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Filter Strip Widths for Forest Roads in the Southern Appalachians

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ABSTRACT. Filter strip standards currently applied to forest roads in the southern Appalachian Mountains may specify greater widths than are necessary with prevailing construction practices. Measurements of the distance that sediment traveled downslope below newly constructed roads were less than previously reported. Distances were notably less if natural obstructions existed on the forest floor, brush barriers constructed at the edge of the right-of-way, road fills grass-covered, and roads outsloped and drained by broad-based dips. Discussion of management considerations lead to proposed revised guidelines for minimum filter strip widths for the southern mountains.

A buffer zone is any area where management is modified to isolate an activity from some sensitive area. Shade strips, visual barriers, and filter strips are each a type of buffer zone. The filter strip provides space between a soil-disturbance, such as a road, and a stream or other site that needs to be protected from sedimentation. The minimum width of filter strip should be greater than the distance sediment can move downslope before effective erosion control is established at the source.

Two guidelines for filter strip widths have been used in the eastern United States. The original work by Trimble and Sartz (1957) measured the slope distance that sediment was carried from 36 open-top culverts on partially graveled roads at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire. They related the distance of soil movement to slope steepness below the road and recommended two guidelines for filter strip widths. Their recommendation for general management zones was defined as a distance, increasing with slope percent, that was greater than 83% of their data points. A more stringent recommendation that exceeded all distances measured was proposed for municipal watersheds or critical management zones. These recommendations were included in logging road standards, for example by Hartung and Kress (1977) and

Haussman and Pruett (1978), and are here listed as the first two entries of Table 1.

The second guideline was produced through the unit planning effort of National Forests in Regions 8 and 9. The *Guide for Managing the National Forests in the Appalachians* (USDA FS 1973) catalogs ten standards for protection of the environment. These standards were circulated within and outside the Forest Service as unpublished working documents. Standard 3, "Specifications for Watercourse Buffer Strips," was derived from Trimble and Sartz's recommendations and has been adopted by most states as part of their Best Management Practices standards (Dissmeyer and Singer 1977). Widths again were related to slope percent of the terrain below the road but were separated into three standards on the basis of erosion hazard of the buffer strip soil. The distances given in the Forest Service standard for soils with severe erosion hazard were numerically identical to Trimble and Sartz's municipal watershed recommendation but were specified to be horizontal distance rather than slope distance as in the original work.

For Table 1, all filter strip guidelines are recalculated in slope distance. As a result, filter strips specified by Appalachian Standard 3 for slight erosion hazard soils are more than 30% wider on steep slopes than those recommended by Trimble and Sartz for general forest management areas. Currently within the Forest Service, documents such as the Appalachian Guide are replaced by regional guides (USDA FS 1984) and by guidelines in each National Forest Land and Resource Management Plan.

For three reasons, users have suggested that filter strip standards should be modified. Road construction methods have improved since the original work was done, so forest managers and engineers question the need for the wide filter strips defined by Standard 3 of the Appalachian Guide. Steepness of terrain is well recognized as a predictor for sediment travel, but the Appalachian standard extends only to 60% slopes, although roads are sometimes built on steeper land. The definitions for erosion hazard categories are not included in the standard or even generally known, thus selection of filter strip width becomes subjective. In western studies, vegetation and forest litter in the filter strip, which can be a variable for erosion hazard determination, were found to be the most important determinants of sediment flow distance (Haupt 1959, Packer 1967).

The objectives of this study were (1) to compare filter strip standards to field measurements of sediment movement in the southern Appalachian Mountains, and (2) to determine the mitigating influences of mulch or grass on fill slopes and of obstructions to flow within filter strips. This test includes slopes steeper than those studied by Trimble and Sartz (1957), and compares outsloped roadbeds with culvert outfalls.

SITE AND METHODS

The study site is in the southern Appalachian Mountains of western North Carolina on the Wayah Ranger District of the Nantahala National Forest. Steep forested slopes bound narrow, but low-gradient, main stream bottoms. Soils are mainly deep sandy loams formed from folded, metamorphosed igneous and acidic crystalline rocks. Infiltration rates of undisturbed forest soils generally exceed 10 in/h. Mean annual precipitation ranges with elevation from 45 to 100 in, and mean annual temperatures are around 55°F.

