istration, and the Department of Civil Engineering, Kansas State University.

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Measuring Surface Erosion on Forest Roads and Estimating Costs of Erosion Control—Preliminary Results

EDWARD R. BURROUGHS, JR., DONALD F. HABER, FREDERICK J. WATTS, AND TERESA L. KADOCH

Simulated rainfall was applied to three types of roadway on six sections of forest road to measure runoff and sediment yield. The three surfaces were native granitic material, native material treated with dust oil, and bituminous surface treatment. The roads are located within the Silver Creek Experimental Watershed, Boise National Forest, Idaho. Test plots of the roadway were isolated from the adjacent roadway with barriers sealed to the surface. Discharge and suspended sediment were sampled continuously. Rainfall was simulated by a large sprinkling infiltrometer at a rate of 2 in/h for 25-40 min. The first test was conducted on a dry plot, followed by a second test 24 h later. Measurements for each plot included bulk density by depth increments, loose soil on the road surface in pounds per unit area, particle-size distribution for each sample, gravimetric soil moisture before and after each simulated rainfall, and a detailed survey of each plot. Results of runoff and sediment yield measurements are presented. Construction costs for standard and nonstandard items on forest roads were determined by recording the labor and equipment necessary to complete each activity based on local rates. Programs for estimating costs of erosion-control features were developed for the HP-41CV calculator and minicomputers with BASIC language capability. Cost estimates derived from current estimating procedures are compared with costs developed from observed labor and equipment times.

Two of the major objectives of the engineering research project in the Intermountain Forest and Range Experiment Station are to (a) develop practical and reliable methods to estimate runoff and sediment yield from forest roads with various erosion-control treatments and (b) determine incremental costs of erosion-control treatments. Easily accessed timber stands have been roaded, and many of the unaccessed timber stands are on steep sites with fragile soils where watershed and fishery values are high. Erosion control remains an important consideration in forest road construction, but the ability to analyze the cost-effectiveness of erosion control must be improved.

Cost-effective erosion control for forest roads is, as the name implies, composed of two parts: (a) estimation of sediment yield from roads with selected erosion-control treatments and (b) estimation of construction costs for these treatments. Proper consideration of these two steps will provide the most erosion control for the least cost for given site conditions. This paper describes a series of research studies on this subject conducted cooperatively by the Engineering Research Project, Intermountain Forest and Range Experiment Station, and the Civil Engineering Department, University of Idaho.

WATER AND SEDIMENT YIELDS FROM ROADWAY SURFACES

Runoff and sediment models most appropriate for general use on forest roads are Road Sediment (ROSED) (1-3), which is a detailed process model, and Simplified Road Sediment (SIRSED) (4), which is a simplified version of ROSED. Input for these models include the geometry of the proposed road, expected climatic events, and many characteristics of the soil. The current version of ROSED requires calibration for the particular locality where it is to be used. The usual calibration method consists of setting up a rainfall simulator over a section of road, applying rainfall at a known rate for a selected time period, and measuring runoff and sediment yield. Initial soil moisture prior to rainfall and final soil moisture immediately after rainfall must be measured. Then model parameters are adjusted until the model output matches measured runoff and sediment yield. These values of model parameters can presumably be used in ROSED to simulate other precipitation events, terrain, and groundcover modification for similar sites. If ROSED performs accurately, it would be an effective planning tool for forest engineers and hydrologists. A systematic effort is needed to verify the ROSED model. If this is successful, a method of obtaining soil parameters for the ROSED model from easily measured site characteristics must be developed.

Our procedure for the evaluation of ROSED and the development of a general surface-erosion-prediction method for forest roads consists of four stages:

1. Testing of the ROSED and SIRSED models on

Figure 1. Plan view of typical 100-ft plot.

