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from

Proceedings of the Federal Inter-Agency Sedimentation Conference, 1963
U.S. Dep. Agr. Misc. Pub. 970. 1965.

SEDIMENTATION AFTER LOGGING ROAD CONSTRUCTION IN A SMALL WESTERN OREGON WATERSHED

[Paper No. 8]

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Abstract

During the summer of 1959, 1.65 miles of logging road were constructed in a 250-acre forested watershed that rises 2,000 feet in a distance of 1 mile. This study evaluates the change in sedimentation subsequent to road construction. Runoff from undisturbed watersheds in this area remains clear during the summer low-flow months and reaches concentrations of 100 parts per million during winter storm peaks. Runoff from the first rainstorms after road construction carried 250 times the concentration carried in an adjacent undisturbed watershed. Two months after construction, sediment had diminished to levels slightly above those measured before construction. Sediment concentrations for the subsequent 2-year period were significantly different from preroad levels. In about 10 percent of the samples, sediment concentrations were far in excess of predicted values, indicating a streambank failure or mass soil movement. Annual bedload volume the first year after construction was significantly greater than the expected yield, but the actual increase was small. A trend toward normalcy was evident the second year.

Introduction

Streams flowing from undisturbed mountain watersheds of western Oregon normally carry very small sediment loads. But when logging roads are built to harvest the old-growth Douglas-fir timber from these watersheds, the construction activities expose considerable raw soil, often resulting in increased sedimentation. In 1952, the Forest Service began a watershed experiment designed to measure the effect of intensive forest land management upon the sediment load carried by streams in the western Cascade Range of Oregon. The first treatment phase began in 1959 when logging roads were built in one experimental watershed. This paper presents an estimate of the change in suspended sediment concentration after construction of these roads.

Colby, Hembre, and Rainwater,[1] in a thorough investigation of the Wind River basin of Wyoming, found annual sediment yield ranged from 1.11 to 0.70 ton per acre during a 5-year period. They found large differences in the sediment load carried from watersheds draining different types of geologic materials. Care must be taken when projecting sedimentation rates from small watershed studies to larger watersheds, particularly where there is a change in geologic material.

Anderson[2] was able to segregate sediment load in the Willamette River basin of western Oregon into three sources: (1) 24 percent from forest lands comprising 77 percent of the drainage area, (2) 22 percent from agricultural land comprising 23 percent of the area, and (3) 54 percent from 205,000 feet of eroding main channel. He predicted that if forest land development continued at the rate existing at the time of the study, sediment discharge would increase to three times the rate that was estimated for the watershed condition in 1950.

The progress of erosion from a small watershed was measured for 3 years after logging in the Sierra Nevada of California. Here Ander-

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[1] COLBY, B. R., HEMBRE, C. H., and RAINWATER, F. H. SEDIMENTATION AND CHEMICAL QUALITY OF SURFACE WATER IN THE WIND RIVER BASIN, WYOMING. U.S. Geol. Survey Water-Supply Paper 1373, 336 pp. 1956.

[2] ANDERSON, H. W. SUSPENDED SEDIMENT DISCHARGE AS RELATED TO STREAMFLOW, TOPOGRAPHY, SOIL, AND LAND USE. Amer. Geophys. Union Trans. 35(2): 268-281. 1954.

son and Richards [3] found that, once logging was completed and the area began to recover, mean sediment concentration during high streamflow decreased markedly. During the second and third years after logging, it decreased to about half what it had been the previous year.

The Study

On the H. J. Andrews Experimental Forest, located near Blue River, Oreg., three small, gaged watersheds (fig. 1) have been under study to evaluate the effects of logging on the quantity and quality of runoff.[4] In the 1 mile between the gaging site and the back ridge of the watersheds, the elevation increases from 1,500 to 3,000 feet. Topography is steep and broken with deeply incised stream channels that flow northwesterly. Geologic structures include basaltic-andesite ridges overdeposited with tuffs and breccias. Tuffs and breccias are parent materials for deep, heavy, and highly aggregated soils on benches and at the toe of slopes. Runoff in stream channels is rapid, though surface runoff has never been observed. The soil mantle is very permeable.