The distances that deposits of sediment extended downslope below two forest roads were measured during construction and for up to 9 months afterward. By the end of measurements, the cuts and fills of both roads were grassed, and all roadbeds were fully graveled. Both roads were built for access to future timber sale areas, but hauling did not

Table 1. Comparison of filter strip guidelines for forest roads in the eastern mountains.

Guideline	Percent slope								
	0	10	20	30	40	50	60	70	80
	Slope distance in ft								
General forest management areas[1]	25	45	65	85	105	125	145	165	—
Municipal watersheds[1]	50	90	130	170	210	250	290	330	—
Slight erosion hazard soils[2]	30	55	82	110	140	173	210	—	—
Moderate erosion hazard soils[2]	40	75	102	146	183	224	274	—	
Severe erosion hazard soils[2]	50	90	133	177	226	280	338	—	—
Finished roads with brush barriers[3]	32	36	40	44	48	52	56	60	64
Finished road without brush barrier[3]	43	57	71	85	99	112	126	140	154
Unfinished road in winter[3]	86	104	142	170	198	224	252	280	308

[1] Trimble and Sartz 1957.
[2] USDA Forest Service 1973 (widths given in horizontal distance in original document).
[3] This study.

occur during the study. The Black Oak Gap Road was built for 0.4 mi in gentle terrain at the edge of the valley bottom on land slopes ranging from 7 to 26%. The Willis Cove Road climbed 4.3 mi in steep terrain ranging up to 80% slope.

The roads in this study were constructed according to Forest Service grade, drainage, and graveling standards. Each was an outsloped single-lane road, about 14 ft wide, with turnouts. Inside ditches were constructed only on the grades steeper than 8%. Ditchline water was diverted about every 140-300 ft under the roads through metal culvert pipe, often discharging onto the fill. The center two-thirds of the Willis Cove Road was on grades of 2 to 5% without ditchlines. Broad-based dips at 150–250 ft intervals diverted storm waters off the road onto fill material that was protected only by grass. Metal culverts carried flow at all live and intermittent stream crossings. Cut banks were backsloped about ½:1. Fills were all sidecast material with compaction only by earthmoving equipment and assumed slopes of 1:1 to 1½:1. In steep terrain, slope lengths of 75-100 ft of loose fill were common. All roadbeds received 4 in of compacted, aggregated base-course gravel.

Where the roads passed through forest, brush barriers were constructed at the lower edge of the clearing limits by piling slash from clearing the right-of-way (Figure 1). Barriers were generally 4- to 6-ft high and 10 ft or more wide. Openings in barriers were left at stream crossings. Logs from the right-of-way were piled at turnouts and later sold for firewood. Effective brush barriers did not exist on some sections of the road where the construction contract called for tops to be scattered or where large fills overtopped prepared barriers. Barriers composed of hay bales were placed below culvert outfalls on one section where land slopes were 25% or less.

Road construction began in spring 1982, was suspended during winter, and completed in early summer 1983. Both roads were graveled and well grassed before winter 1982–83 except for a portion of one in the steepest terrain. Part of that roadbed was graveled with the cut and fill slopes mulched by straw lightly sprayed with asphalt. The remainder was unfinished without outsloping, gravel, grass, or mulch. Rainfall was slightly below normal during most of road construction (about 4–6 in/mo), except that winter precipitation was about 16% above average. A February storm dropped 4 in in 13 hr. Erosion and fill failures from storms in February and April 1983 necessitated some reconstruction, particularly in the unfinished portion.

Figure 1. Brush barrier at toe of fill constructed from vegetation cut from the right-of-way of forest road. An opening was left in the barrier at each stream crossing.

