mean area loss	Mean trail grade	Mean elevation
	No.	*cm²*	*Percent*	*Feet*
High	26	5,983	15	4,550
Medium	24	4,956	22	5,240
Low	19	6,959	25	5,490

It is possible that, as is true for campsite deterioration (Frissell and Duncan 1965; LaPage 1967; Merriam and others 1973) the first, limited use may cause the greatest amount of damage, followed by much slower deterioration with continued, heavier use. Removal of the vegetative cover creates the potential for trail deterioration. Maintenance, usually concentrated on high- and medium-use trails, should also be considered. A trail system with the same amount of use throughout still would have variable amounts of deterioration dependent on site factors. Trail location might be more important than use in causing deterioration of trails. In any event, the role of use in causing trail deterioration is anything but simple and direct.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The study indicated that vegetative habitat, landform, and trail slope are factors importantly related to trail erosion. Aspect, elevation, use, and parent material have variable relations and should be further examined. Soil horizons had no apparent relationship to trail deterioration. A high or perched water table caused trail deterioration in the form of bog formation. This is an easily defined factor which is readily identifiable in the field. High water tables are associated with layering of the parent materials, position on the landform, and vegetative type. Mass failure of trails was associated with steep, convex sideslopes, and vegetative habitat type.

Use, generally blamed in the literature and by management personnel as the factor causing deterioration, was not shown to have a high correlation with trail deterioration. There are two possible reasons: (1) trail slope was highest in low use areas and lowest in high use areas; and (2) maintenance tends to be emphasized on high use areas. The data suggest, however, that use is less important than site in causing trail deterioration.

Resource management can solve many of the problems of trail deterioration. Deterioration is not the inevitable result of increasing use. Management thus could increase biological carrying capacity by avoiding or minimizing limitations imposed by site factors. However, wilderness objectives require protecting both natural conditions and providing visitors with outstanding opportunities to experience solitude. If user impacts on natural conditions (at least on trails) can be managed, then the problem of social carrying capacity (the quality of the visitor's experience) would become critical.

Figure 5.--On some biophysical units, trails erode even at low grades.

BIOPHYSICAL UNITS

Managers need a concept on which to base trail management guidelines. One promising approach is the combining of landform and vegetative habitat into "biophysical units" that express the forces that create the potential for deterioration in a specific environment. For example, critical trail grade seems to vary greatly between different landforms and vegetative types. General guidelines based on an entire forest, region, or agency are not sensitive to varying environmental conditions. For example, the Forest Service Manual[3] states an overall 30 percent grade limitation on trail construction in wildernesses. Many of the trails in the Selway-Bitterroot Wilderness showed excessive deterioration at only a 15 percent trail grade. On some biophysical units trails steeper than 30 percent could be constructed without inducing erosion. In one habitat type, western redcedar-ladyfern Glacial Valley Train, even a 5 percent grade produced serious erosion (fig. 5).

The biophysical units can be mapped. Each unit should contain a description of soils, vegetation, and landforms. Limitations such as period of use can be described. The type of trail deterioration found in that biophysical unit would be identified. Then each unit would have standards for location, construction, and maintenance of trails. Although trails are emphasized in this paper, it should be noted that the concept of biophysical units could be used to manage campsites, too. Three examples of

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[3]USDA Forest Service Manual, 2300 R-1 Suppl. 35 and 41, 1970 and 1971, respectively.

biophysical units in the Selway-Bitterroot Wilderness and tentative trail management guidelines are presented below.

1. Western redcedar-ladyfern, Glacial Valley Train

The vegetation in this habitat is dominated by western redcedar. Ferns are more plentiful than in the western redcedar-*Pachistima* habitat type. Western redcedar-ladyfern are small enclaves within the western redcedar-*Pachistima* vegetative types.

The soils appear to be finer textured than in the western redcedar-*Pachistima*.

The parent material was transported by the valley glacier. There is a high water table and lateral subsurface drainage. Overland flow appears to be more extensive than in western redcedar-*Pachistima*.

The landform is glacial valley train. Located in valley bottoms, glacial valley train is a result of valley glaciation. The slope ranges between 0 and 7 percent.

Trail damage occurs as entrenchment.

Trails should not be built on this enclave. Trails can be routed around the area. If trails are built, planking or corduroy should be used.

2. Subalpine fir-*Pachistima* Over-Steepened and Concave Slopes.

Subalpine fir is the dominant tree in this habitat type. Other overstory species include Engelmann spruce (*Picea engelmannii*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and larch (*Larix occidentalis*). The understory is varied and ground cover is moderate. Roses (*Rosa* spp.) are likely to become more numerous close to the trail while strawberries (*Frageria* spp.), violets (*Viola* spp.), and twinflower (*Linnaea borealis*) usually decrease in numbers. There is a *Menziesia ferruginea* phase of this habitat type.

