THE EFFECT OF UNCONTROLLED LOGGING ON STREAM TURBIDITY

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GOOD water and good land management go hand in hand. Water supply engineers, foresters, and land use planners are learning more and more that the relation between water and the condition of land resources is intimate and continuous. The whole purpose of watershed management is to maintain this relation so that all the watershed resources may be utilized to their fullest advantage and economic extent. One of the problems that has arisen in connection with the maintenance of this principle is whether the harvesting of timber would jeopardize a city's water supply. Seattle's Cedar River watershed is a concrete example of this question[1]. There the controversy arose as to whether logging on the watershed should be continued or prohibited for the indefinite future. After detailed study an expert commission concluded that with the given climate, soils, vegetation, and other circumstances, "there are no inconsistencies in a policy and program which results in protecting the water supply values simultaneously with the conservation and use of the timber resources of the Cedar River watershed." Logging was continued. The commission also pointed out that "For over half a century lay and professional groups have argued with more heat than light about the effect of forest cover and forest practices upon precipitation and runoff. Even at this late date authoritative quantitive data which shed light upon these important effects are exceedingly meager."

The Coweeta Hydrologic Laboratory was established by the U. S. Forest Service to supply this lacking information for the southeastern United States[2]. This article is primarily concerned with the effect of forest practices on water quality. It describes in particular the increased stream turbidities resulting from a typical logging operation in the southern Appalachians. In addition, it indicates specific trouble spots and possible remedies.

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Description of Area

The 5500-acre laboratory of the Southeastern Forest Experiment Station is situated in the Nantahala Range of the southern Appalachian Mountains which places it in the zone of maximum precipitation in the eastern United States and within the major water source area of the Southeast. The annual precipitation on the experimental forest varies between 65 and 90 inches depending on elevation, which ranges from 2200 to 5200 feet above mean sea level. Precipitation (of which less than 2 per cent is in the form of snow) is uniformly distributed throughout the year. The mean annual temperature is approximately 55°F. During the growing season, which is from April to October, the average temperature is 65°F. Natural vegetation on the experimental area is composed almost entirely of deciduous trees. There is an abundance of shrubs, principally rhododendron and laurel, in the minor vegetation. With the existing favorable climatic conditions, plant growth is rapid and is practically never checked by summer droughts. At Brevard, N. C., which is in the same general physiographic area as the Experimental Forest but about 60 miles to the northeast, at no time during the year is there any moisture deficiency or an over utilization of soil moisture[3]. The underlying geologic formation of the area is pre-Cambrian Carolina gneiss. The average depth of soil is greater than four feet and the soil is underlain by soft, disintegrated rock.

The Problem

At Coweeta we have been able to separate the effects of tree cutting from the effects of erosion caused by logging. The effect of tree cutting, with minimum disturbance of the soil, was determined on a complete 33-acre experimental watershed[4]. The runoff characteristics of the watershed were established from five years of continuous streamflow measurement. At the end of this standardization period all major vegetation was cut. To prevent any unnatural soils disturbance the trees were left lying where felled and were not removed from the area. As a result of this treatment, there was a 65 per cent *increase* in water yield from the area during the first year following cutting. This increase was entirely in the form of usable base flow. Thus it was demonstrated that in this climate the reduction of vegetation was not detrimental to the water supply *as long as forest soil conditions were maintained.*

When these forest soil conditions were disturbed, however, the water supply was adversely affected. From a nearby 212-acre experimental watershed, wood products were removed with the use of typical, local logging practices without any restrictions because of water values. In this case there were decided increases in stream turbidity and sedimentation.

As is typical of the southern Appalachians, this logging chance was characterized by steep, generally rough topography, with the valuable trees in scattered stands. Logs were ground-skidded by horse teams. Steep access roads and skid trails were constructed parallel and adjacent to natural stream channels, and comparatively little thought was given to their location and design. These latter deficiencies subsequently resulted in most of the erosion and the transportation of sediment into the stream.