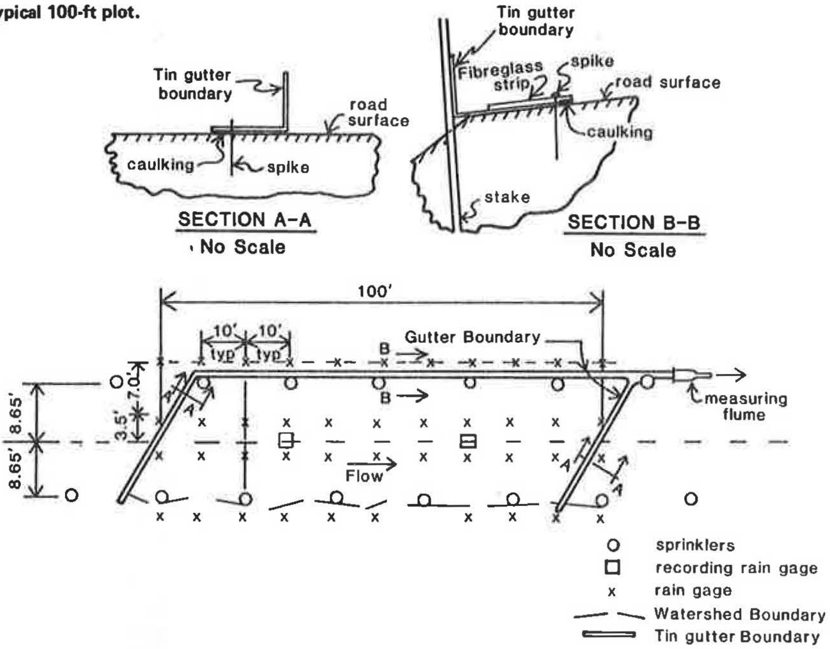


Figure 2. Typical test plot with rainfall simulation in operation.

roadways for limited types of geologic materials by using simulated rainfall and data from established streamflow monitoring stations;

2. Collection of data from an expanded set of geologic materials and road geometries by using simulated rainfall; these data will be supplemented with measurements from a few streamflow monitoring stations established in each of the geologic materials;

3. Major modification of ROSED and SIRSED based on extensive tests with simulated rainfall and preliminary results from monitoring stations to yield a general surface-erosion-prediction model; and

4. Regional testing of the prediction model by using simulated rainfall and data from monitoring stations.

Progress through this four-stage effort will depend on technical difficulties encountered in each stage and available resources. It is expected to require 6-10 years. In the first step, six roadway sections were selected from the new forest access roads in the Silver Creek Experimental Watershed on the Boise National Forest, Idaho, for measurement of runoff and sediment yield. This area is within the Idaho Batholith, an extensive mass of granitic rock (16 000 mile^2), which covers a large portion of Idaho and parts of western Montana (5). Construction costs were measured on the new access roads, including costs for cut slope and fill slope erosion-control treatments. Study procedures and preliminary results are described and discussed in the next sections.

MEASUREMENTS OF RUNOFF AND SEDIMENT YIELD FROM FOREST ROADS

Test Plots

Six road sections with three different surfacing materials were tested with simulated rainfall. The test plots of roadway surface, 50 or 100 ft long by approximately 17 ft wide, were isolated from the adjacent roadway with barriers sealed to the surface (Figure 1). The longitudinal slope of the test sections varied from 5 to 14 percent. Cut slopes were covered with plastic sheets; runoff from this area was not measured and was routed around the test section. Runoff from the roadway surface was routed in a metal trough to a modified cut-throat flume for discharge measurement and collection of sediment samples.

Rainfall Simulation Equipment

A large sprinkling infiltrometer of the type developed at Colorado State University (6,7) was used to apply rainfall uniformly over the plot surface at a rate of about 2 in/h for 25-40 min. The system consists of 15 irrigation sprinklers on 11-ft risers supplied by a 250 gal/min pump from a 5000-gal butyl rubber bag reservoir. The sprinklers were spaced 20 ft apart in rows 17.3 ft apart. Alternate rows were staggered 10 ft for more uniform rainfall coverage (Figures 1 and 2). A pressure regulator at the base of each riser ensured a constant pressure of 31 psi at each sprinkler. This configuration provides a uniform aerial distribution of rainfall for windspeeds less than 7 mph. The kinetic energy of the applied rainfall at 2 in/h is only about 40 percent of natural rainfall events at the same intensity (7).

Table 1. Plot description and soil properties.

Plot Description						Soil Properties			
								Loose Soil	
Plot No.	Run	Surface Treatment	Length (ft)	Area (ft^2)	Slope (%)	Depth (ft)	Density (lb/ft^3)	(lb/ft^2)	D_{50}(mm)
1	Dry	Native	100	1502	7.5	0-0.1	110.2	0.68	0.59
						0.1-0.2	122.1		
						0.2-0.3	133.0		
2	Dry	Native	100	1537	5.4	0-0.1	119.0	0.57	0.57
						0.1-0.2	124.3		
						0.2-0.3	123.4		
	Wet					–[a]	–[a]	0.37	0.67
3	Dry	Native	50	940	5.3	0-0.1	117.4	0.41	0.52
						0.1-0.2	126.9		
						0.2-0.3	124.6		
	Wet					–[a]	–[a]	0.38	0.68
4	Dry	Native	100	1815	7.5	0-0.1	110.2	0.72	0.54
						0.1-0.2	122.1		
						0.2-0.3	133.0		
5	Dry	Dust oil	100	1713	9.1	0-0.1	108.8	0.12	0.71
						0.1-0.2	129.3		
						0.2-0.3	139.5		
	Wet					–[a]	–[a]	0.06	1.22
6	Dry	Bituminous	50	808	10.3	–[b]	–[b]	0.24	2.70

[a] Although not measured, measurements for wet depth and density are assumed to be identical to dry measurements.
[b] Not measured.