Both roads were constructed of soil materials typical for much of the southern Appalachian Mountains. Deep loamy soils grade into decomposing gneiss or schist with hard rock outcrops. Fine loamy, oxidic, mesic Typic Hapludults such as Evard predominate along with the more clayey Hayesville on ridges and gentler slopes. The Hayesville soil carries American Association of State Highway Officials classification of A-4, whereas Evard is A-2. Both are listed as good road construction material grading to poor on steep slopes or in the stony phase. Erodibility K factors are 0.17 to 0.24 for the C horizon of these soils.

The emphasis of this study was to describe the movement of waterborne soil particles. Test sections totaling 2.1 mi of roadway were selected to represent various combinations of conditions believed to affect the distance that soil is carried downslope by storm waters. Test sections did not include stream crossings where sideslopes between road and streambed would be too short to display the sediment deposit. Sections were selected to illustrate a range of construction practices that included leaving the road to overwinter in various stages of completion. Sites were classified by the cover and condition existing when the major increment of sediment deposit occurred, i.e., graveled and grassed, graveled and mulched, or unfinished and bare. Some road fills were eroded by water from outsloped roadbeds and others by culvert outfalls. About 0.2 mi of road was built through areas that had been clearcut and burned, thus neither forest litter nor brush barriers existed below the well-grassed road fill.

After the limits of each test section were defined, the forest floor below the toe of the road fill was examined and all sites marked where visible deposits of sediment extended more than 20 ft downslope from the clearing limits of the roadway. On gentle terrain and where there were no brush barriers, some shorter deposits were also measured. Measurements at each site began at a stake set at the toe of the fill or in the brush barrier. The slopes below the roads were rechecked periodically, new deposits measured, and previous sites remeasured until downslope movement of soil had ceased. Measurements were taken as slope distance to the end of each fresh deposit of soil particles. When mud stains could be found on the forest litter downslope from a sediment deposit, this additional distance was noted. Because the purpose was to determine the distance sediment moved across the forest floor, a site was eliminated from further measurement if sediment reached a stream channel. A stump or rock rolled out of the roadway would leave discontinuous patches of sediment. Only continuous runs of sediment originating at the road fill were measured.

RESULTS

Eighty-eight sediment deposits were measured on slopes ranging from 7 to 80%. The average slope distance was 71 ft. Twelve short runs of less than 20 ft were included in gentler terrain where lateral spread of sediment was often greater than downslope movement. The mean distance of all deposits greater than 20 ft was 80 ft. During construction, the driving surface or roadbed was a temporary source of sediment. This became an important source for the section that was left unfinished for several winter months. Generally, deposits originating from rills and small gullies in well-grassed fills were small. Fills that were large, poorly grassed, or left ungrassed produced the longest deposits. Forest litter and brush barriers trapped sediment. Some fills settled during the winter, buried the brush barriers, and slumped onto the slope below. Culverts were a source of material from both eroding ditchlines and water cutting into exposed road fills below the culvert outfall. Thus, the site characteristics chosen to predict sediment distance were percent slope, the overwinter condition of roadbed and fill, the presence of forest litter or brush barriers, and the type of drainage structure (outsloped roadbed or culvert).

Table 2 summarizes the downslope soil movement distances for various categories of roadway and slope conditions. These categories are grouped by sets that compare combinations of conditions. The same data appear in more than one entry in Table 2, and each comparison includes all possible cases of the other variables. The downslope distances measured at all 88 sites are plotted over the slope percent in Figure 2 and summarized in the first entry of Table 2. The three longest deposits in Figure 2 average 308 ft.

The vegetation comparison in Table 2 (grassed vs. mulched vs. bare fill slopes) confirm the previously demonstrated fact that a good vegetative cover on disturbed soil will reduce soil loss (Swift 1984b). The mean distance for soil deposition below the grassed fills was about half that measured below the bare slopes, and both the maximum and minimum distances for mulched and bare fills were much greater than for grassed fills. Two factors were associated with the longer deposits below ungrassed road fills. Precipitation during early spring, when these slopes were unprotected, was 28% above normal, and the land slopes below the unvegetated

Table 2. Comparison of downslope movement of sediment from roads for various roadway and slope conditions.