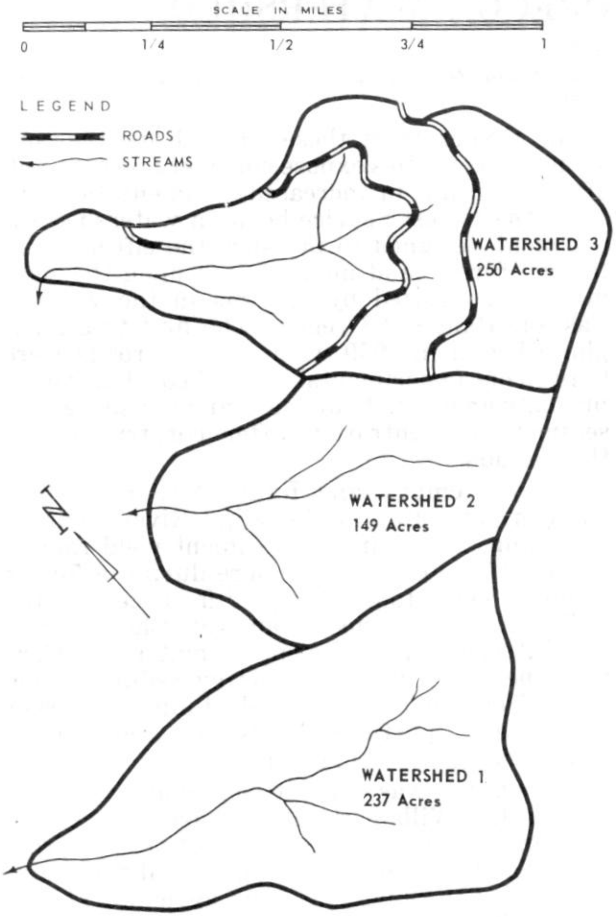

FIGURE 1. — Experimental watersheds.

Cover is predominately overmature Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], varying from 20,000 to 120,000 board feet per acre. The dense cover has remained essentially unbroken for a period of 450 years.

The maritime climate of western Oregon is typically dry in summer and wet in winter. Annual precipitation averages 91 inches but may vary from 56 to 114 inches, with 95 percent of the precipitation falling between October and May. Although large storms with 3 or more inches of precipitation per day may occur during this period, rainfall intensities seldom exceed 0.3 inch per hour. Snow may be present at this elevation from November through March, but only occasionally remains on the ground for more than two weeks at one time.

Road Construction

The experimental watersheds remain undisturbed until the spring of 1959 when construction of logging roads began in watershed 3. By October 1, 1.65 miles of all-weather logging road were completed with a 14-foot roadbed topped by a 10-foot, crushed-rock driving surface. This transportation system consists of three roughly parallel roads at elevations of 1,900, 2,400, and 2,800 feet. (fig. 1). Continuously flowing streams are crossed in two places by the middle road. No surface flow is evident at the lower or upper roads except during major storms.

Annual road maintenance, performed during the summer, consisted of removing several minor slumps along cut banks and clearing drainage ditches. During September 1959, all cut and fill slopes were seeded with grass, fertilized, and mulched with straw, but only a poor stand of grass resulted. No logging trucks used the roads during this phase of the study.

Methods

Beginning in 1955, suspended sediment was sampled at each stream gage (trapezoidal flume). Vertically integrated samples were taken in pint milk bottles from the upstream end of each flume. Results of analysis, by the Gooch filtration technique, are expressed in parts per million (p.p.m.). Bedload has been measured in catchment basins below the gaging sites since 1957. The basins, with 1,650 to 2,050

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[3] ANDERSON, H. W., and RICHARDS, L. G. FOURTH PROGRESS REPORT, 1960-61, CALIFORNIA COOPERATIVE SNOW MANAGEMENT RESEARCH. U.S. Forest Serv., Pacific Southwest Forest and Range Expt. Sta. Study 112, pp. 154-155. 1961.

[4] BERNSTEN, C. M., and ROTHACHER, J. A GUIDE TO THE H. J. ANDREWS EXPERIMENTAL FOREST. U.S. Forest Serv. Pacific Northwest Forest and Range Expt. Sta., 21 pp., illus. 1959.

square feet of surface area, have a low trap efficiency. Bedload volume was calculated annually from the mean rise in pond-bottom elevation, measured on intersections of a 3-foot grid.