Table 2. Soil moisture data for test sections.

			Moisture Content[a]			
			Initial		Final	
Plot No.	Run	Surface Treatment	Depth (in)	Weight (%)	Depth (in)	Weight (%)
1	Dry	Native	0-0.5	2.77	0-0.5	13.60
			0.5-1.0	3.38	0.5-1.0	8.50
			1.0-2.0	4.18	1.0-2.0	5.20
2	Dry	Native	0-1.0	2.89	0-0.85	15.03
			1.0-2.0	4.40	0.85-1.5	10.79
			2.0-3.0	4.03	1.5-2.25	5.40
	Wet		0-1.0	6.08	0-0.8	15.31
			1.0-1.8	7.28	0.8-2.2	10.08
			1.8-2.5	8.59	2.2-3.0	8.90
3	Dry	Native	0-0.8	0.44	0-0.8	13.26
			0.8-2.2	2.64	0.8-1.8	10.76
			2.2-3.2	3.16	1.8-2.5	5.86
	Wet		0-0.5	1.96	0-0.9	14.78
			0.5-1.5	4.11	0.9-1.4	11.65
			1.5-2.75	3.23	1.4-2.5	7.69
4	Dry	Native	0-0.9	3.20	0-1.0	14.03
			0.9-2.1	4.89	1.0-2.0	11.50
			2.1-3.25	6.04	2.0-3.0	7.45
5	Dry	Dust oil	0-1.2	4.02	0-0.75	5.24
			1.2-2.4	5.03	0.75-2.25	6.39
			2.4-3.6	7.21		
	Wet		0-2.5	5.91	0-1.0	5.57
					1.0-3.0	6.41
6	Dry	Bituminous	–[b]	–[b]	–[b]	–[b]

[a] Oven dry weight basis.
[b] Not measured.

Data Collected

Soil samples were taken from each plot to determine the following data:

1. Bulk density by 0.1-ft depth increments to 0.3 ft below the road surface,
2. Quantity of loose soil on the roadway surface in pounds per square foot,
3. Gravimetric soil moisture samples by depth increments determined by consistency before and immediately after each simulated rainfall, and
4. Determination of particle-size distribution for each density, loose surface soil, and suspended sediment sample.

Rillmeter measurements (8) were taken across the full width of the roadway on cross sections spaced 10 ft apart the length of the test section. These measurements were taken before each simulated rainfall and 24 h after the last rainfall on each plot. Each plot was also surveyed to provide data for construction of a detailed topographic map.

Runoff-related data that were collected for each test included a record of the time that rain began, time to surface ponding, time rainfall ceased, a continuous recording of flume stage, time each suspended sediment sample was taken (1-min intervals for the rising limb of the hydrograph and 2-min intervals thereafter), signals from two tipping-bucket rain gages, flow velocity in rills by dye travel measurements, and the increment of time when wind velocities exceeded 400 ft/min. All data were recorded on an eight-channel digital data-logging system with an Instrumentation Specialties Company (ISCO) recorder as a backup system for signals from the ISCO flowmeter.

Field Procedure

The field procedure was as follows:

1. Establish plot boundaries;
2. Construct leak-proof flow barriers at the upper, lower, and ditch sides of the plot;
3. Set up the sprinkler system and the recording and nonrecording rain gages;
4. Cover cut slopes with plastic (to prevent erosion) and route water to a safe disposal area;
5. Install the measuring flume and connect to the plot outlet by metal troughs;
6. Wire the data-collection systems;
7. Fill the water reservoir;
8. Collect initial soil samples;
9. Conduct the sprinkling operation; and
10. Collect final soil samples.

Bulk density was measured at 0.1-ft depth intervals before the first rainfall. Loose surface soil (in pounds per square foot) and soil moisture samples were measured at random locations before and after each applied rainfall.