The soils are relatively deep sandy loam that is saturated with water in the spring and is moist most of the year.

The concave, oversteepened slopes are a result of an active erosion process, either glacial or alluvial. The head of the concave slope is more actively eroding than the base. The oversteepened slopes often are above an actively eroding stream. The side slopes range between 70 and 99 percent.

Trail deterioration occurs in the early spring. The first signs of deterioration are cracks along the trail. The cracks accelerate the overloading of the mantle by increasing the water flowing into the soil. Then mass failure occurs, as that section of the trail slips out and downslope.

In this biophysical unit, trails should not be built where the side slope is greater than about 75 percent. Trails should be located well above the heads of these areas.

3. Subalpine fir-*Pachistima* Compacted Till.

The vegetative characteristics are similar to those in the subalpine fir-*Pachistima* Alluvial Erosional.

The soils are highly layered. A loess layer lies over compacted till, which is impermeable to water. Subsurface lateral drainage occurs on the valley side slopes to the valley bottom and emerges at the base of the slope.

"The loess cap is highly erodible especially when the slope hydrology is changed, such as by the construction of a trail where the compacted layer is disturbed by trail construction or presence. This brings subsurface water to the surface, accelerating surface erosion. Also, any disturbance vertically along the slope accelerates surface erosion."[4]

The soil is moist throughout the season except from mid-July to the end of August.

Compacted till occurs on the high glaciated valleys in the Selway-Bitterroot Wilderness. Although the till is stable, the loess cap is highly erodible.

Trails become entrenched down to the compacted till. The tread often has boulders in it. When a trail is constructed on a side slope, the subsurface drainage emerges as springs on the trail. The water becomes a virtual stream eroding the trail.

It is difficult to build trails through this biophysical unit because precaution has to be taken not to interrupt the subsurface drainage. It is best to locate trails high on the valley walls and avoid the base of the hill or the valley bottoms. Water brought to the surface should be countered by placement of water bars and rock culverts.

IMPLICATIONS FOR TRAIL MAINTENANCE AND RELOCATION

Trail relocation is a major approach to trail management. Most trails now in use were not designed for current management objectives. Where feasible, many of these trails should be relocated to serve present and future needs with less resource damage. This program would be implemented over a period of years.

Detailed records of trail maintenance and costs by locations would enable the manager to analyze costs of trail construction on each biophysical unit and help in selecting the least expensive unit on which to locate a trail within minimum resource damage.

A quantitative periodic record of trail conditions would help determine future trends and guide maintenance and redesign efforts. A trail crew could be quickly trained to record the area loss index at intervals along trails.

Professionals who now participate in major trail construction projects also need to be included even on minor trail relocation. Professional soil scientists, hydrologists, plant ecologists, and geologists who should map the biophysical units and write management guidelines might recommend not to build trails on that unit.

Preventive maintenance is important; poorly maintained trails promote greater trail deterioration. For example, multiple trail treads might be caused by hikers or livestock walking out of the tread to avoid boulders or other obstructions. Water bar placement and maintenance can prevent the channeling of water that erodes the trail tread.

FUTURE RESEARCH

Future research on trail deterioration is needed on both the social and the physical aspects of the problem, which are interrelated.

In the Selway-Bitterroot Wilderness, a study similar to the one reported here, but covering less deteriorated trail sites, is needed. There is also a need for a larger sample of the deteriorated sites. The new study could include completion of the bio-

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[4]Personal communication with Mel Bennett, Hydrologist, Clearwater National Forest. January 1974.

physical unit map and development and testing of trail management guidelines based on the biophysical concept. Extensive sampling within each biophysical unit is needed. Economic analysis of trail construction methods and costs within each unit also would be valuable.

Studies are needed in areas having vegetative communities and geologic formations other than the highly erosive Idaho Batholith. This research would also help determine the feasibility of the methods on a large scale.

Soil characteristics such as infiltration rates, cobble content, and texture that were not included in this study might be related to trail deterioration. Length of slope is another omitted, possibly important factor. A study of these factors, aimed at producing guidelines for the manager, would be useful. For example, a table relating soil texture and trail grade to deterioration could define needed water bar spacings. Another possibility is a table relating trail damage to soil moisture content which would help the manager decide when to limit or prohibit use on a particular trail to control damage.

Trail systems are one of the major marks of man on wilderness. They strongly influence use patterns and visitor experiences. Research and improved management of trails could produce many important benefits.

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