Results

Annual Sediment Distribution From Undisturbed Watersheds

Distribution of annual sediment concentrations measured in the experimental watersheds follows a pronounced cyclic pattern. Sediment concentration of samples plotted in figure 2 show considerable variation caused by major storms and the short 6-year period of record. But the figure shows clearly that sediment concentrations are small during low runoff summer months and rise in autumn to a peak during high runoff in winter months. Sediment seldom rose above 100 p.p.m. from these undisturbed watersheds, though greater concentrations have been measured. Localized failures of streambanks during storm peaks probably account for the short-lived surges to slightly over 200 p.p.m.

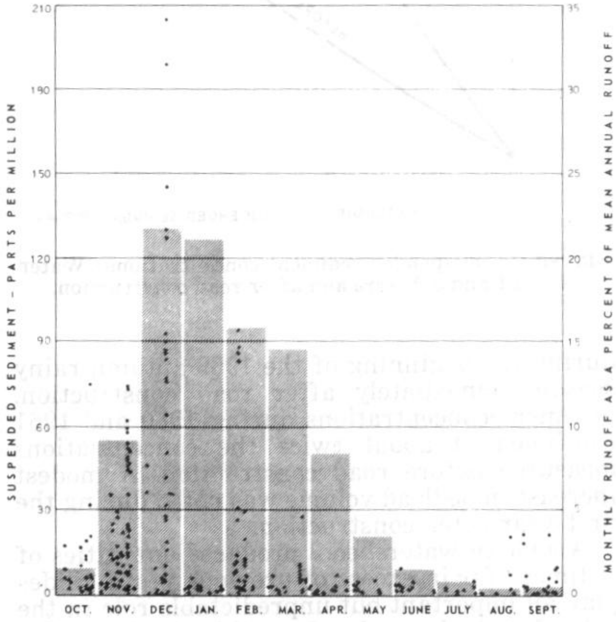

FIGURE 2. — Annual distribution of suspended sediment samples and monthly runoff from undisturbed watersheds, 1957-62.

Changes in Suspended Sediment After Road Construction

A drastic change in sedimentation was apparent immediately following road construction. The increase, measured when the rainy season began in autumn of 1959, compares with results reported by Guy[5] during the construction phase of urban development.

Sediment loads, when streams were near peak flows, are shown as ratios (watershed 3 to watershed 1) in figure 3. Before road construction, peak sediment loads in watershed 3 were 2.3 times those in watershed 1. During the first storm of September 21, 1959, when roads were nearing completion, sediment reached a maximum concentration of 1,780 p.p.m., 250 times the concentration in watershed 1. Two months later, the initial effect of road construction had apparently passed. By November 23, 1959, sediment concentrations in watershed 3 subsided to levels slightly above those measured before construction and remained at about these levels for the following 2 years.

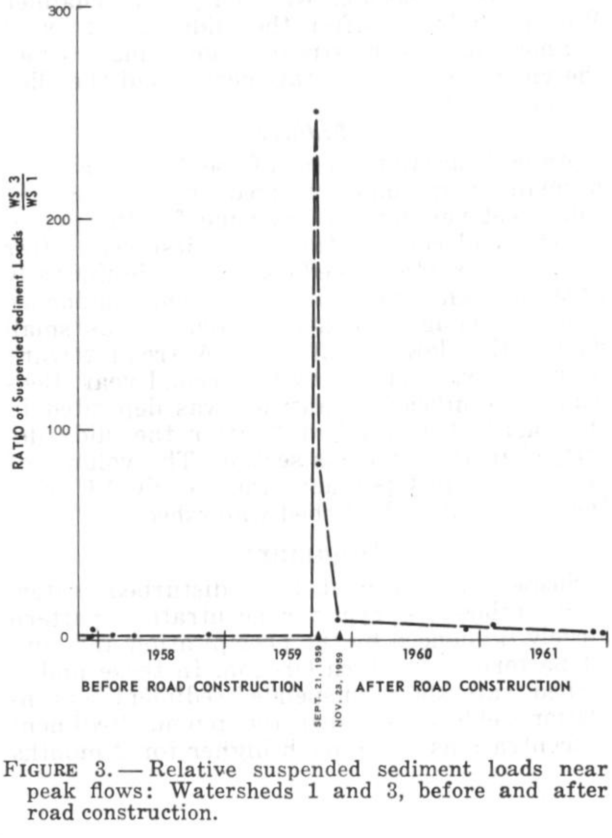

FIGURE 3. — Relative suspended sediment loads near peak flows: Watersheds 1 and 3, before and after road construction.