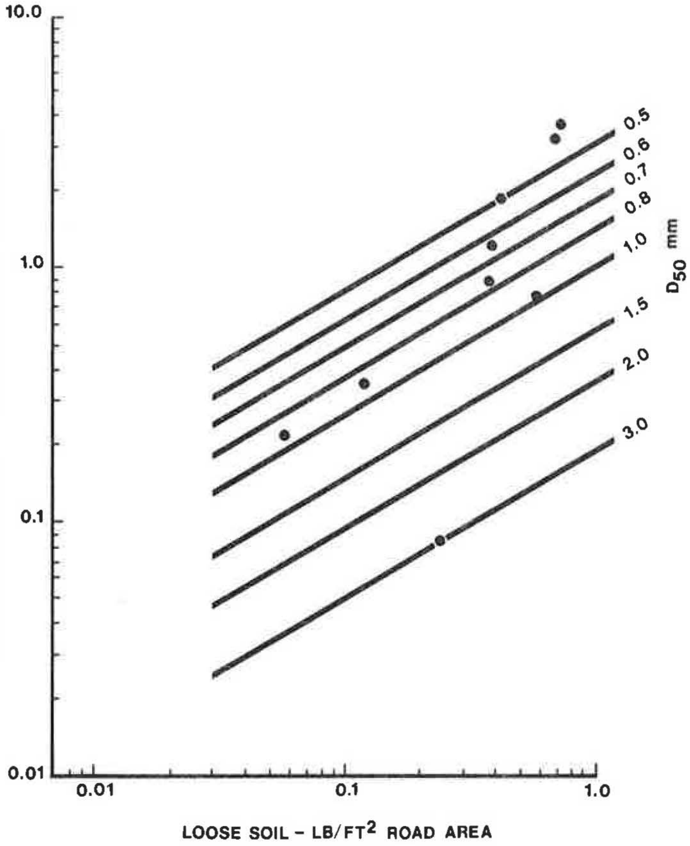
Wind velocity and direction were carefully monitored. If a steady wind of 400 ft/min or gusts in excess of 600 ft/min occurred, the test was postponed until evening or until the next morning when the air usually was still.

Table 3. Hydraulic data for test sections.

Plot No.	Run	Surface Treatment	Rainfall Applied (ft^3)	Volume Infiltrated (ft^3)	Measured Runoff (ft^3)	Error[a] (%)	Sediment Yield of Runoff per 1000 ft^2 of Road Area (lb/ft^3)
1	Dry	Native	112.7	23.2	59.7	-51.5	3.22
2	Dry	Native	126.2	28.6	95.4	-2.3	0.77
	Wet		129.4	26.0	109.3	+5.4	0.88
3	Dry	Native	81.9	29.4	55.7	+5.7	1.84
	Wet		105.5	27.6	77.1	-1.0	1.22
4	Dry	Native	135.4	57.5	57.0	-36.7	3.68
5	Dry	Dust oil	142.4	9.0	123.3	-8.2	0.35
	Wet		149.3	11.8	124.0	-10.9	0.22
6	Dry	Bituminous	56.6		46.0		0.084

[a] + = more off and - = less off.

Figure 3. Relation among loose soil on road surface, D_{50}, and sediment yield.



Results and Discussion

Preliminary analysis of one season's work with the sprinkling infiltrometer has been completed for three types of road surface treatments: native granitic material, dust oil on native material, and bituminous surface treatment.

Tables 1, 2, and 3 provide a summary of the physical characteristics and the hydrologic data for the test sections. These data show that sediment yield is correlated directly with the amount of loose soil on the road surface and inversely correlated with the D_{50}, the mean size of the loose surface material. These relations are illustrated in Figure 3 and by the following equation:

$$SEDY = 1.048(LS^{0.585})(D_{50}^{-1.568}) \quad (1)$$

where

SEDY = sediment yield (lb/ft^3 of runoff per 1000 ft^2 of runoff area),
LS = loose soil (lb/ft^2 of road surface), and
D_{50} = mean size (mm) of loose surface material.

The four graphs shown in Figures 4 through 7 illustrate the amount and intensity of runoff and sediment yield from selected road sections with various surface treatments and surface conditions. These tests are for 100-ft road sections and 30-min rainfall applications except as noted. Runoff and sediment yield are from the roadway only (except for one plot); no sediment from road cuts, fills, or ditches is included.

Figures 4 and 5 show hydrographs and sediment graphs from sections with bituminous surfacing and native granitic material with dust oil. In each case, the hydrograph climbs rapidly to a nearly constant flow rate and remains at this rate until rainfall stops. Sediment yield, in pounds per cubic foot of runoff per 1000 ft^2 of road surface, is quite low for these protected surfaces. For comparison, Figure 6 shows a typical hydrograph and sediment graph for a road surfaced with native granitic

Figure 4. Runoff and sediment yield for plot 6, bituminous surface treatment.

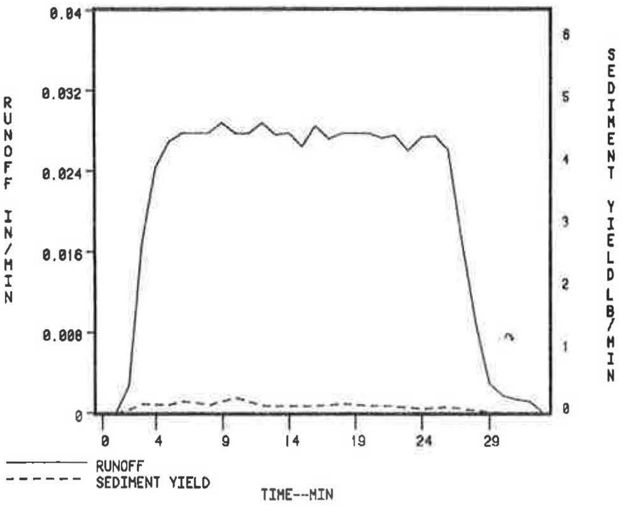


Figure 5. Runoff and sediment yield for plot 5, dust-oiled native material.