Logging on the 212-acre experimental watershed was begun in June, 1942. In early 1946, in order to facilitate the operation, an access road 0.8 miles in length was bulldozed into the area by the logging contractor. In early 1947 he constructed a spur road about 0.3 miles long. To date approximately 900 cords of extract wood (wood for making leather tanning extract) and 170,000 bd. ft. of timber have been taken from the area. No logging or road specifications were set up for the operator and the whole

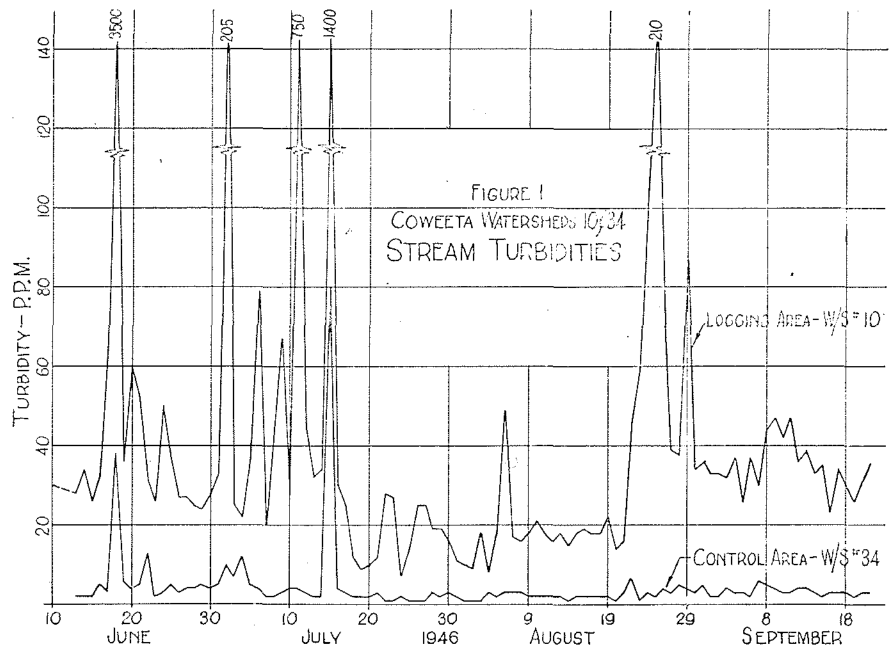

Fig. 1—Comparison of Stream Turbidities from Control Watershed and Logged Watershed.

situation is typical and average for the southern Appalachians.

Data and Results

The results of the logging were soon apparent to workers on the experimental forest whose general remark was, "that used to be one of our best drinking places, but it's too muddy now."

To measure quantitatively and systematically the changes in water quality associated with the logging operation, water samples were collected from the logged area (Watershed No. 10) and turbidities of these samples were compared with those collected from an adjacent control watershed (Watershed No. 34) on which there was no man-made disturbance. The daily samples from the two watersheds were obtained within fifteen minutes of each other. An analysis of the turbidity determinations for the period June 10 to September 21 shows that on the area that was being logged, the average turbidity was 93.7 parts per million. More important, the maximum turbidity was 3500 ppm. and the modal value of turbidity was 36.0 ppm. Comparatively, on the control area, the average turbidity was 4.3 ppm., the maximum turbidity was only 80 ppm. and the modal value of turbidity was 2.0 ppm. Table 1 gives this comparison in tabular form. Figure 1 shows the turbidity plotted by days for the two watersheds, and Figure 2 indicates the daily precipitation during the period. As was expected, the higher turbidities were recorded when logging disturbance was followed by heavy rainfall. The results of a frequency analysis of the turbidities are shown graphically on Figure 3.

TABLE 1.
SUMMARY OF STREAM TURBIDITIES
Coweeta Watersheds No. 10 and No. 34, June 10 to September 21, 1946

	Watershed #10 Logged Area	Watershed #34 Control Area
	ppm.	ppm.
Average turbidity	93.7	4.3
Modal value of turbidity	36.0	2.0
Maximum turbidity	3500.0	80.0

Sources of Turbidity

Measurements and observations on the watershed readily revealed the sources of this turbidity. In the summer of 1942, during a three-months' period, 250 cubic feet of eroded material were collected from a portion of skid road 450 feet long and 5 feet wide on a 30 per cent grade. This is equivalent to an erosion rate of over 160 cubic yards per acre of road surface. Cross-sections of the access road measured at intervals showed lowering of the road level as much as a foot, with recession of the road bank (due mainly to frost action) of an equal amount. Wheel ruts eight inches to a foot deep and two feet wide were not uncommon.