Comparisons	Sites (no)	Mean slope (%)	Distance Mean (ft)	Distance Max (ft)	Distance Min (ft)
All sites	88	46	71	314	2
Vegetation					
Grassed fills	63	41	58	198	2
Mulched fills	16	64	96	314	37
Bare fills	9	55	112	310	39
Barrier					
Brush barriers	26	46	47	156	3
No brush barrier	62	47	81	314	2
Forest floor					
Forest litter	71	47	65	314	2
Burn	17	42	96	198	32
Drainage					
Culvert	21	40	80	314	30
Outsloped without culvert	56	47	63	287	2
Unfinished roadbed with berm	11	57	95	310	25
Grass fill and forest litter	46	40	45	148	2
With brush barrier	16	39	34	78	3
With culvert	4	20	37	43	30
Without culvert	12	45	32	78	3
Without brush barrier	30	41	51	148	2
With culvert	7	37	58	87	30
Without culvert	23	42	49	148	2

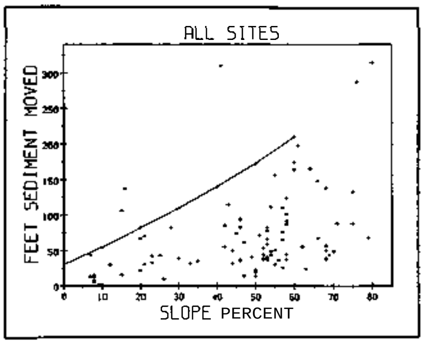

Figure 2. Soil movement distances for all sites in this study. Line is Appalachian Guide standard for filter strip width on slight erosion hazard soils.

fills were all steeper than 40%. Comparing extremes, the three maximum deposits measured below well-grassed fills averaged 139 ft for those sites with a forest floor and no brush barrier. This is about 46% of the mean for the three longest deposits below ungrassed sites. The greatest distance of all 88 points occurred below a culvert outlet on a mulched fill.

The barrier comparison in Table 2 demonstrates the value of brush barriers. Regardless of all other factors, b.oth mean and maximum soil deposition distances were about half as great where brush barriers were in place and not overtopped by fills. Cook and King (1983) found that brush barriers trapped 75 to 85% of soil eroded from road fills.

The forest floor comparison in Table 2 demonstrates the value of natural forest litter for slowing the extension of soil deposition downslope. Where leaves, branches, and fallen logs were consumed in a prescribed burn, mean distances were 50% greater. The top line in Figure 3 is the approximate upper boundary of 95% of the data for sites without forest litter. Very few short sediment flows were found in the burned area. Soil surfaces within the burn did not erode during this study if unaffected by road construction.

The drainage comparison shows somewhat greater sediment movement where storm waters were concentrated at culvert outlets. However, because of other, more

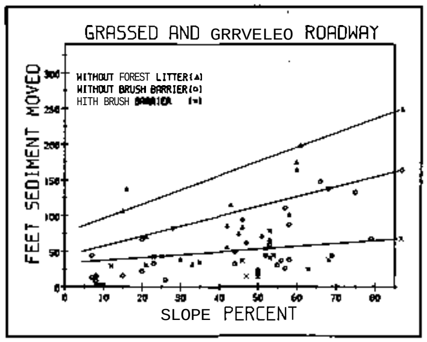

Figure 3. Soil movement distances for sites below graveled and grassed roadways. Lines are approximate upper boundaries for 90 to 95% of the data. The lines from upper to lower represent without forest litter, without brush barrier, and with brush barrier sites.

influential factors, only 2 of the 8 longest sediment deposits were below culverts. Three of these long deposits (160-200 ft) began on grassed but eroded fills in the burn (Figure 3). The other five (155–315 ft) originated from mass failure or gullies on ungrassed fills of the portion of the Willis Cove Road, which was unfinished during winter (Figure 4). Before suspending work for the winter, a berm was built on the outside edge of the unfinished roadbed to prevent drainage over the ungrassed and unmulched fill. Nevertheless, both roadbed and fills were eroded by early spring storms. Soil movement was distinctly less on ungrassed sites that had brush barriers (Figure 4).