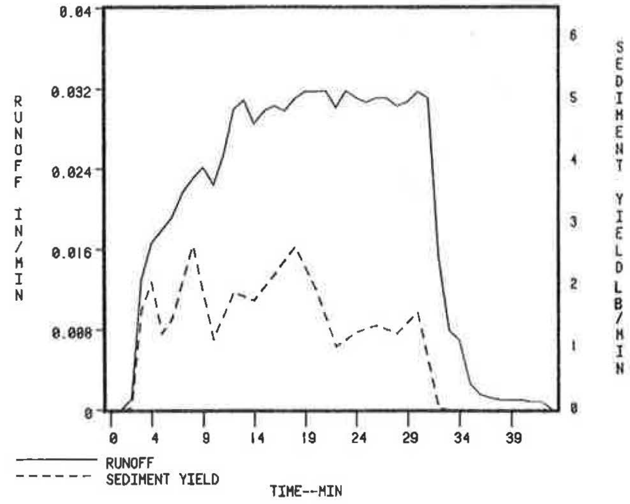
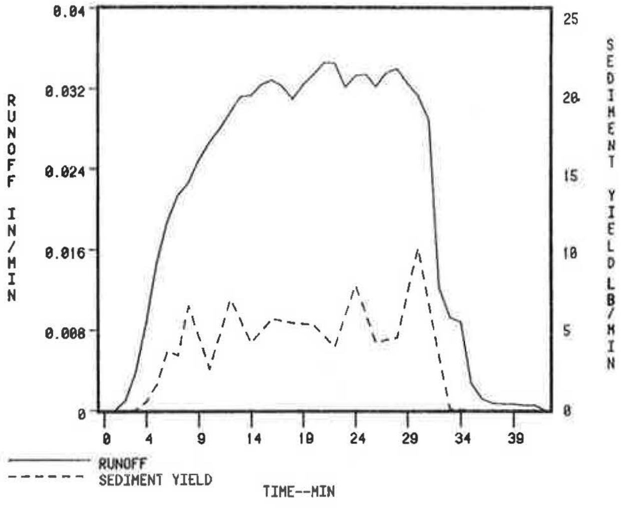


Figure 6. Runoff and sediment yield for plot 2, native granitic material.



material. The hydrograph also exhibits a rapid rise to a nearly constant runoff rate, but the sediment yield from the native material is 3.1 times that for native material with dust oil and 9.8 times that for bituminous surfacing. These values were based on the average sediment yield from wet and dry runs for each plot.

Figure 7 shows results of tests on a native granitic-surfaced plot that is noteworthy for the shape of its hydrograph and sediment yield. This hydrograph rises gradually until rainfall stops without reaching a constant runoff rate; thus, it is in sharp contrast to the hydrographs in Figures 4, 5, and 6. A check on the water balance for this plot shows a discrepancy of -51.5 percent or a 29.8-ft^3 difference between the volume applied, the calculated infiltrated volume, and runoff volume; other plots check within 11 percent. Repeated tests on this section gave nearly identical hydrographs with no evidence of leakage under or around any flow barriers.

The same section of road was used for plot 1 and plot 4. Boundaries were completely reset at a later

Figure 7. Runoff and sediment yield for plot 1, native granitic material.