Data for this 2-year period after road construction were analyzed to determine their relation to data collected before construction. Two regressions of paired samples[6] from watersheds 1 and 3 were calculated and are compared graphically in figure 4. Sediment concentrations in watershed 3 were slightly more than twice

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[5] GUY, H. P. EFFECTS OF URBANIZATION ON THE SUPPLY OF FLUVIAL SEDIMENT. U.S. Geol. Survey Res. Prof. Paper 424-A, p. 85. 1961.

[6] Samples were considered paired if both were collected within a 1-hour interval.

the corresponding concentration before construction. This increase proved highly significant.

Slides Add Unpredictable Quantities of Sediment

Relationships shown in figure 4 reflect only "normal" erosion of the soil mantel. The analysis does not include sediment concentrations caused by sudden movements of soil such as slippage of streambanks. In the period of observation, 8 samples out of 83 collected during major storms contained sediment contributed by these unpredictable events and were not included in the analysis.

The largest sediment concentration in watershed 3 during this period was caused by a slide that originated from the middle road and dammed a small tributary. When the dam was breached, a wall of water and debris scoured one-half mile of stream channel to bedrock. Two debris dams containing about 5,000 yards of rock, gravel, and logs were left in the channel. Within 20 hours after the slide, 260 tons of sediment passed the stream gage — many times the yield expected for this period had the slide not occurred.

Bedload

Annual accumulation of bedload material, normally very small, ranged from 1/4 to 3 1/2 cubic feet per acre of drainage for the period before road construction. The first year after road construction, bedload was significantly greater than expected (95-percent confidence level), although the actual volume was small during this low runoff year. A trend toward normalcy was evident by the second year. Bedload in significant quantities was deposited in the basin at watershed 3 after the slide described in the previous section. The volume of 10.84 cubic feet per acre was nearly 18 times the volume at undisturbed watershed 2.

Summary

Suspended sediment in undisturbed watersheds follows a cyclic concentration pattern largely influenced by the precipitation and runoff pattern in western Oregon. In these undisturbed watersheds, suspended sediment concentration seldom exceeded 100 p.p.m. Sediment concentrations were much higher for 2 months during the beginning of the 1959 autumn rainy season, immediately after road construction. Sediment concentrations during 1960 and 1961 continued at about twice the concentrations measured before road construction. A modest increase in bedload volume was noted during the first year after construction.

A slide in watershed 3 produced quantities of sediment far in excess of previous years. Slides play an important but unpredictable role in the rate of geologic erosion from this physiographic type.

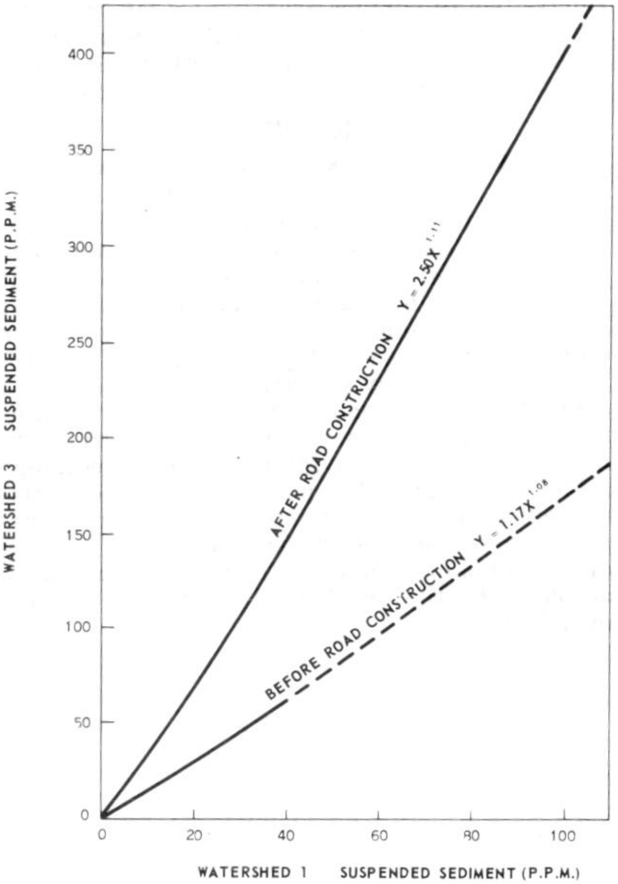

FIGURE 4.—Suspended sediment concentrations: Watersheds 1 and 3, before and after road construction.