The final comparison of Table 2 is a multiple contrast for the effects of both brush barriers and

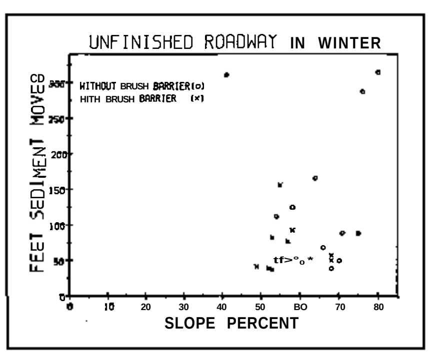

Figure 4. Soil movement distances for sites below ungraveled and ungrassed roadways that were unfinished during winter and early spring storms.

drainage on just the 46 stabilized sites where fills were protected by grass and the forest floor by litter. Without brush barriers, the maximum sediment distance doubled, and the mean distance was 1.5 times that for sites with barriers. These same data are plotted in Figure 3. Two maximum effect lines for the "with barrier" and "without barrier" data bound about 90% of the points and highlight the strong reduction in soil movement below brush barriers for steeper slopes. The barrier categories are further subdivided in Table 2 to show the effect of culvert outfalls on distance sediment moved. Ditchline length above culverts averaged 200 ft. For the grass and forest litter case, mean sediment distances were about 20% greater below culverts, but the principal effect was that minimum distances were considerably greater. Maximum distances in Figures 3 and 4 were more the result of having no protective cover or barrier on steep slopes than the presence of culvert outfalls.

The frequency of occurrence of downslope sediment deposits also was a function of vegetation and forest litter. The more grass on the road fills and the more obstructions on the forest floor, the fewer the deposits over 20 ft long (Table 3). Brush barriers further lowered the frequency of occurrence. The firewood operation disturbed the roadbed and prevented good grass growth on fills, but the dense slash and the gentler topography typical at turnouts where logs were piled resulted in no measured sediment deposits below landings.

DISCUSSION

Original filter strip standards were based on soil deposition distances measured below open-top cross drains on a graveled road in New Hampshire. Current recommendations for the southern Appalachian Mountains are more restrictive modifications of the original work and specify wider filter strip widths. Soil erosion hazard was an added variable. Ninety-

Table 3. The number of sediment deposits more than 20 ft long is reduced by grass and forest debris.

Degree of soil protection	Number of deposits per 1,000 ft of road
Grassed fill, litter and brush burned	13.9
Bare fill, forest litter	9.9
Mulched fill, forest litter	8.1
Grassed fill, forest litter, no brush barrier	6.9
Grassed fill, forest litter, brush barrier	4.5

four percent of the soil deposition distances measured for the various conditions in this study were less than the Appalachian Guide standard for "slight" erosion hazard soils (Figure 2). In this and the Trimble and Sartz (1957) study, percent slope was the most important predictor of soil deposition distance. However, both Haupt (1959) and Packer (1967) found logs and obstructions in the filter strip to be their most significant variable. Trimble and Sartz (1957) did not have contrasts in forest floor conditions in their data, but the current study does show that vegetation on the road fills plus forest litter and brush barriers on the slopes below the road strongly influenced deposition distance. The effectiveness of grass, forest floor, and brush barriers demonstrates that management practices can be used to reduce the width of the required filter strip. Results also draw attention to overwinter construction practices that should be avoided.

Each newly constructed road undergoes a critical period with unfinished roadbed and ungrassed cut and fill slopes. Construction should be planned so that the period during which soils are unprotected is short, and earth moving should not extend into a season when opportunities to plant and grow grass are limited. The overwinter mulch of straw and asphalt, at the rate applied, was a very poor substitute for grass. Compared with grassed fills, the frequency of downslope deposits was 17% greater with mulch cover and 43% greater without any cover (Table 3). Functionally, grass reduces the frequency and distance of deposits by binding the soil and shielding it from erosion, thus reducing the amount of sediment available for movement downslope. The deposition distances without grass ranged from 37 to 314 ft; typically much shorter distances were found below grassed fills (Table 2).