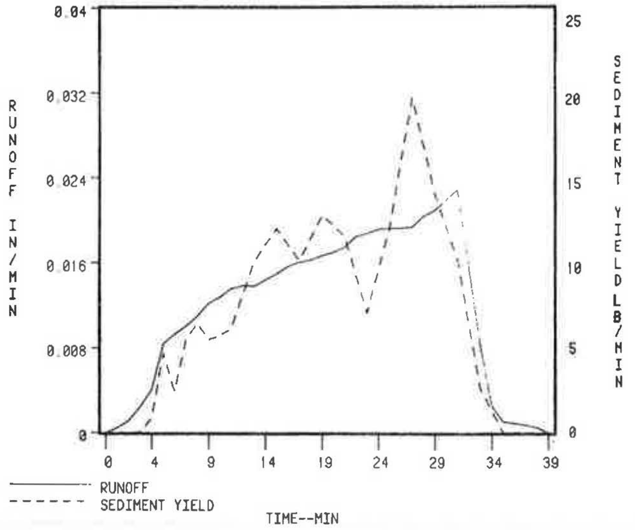
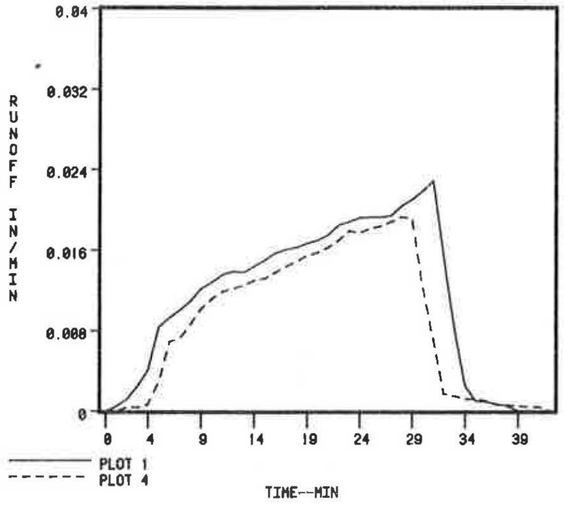


Figure 8. Runoff hydrographs for plots 1 and 4, native granitic material.



date and the ditch section was included for plot 4. Note that the hydrograph shapes for plots 1 and 4 are essentially the same (Figure 8). The decreased flow volume from plot 4 compared with plot 1 is consistent with the increase in infiltrating area associated with the ditch. The above information suggests that the barriers did not leak. We suspect that water infiltrated into weathered bedrock, the fill material, or along the interface of the cut and fill.

Sediment yield from plots 1 and 4 is nearly 3 times greater than that of other native granitic road surfaces and 41 and 12 times greater than the bituminous and dust-oil surface treatments, respectively (Table 2). This emphasizes the importance of measuring the amount of loose surface soil and D_{50} for use in predicting sediment yield from forest roads.

Future Work

Development of a regional surface-erosion-prediction model will continue through the four-stage process outlined earlier. Road sections in various geologic materials and climatic zones in Idaho and Montana will be selected for sprinkling infiltrometer tests and for monitoring of runoff and sediment yield from snowmelt and thunderstorms.

A monitoring station will consist of a flume and an automatic sediment sampler placed immediately above a live water road crossing and a similar installation at the culvert outfall, or below any erosion-control treatments at the culvert outfall. Supplementary instrumentation will include a tipping-bucket rain gage. The road section will be selected to provide runoff from a well-defined area of travelway, ditch, and cut slope. Monitoring will begin during road construction to measure the immediate impacts; then continuous measurements will begin at the onset of spring snowmelt through the summer thunderstorm season until late fall. Monitoring will be maintained through three snowmelt seasons. Physical characteristics of each road section will be measured periodically to define changes with time, traffic, and road maintenance.

COSTS OF EROSION-CONTROL TREATMENTS FOR FOREST ROADS

Research Methods

Construction of the Silver Creek forest access roads began in 1980, along with a study that had three principal objectives:

1. To develop and quantify forest road construction costs, including costs of several erosion-control treatments;
2. To develop a computer algorithm for a small programmable calculator to estimate costs of erosion-control treatments by using parameters such as material quantities, labor and equipment rates, and certain site factors such as slope, clearing classification, and rock type; and
3. To compare costs based on current estimating procedures with those costs actually measured on the Silver Creek road construction project.

Construction requirements for Forest Service roads include standard items that are generally required and nonstandard items that require a special type of construction not specified on most forest roads. Examples of standard items are clearing and grubbing, sidecast embankments, and various types of surfacing, such as crushed rock, bituminous treatment, dust oil applied to native material, and double seal coat. Nonstandard items include nonmerchantable log placement, controlled embankment compaction, rolled embankment faces, terraced cut slopes, concrete curbing, hydromulching, underdrains, bin walls, gravel berms, earth berms, and seed, fertilizer, rolled straw mulch, and netting on fill slopes. Descriptions of all standard and most nonstandard items may be found in the Forest Service Standard Specifications for Construction of Roads and Bridges (9).

Daily records were kept, including person-hours, machine-hours, type of equipment used, and crew composition for each activity by stations. For all special erosion or nonstandard items, estimates of idle time and supervisory time were also recorded. An actual cost for each activity was determined from these data by using two methods:

1. Boise vicinity: Costs determined by this method used local labor and equipment rates determined from Boise-area contractors and suppliers. County and state taxes and insurance rates were added directly to this cost. A servicing rate and cost of fuels and lubricants, as determined from various equipment manufacturers' handbooks, were also added on an hourly basis. Local labor rates were determined from the basic labor rate plus fringe benefits plus 20 percent for Social Security, unemployment insurance, and workman's compensation. Total costs were the sum of all equipment and labor costs, including a 10 percent profit and risk margin.
2. Blue book: Rental rates for this method were obtained from the regional equipment blue book guidebook (10), which includes margins for profit and risk, fuel, oil, lubrication, repairs, maintenance, insurance, and any incidental expenses. Labor rates were calculated as in 1 above except that 5 percent of the total labor cost was added for profit and risk. Total costs were determined as the sum of all equipment and labor rates.