How a small, local trouble spot may affect a larger stream system was brought out during the storm of April 11, 1947. Following this storm of 1.02 inches in 14 hours, samples were collected from (a) the stream draining Watershed No. 10; (b) from the main stream just above Watershed No. 10; (c) from the main stream, draining an area of 1800 acres, at a point below Watershed No. 10; and (d) from another main stream in the experimental forest draining slightly less than 1800 acres, on which there is no logging activity. The turbidities of these samples were as follows:

Watershed No. 10 (212 acres)	1200 ppm.
Main stream above Watershed No. 10	25 ppm.
Main stream below Watershed No. 10 (1800 acres)	395 ppm.
Another comparable main stream of nearly 1800 acres —(no logging)	25 ppm.

Thus it is seen that the origin of high turbidity in a larger stream may be traced to a fairly small or localized area.

Although no chemical analysis of the material causing turbidity was made, a visual examination of the samples from the two watersheds indicated a marked difference in the composition of the material. Generally speaking, the matter in the water samples collected from the logging area was of a finely divided mineral character with low settling rates and no marked flocculating tendencies. On the other hand, in the samples collected from the control area the material causing turbidity was, except in one or two instances, almost entirely organic in composition. It exhibited a definite flocculating characteristic, and the floc settled rapidly.

Discussions and Conclusions

Correction of the deficiencies described would go a long way toward ameliorating the destructiveness of most logging operations in the southern Highlands. First, considerably more attention should be given to the location and grade of access roads. For instance, on Watershed No. 10, the road is so laid out that slopes as high as 28 per cent alternate with relatively flat stretches. Erosion on the steep sections is much harder to control because of the increased velocity and erosive force of the flowing water. Also, because of these steep slopes the road is highly dangerous in wet weather and in many cases impassible to truck traffic. In laying out the road the location of the valuable trees and stands and wood forest products should be well known in relation to each other so that the least amount of road necessary to remove these forest products has to be constructed. In other words, the road layout should be designed. An important factor involved here is the length of time of the operation. It is not only important to the timber operator, but also extremely important to the watershed manager since turbidities and soil losses are increased proportionately. In many cases where a proposed timber sale or removal contract is supposed to be completed in a year, it is still going at the end of 2, 3, or 4 years. Further exploitation for other forest products very often lengthens the time that the road is in use. Thus the widely-held opinion that the sale will be consummated in a short time and that the damaging effects of the road or roads can be rectified following the operation is false. It is false also because, as has been pointed out, the greatest erosion, transportation of sediment, and resulting high turbidities occur while the actual logging is in progress on the watershed.

Secondly, the matter of road drainage can hardly be over emphasized. The motto of the military road builders is "Keep the water off and the rock on." The first part of this maxim definitely applies to the construction of logging roads. Since the roads are generally unsurfaced, the ever-present wheel ruts nullify the use of crowning or sloping the road surface for drainage. The ruts concentrate water and are frequently sources of serious erosion. This means that water bars or turnouts are almost invariably necessary in order to overcome the erosive concentraton of water. Experience at Coweeta has shown that an open top culvert made of sawn timbers and pipe spacers has been entirely satisfactory for this purpose. However, more information about the design and installation of these water bars is needed.

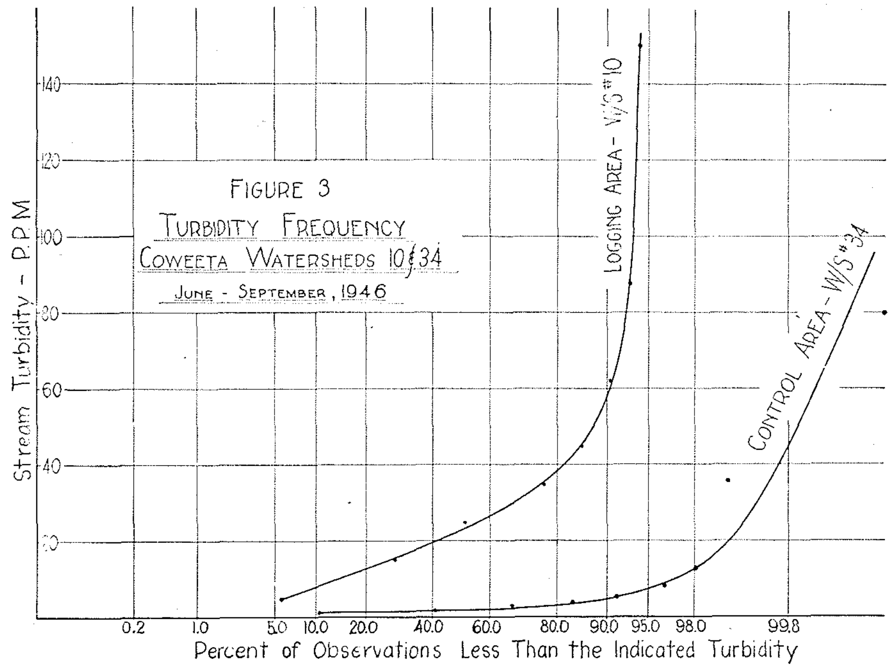

Fig. 3—Turbidity Frequency of Streams from Controlled and Logged Watersheds.