An effective grass sod covered the road cuts and fills within the prescribed burn area. Nevertheless, some sediment was produced by rilling of fills and culvert outflow. Both soil deposition distance and frequency of deposit were greater in the burn where neither brush barriers nor forest litter were present to obstruct downslope flow. The lack of sediment movement and deposition in burned areas above the road shows that measured deposition originated with road construction and was not due to erosion of soil surface following the fire.

The presence of brush barriers dramatically reduced the length and number of sediment deposits and essentially eliminated the percent slope relationship for both grassed and ungrassed roadways. Hay bales were usually effective on the gentler slopes. Tops and brush cut from the right-of-way and piled at the clearing limits could not form as dense a barrier as hay bales, but nevertheless reduced downslope movement of sediment. Unfortunately, some barriers were covered by fill, allowing large sediment deposits to move downslope. On steep slopes where barriers are more easily overtopped, a second barrier, hay bales or a silt fence below the clearing limits, could intercept sediment and further reduce soil movement.

The purpose of a filter strip is to keep sediment away from the stream. Therefore, any guidelines for filter strip width should be based on extreme sediment flow distances rather than an average distance. However, a guideline that protects against all possible cases would require impractically wide filter strips. If the lines enclosing 90% of these data are accepted as guides for filter strip width, then:

$$\text{Slope distance in feet} = 43 + 1.39\,(\text{slope }\%)$$

for sediment on the forest floor below a grassed fill without a brush barrier. Adding a brush barrier reduces the coefficient for slope percent from 1.39 to 0.40 and the intercept to 32 ft. Table 4 is based on these coefficients and shows adjustments to filter strip distance appropriate for surfaces without forest litter and unfinished roadways.

The user of these data should recognize that the distances represent only the downslope extent of coarse particles of sediment (>0.05 mm) and that storm waters muddied by fine particles reached farther downslope. Neither this additional distance nor the amount of fine soil particles moved could be determined consistently. At a few sites, mud stains were observed on forest litter at 7 to 20 ft below the points where deposition ended. If the soil mate-

Table 4. Minimum filter strip width for graveled forest roads.[1]

	Percent slope								
Filter strip	0	10	20	30	40	50	60	70	80
	(Slope distance in ft)								
Without brush barrier	43	57	71	85	99	112	126	140	154
With brush barrier	32	36	40	44	48	52	56	60	64

Note: For prescribed burn without brush barrier or forest litter, add 31 ft + 6.4 ft/10% slope. For ungrassed fill and unfinished roadbed in winter and early spring, double the table values.

[1] Distances are for roads with grassed banks, either outsloped or drained by ditchline and culvert onto forest floor that is covered by hardwood litter. Storm runoff that does not infiltrate into the forest soil will carry suspended clay and silt particles farther.

rial exposed and eroded from a road contains a high percentage of silt and clay, then the transport of fine particles downslope could have an important impact beyond the distances in Table 4. However, most of the exposed material on these mountain roads was coarse-textured saprolite.

Existing guidelines specify different filter strip widths based on the erosion hazard of the soils in the filter strip. Rarely did water from the roads erode the filter strip in this study. This result suggests that the erodibility of filter strip soils is not a significant factor when the filter strip is protected by forest litter and not eroded by large volumes of water. In this situation, the erodibility of the exposed soil and saprolite in the road fill might be a better variable for determining the amount of material moved onto the filter strip. The influence of soil erodibility was untested in this study because of the narrow range of K factor for Hayesville and Evard soils.

Sediment deposits were somewhat longer below culvert outfalls, especially where there were no brush barriers or hay bales (Table 2). Increased sediment was due to soil eroded from ditchlines above the culverts and to the force of water falling on unprotected fills below the culverts. Slash or brush scattered on the fill below a culvert outfall may reduce erosion of fills. Because data for culverts were quite variable, no factor for culverts and outsloped roadbeds was calculated for Table 4.

The shape of the slope below the road influenced occurrence and size of soil deposition. No soil movement beyond 20 ft was found on outside curves despite heavy disturbance where roads crossed side ridges. Many of the largest soil depositions were below inside curves where storm runoff naturally gathers in hollows and undeveloped channels, especially when supplemented by runoff from the road. Typically, roads crossing these hollows have larger uncompacted fills that are exposed to concentrated water at culvert outfalls. Fills on steep slopes that were not grassed before winter were especially unstable, and most slid and covered the brush barriers. Reconstruction added more soil material to the filter strip.