After the actual cost for each activity was calculated, an average cost per unit of production was determined based on design quantities. Average production rates for all activities were used in a cost-estimation program for road construction.

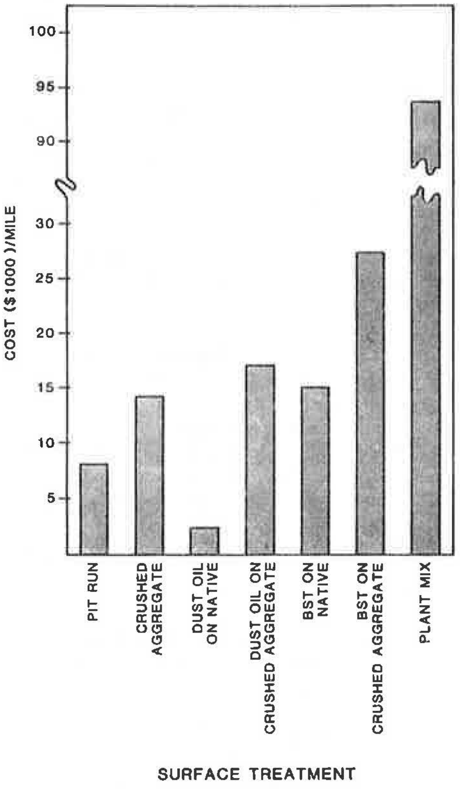
These programs were then integrated into the Forest Service cost-estimation guides for roads for Region 1 (Montana, northern Idaho, and eastern Washington) (11) and for the Boise National Forest (part of Region 4) (12). Programs for the HP-41CV were developed for each estimation guide. This increases the utility of estimating costs of roads that incorporate erosion controls because one can easily estimate the incremental cost of erosion-control treatments above the cost of standard road construction. Each program functions interactively with the user by requesting necessary site data, equipment costs, and labor rates.

Two additional steps were taken to increase the efficiency of the cost estimation of roads and erosion control for Forest Service users. All HP-41CV programs were placed on a Hewlett-Packard IL system with cassette drive so that the cost estimation may be accomplished without interruptions to read program cards into the calculator. Also, the two Forest Service cost-estimation guides were translated into BASIC for use with minicomputers.

Results and Discussion

Costs of road-surfacing treatments for erosion control, costs of cut slope and fill slope erosion-control treatments, and costs associated with different types of embankment placement are shown in Figures 9, 10, and 11. Costs for road-surfacing treatments exclude materials hauling costs, so that

Figure 9. Road-surfacing treatments, cost per mile (excluding materials hauling costs).



the materials cost plus placement costs for these surface treatments can be compared (Figure 9). Similarly, costs per acre for various types of fill slope treatments may be compared in Figure 10. Some caution should be used in extrapolating costs of rolled embankment faces because these data are from small areas and the contractor lacked experience in applying this technique. Cost comparisons in Figure 11 are for three types of embankment placement. Sidecast embankments and layer-placed embankments are considered standard items, and controlled compaction was considered a nonstandard item for this road.

Measurement of the effectiveness of these slope treatments in reducing sediment yield is the responsibility of the Intermountain Station's Watershed Research Project in Boise, Idaho. Results of these determinations will be reported by the watershed research unit at a later date.

Cost comparison between various erosion-control methods should be valid because it is a relative comparison. This is based on the assumption that the contractor's efficiency did not change significantly during construction. If this is true, then a relative comparison would not require that the contractor's actual efficiency be known (13).

Analysis of costs by using the various techniques indicates that the contractor exceeded average production rates incorporated in standard cost-estimation procedures. We conclude that the cost-estimation procedure developed in this study will give realistic estimates of forest road construction costs in central Idaho, especially for those roads that include nonstandard items for erosion control (13).

Figure 10. Fill slope erosion control, cost per acre.