Track laying equipment and winches are valuable aids in any logging operation. These, however, must be used with the watershed values kept well in mind, because their promiscuous use can very often result in conditions extremely conducive to erosion. The careful use of arches, sulkies, pans, cable systems and other equipment may do much to eliminate or reduce destructive erosion and sources of turbidities.

Other items, such as location of skid trails to avoid both the concentration of skidding and the formation of gullies, also deserves thought and attention.

Ultimately, the problems and their solutions are related to economic considerations. The complications of logging contracting, sub-contracting, and sub-sub-contracting divide and obscure responsibility. In such a situation no one feels responsible for the preservation of water values. A complete discussion of these considerations is somewhat beyond the scope of this article. In almost all cases, however, the economic problems resolve themselves into one of possible increased initial capital investment versus much higher maintenance costs. Experience has clearly indicated that a properly regulated and operated logging job, while it may require higher initial outlay of capital, results in lower maintenance cost in the final analysis and a more efficient and profitable operation. In addition, the properly operated job which abides by known and demonstrated principles of watershed management maintains the water resource of the watershed. This is of utmost importance in connection with municipal and industrial watershed management.

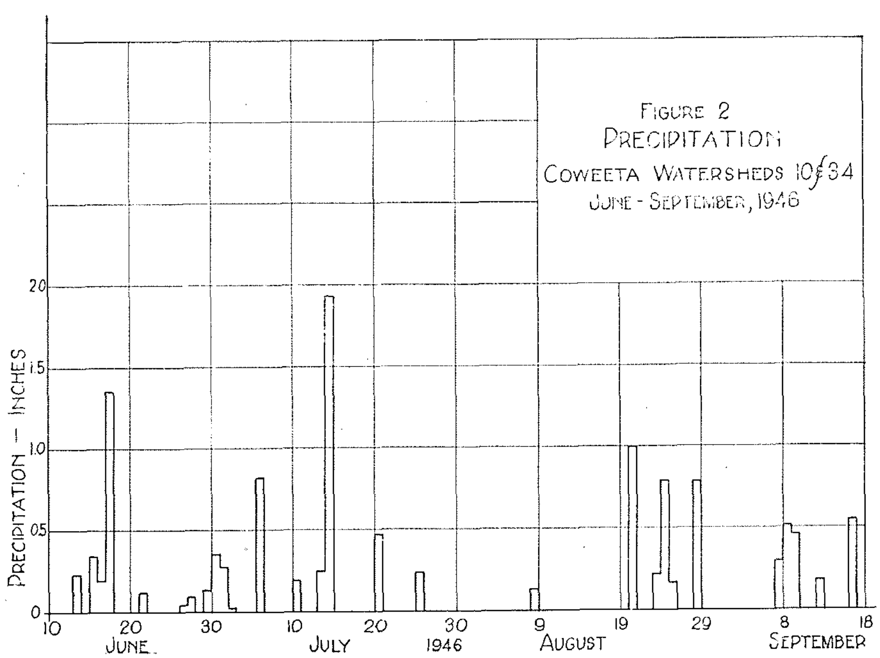

Fig. 2—Precipitation Record for the Two Watersheds.

Summary

For the most part, the difficulties of harvesting wood products from areas of high watershed values center around the general problem of transporting the forest products out of the watershed onto main roads.

The general problem may be broken down into three sub-problems connected with:

1. Location and design of access road and skid trails.
2. Use of heavy building and logging equipment.
3. Road maintenance.

We believe that the correction of known deficiencies will reduce the turbidity associated with the common uncontrolled logging operation and also improve the overall efficiency of the operation itself. In order to test this on a practical basis, another experimental watershed of some 300 acres will be logged using the best existing knowledge. Similar quantitative measurements will be taken on the area.

These studies are a part of the research at the Coweeta Hydrologic Laboratory to determine adequate bases for the utilization of water source areas for public water supply, timber production, recreation and other compatible uses.

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