Eighty-three of the 88 sediment deposits measured were easily contained within the minimum filter strip standard for the Appalachian Mountains (Table 1, slight erosion hazard). The longer flows all occurred in road sections where at least two mitigating practices were missing, i.e., no brush barriers and either without forest litter or without grassed fills.

As with all previous studies of filter strips, only certain soils, rock types, climatic conditions, and road designs are represented in the data. For this study, both soils and climate tend toward conditions demanding wider filter strips. Materials are representative of moderately erosive soils overlying strongly metamorphosed gneiss and schist bed rocks of the southern Appalachians. The climate for this region is characterized by year-round precipitation with frequent and sometimes intense rainstorms. The roads studied were typical of forest development roads with complete gravel surfacing, designed drainage structures, and fully grassed slopes.

Bare or lightly graveled roadbeds yield more sediment per area of running surface than a well-graveled roadbed (Swift 1984a). However, results from this and earlier studies (Swift 1984b) strongly suggest that before revegetation, cut and fill slopes are the primary sources of road-caused sedimentation. Although lower standard roads usually have less administrative controls on construction and maintenance practices, their construction rarely involves the amount of soil disturbance accompanying a higher standard road. In addition, a portion of road in the steepest terrain was unprotected by grass, gravel, or drainage structures during the most critical precipitation period of the project. Thus, the length of soil deposits measured in this study should represent an upper range of filter strip widths.

However, the site of the most critical impact of a road on a stream was consciously excluded from this and most other studies. As a road approaches a stream crossing, the filter strip width drops to zero, and thus other mitigating practices must be considered (Cook and King 1983). For example, measurements were made on one additional deposit where a slumped fill reached an ephemeral stream bottom. Soil was carried by storm water 590 ft down a 7 to 10% slope to the live stream. Loose soil from road fills entered the stream system at all such sites. In steep terrain, stream and drainage crossings usually require large fills of exposed soil and thus become critical impact locations.

The user of these data must make a risk judgment of how often sediment from a project can be allowed to reach the stream. The lines drawn on Figure 3 include 90% of the measured deposits. Table 1 compares the distances for three road conditions with guidelines taken from previous works. The current operational standard in the southeastern mountains covers slopes up to 60%. The vast majority of distances measured for this study are much less than the 210 ft specified for slight erosion hazard soils on 60% slope. All but data for the unfinished road in winter are less than Trimble and Sartz's (1957) guideline for general forest management areas, and all distances are less than their municipal watershed guideline.

CONCLUSIONS

The distance sediment moved downslope was influenced by these factors:

- Distance increased with increasing land slope.
- Distances were less below grassed fills than below mulched or untreated fills. The type and amount of mulching used on these roads was an ineffective overwinter cover.

- Normal forest litter reduced sediment movement distance.
- Brush barriers obviously reduced distances, and the effectiveness of barriers increased as slope percent increased.
- Storm waters discharged by culverts tend to carry sediments farther than diffuse flows from outsloped roads and broadbased dips.

Table 4 summarizes the sediment movement distances found in this study. Fine silt and clay particles suspended in storm runoff may be transported farther. Values are given for slope distance, with and without brush barriers, for up to 80% slopes. The basic table estimates distances for a graded and graveled roadbed with outsloping or culverts draining across a grassed fill onto a natural forest floor covered by hardwood litter. Two footnotes list adjustments appropriate for filter strips without forest litter and roadways under construction during high erosion season. Thus, Table 4 places relative values on several road construction practices that may be used to reduce the required width of filter strips. These relationships are based on roadside measurements and are not appropriate for wider disturbances such as log decking or site-prepared areas. Results apply where major instability problems typically are not found. Soils and geology become important additional considerations if the underlying material is inherently unstable in deep cuts and large fills or if material is difficult to stabilize and revegetate. As a first approximation, the allowance for a filter strip should begin where a slipped fill ends. □

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