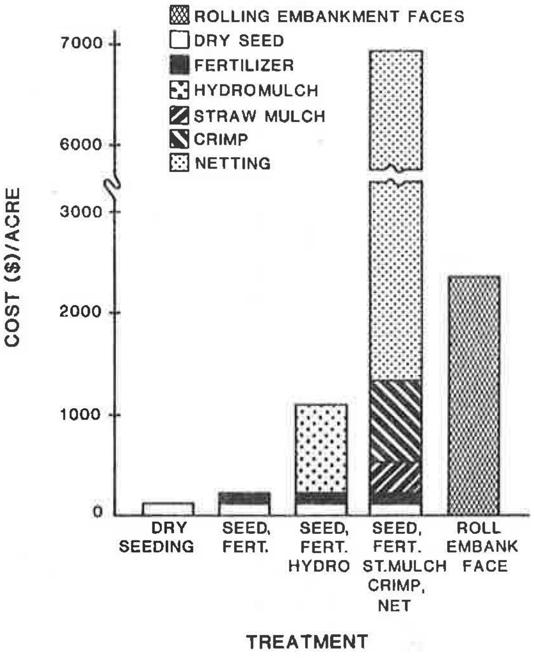
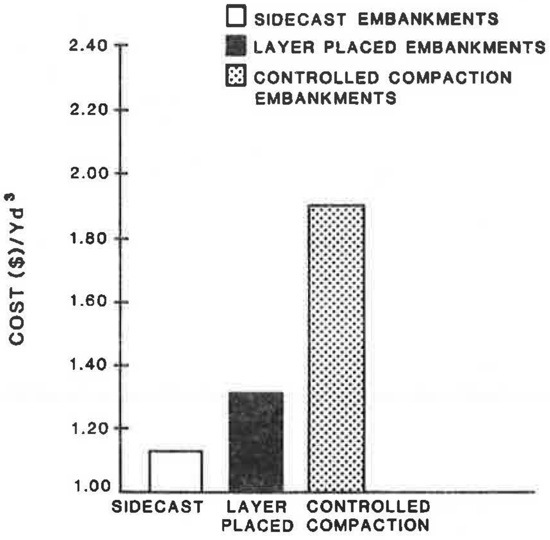


Figure 11. Excavation cost comparison, cost per cubic yard.



Future Work

Future engineering research work will expand production rate and construction cost data collection to other geologic materials and other site conditions so that the erosion-control cost-estimation procedure is as widely applicable as possible. Data collection will concentrate on the use of new types of construction equipment, such as hydraulic excavators, which may reduce forest road construction costs and may reduce the environmental impacts of construction, especially for culvert placement. Forest road construction projects will be monitored to develop better correlations between production rates, construction costs for erosion-control treatments, and site factors such as slope, timber size, and timber density.

SUMMARY

Methods to estimate road construction costs, including treatments for erosion control, have been developed as operational tools for Forest Service preconstruction engineers. Good progress has been made on estimating runoff and sediment yield for selected road surface treatments for the granitic materials of the Idaho Batholith. Measurements are for roadway surfaces only; contributions from cut slopes, fills, and ditches (with one exception--plot 4) are not included.

The research studies outlined in this paper represent a reasonable approach to developing a method for estimating surface erosion from forest roads and for predicting the cost of erosion-control treatments. Infiltrometer tests supplemented with data from continuously monitored road sections should provide sufficient information to achieve research objectives.

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Opinion Survey for Selection of Low-Water Crossing Structures

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The low-water crossing structure (LWCS) frequently represents a significant financial saving, although these structures may be overtopped and damaged by floods. Thus, decisionmakers are hesitant to build them. Currently, there is no guide on the selection of the LWCS. Consequently, a public opinion survey was conducted and the results are presented to serve as a useful guide for the selection of the type of structure to build. About 60 responses (36 detailed, 24 brief) from the United States and 3 responses from Canada were received and analyzed. The most important tangible factors (in order of importance) are possible damage to human life, average daily traffic (ADT), frequency of possible flooding, legal considerations, and location as part of an emergency route. Availability of an alternate route, duration of traffic interruptions, and possible property damage form the second most important group of factors. There is no difference of opinion among different regions of the country. For a 28 percent saving of total tangible costs, decisionmakers would consider the LWCS. The desirable conditions are less than 5 ADT, average annual flooding frequency less than 2, good hydrologic analysis, average duration of traffic interruption less than 24 h, not more than 60 min of travel by alternate route, chance of having a human life involved less than 1 in 1 billion, and an excellent warning system. A set of absolute constraints below which no LWCS would be considered was also obtained. It must be emphasized that each decisionmaker must use his or her judgment to decide on which type of structure to build for each location, and there can never be any rigid rule to be followed. Ultimately, the decisionmaker must evaluate all the tangible and intangible factors involved for a given case to make the selection of the structure to build. The method must be chosen, the analysis conducted, and the decision made. Defense of the decision may also be required.

The first purpose of this study is to collect, summarize, and analyze information from different regions of the United States and Canada regarding the use of the low-water crossing structure (LWCS). The second purpose is to develop a simple decision model to assist highway engineers in the selection of either an LWCS or a regular bridge.

The LWCS is a structure designed to carry traffic across a stream. It is different from the regular bridge, which is designed to span above anticipated floods with rather long return periods and thus is