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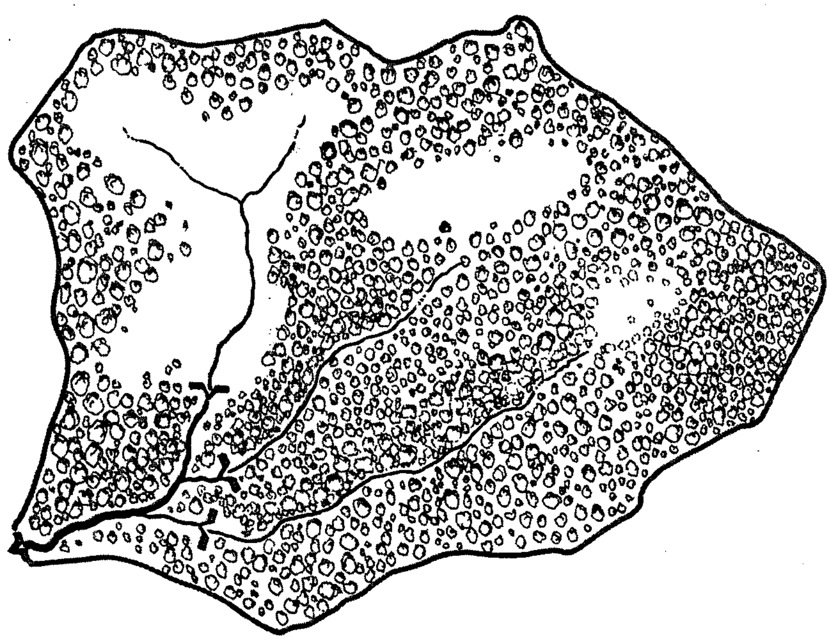
The Workman Creek Experimental Watershed

By Lowell R. Rich, H. G. Reynolds, and J. A. West



SALT RIVER VALLEY WATER USERS' ASSOCIATION
Victor Corbell, President Phoenix, Arizona

In Cooperation With

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Raymond Price, Director Fort Collins, Colorado
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COVER.--The Workman Creek watersheds (1,087 acres) are furnishing information on effect of natural cover, type conversion and timber harvesting on water yield and sedimentation.

Middle Fork (middle) measurements of precipitation-streamflow relations in the pine-fir type were started in 1938.

South Fork (right)--A timber-harvest and improvement cut was made between 1953 and 1956.

North Fork (left)--The Douglas-fir and white fir were removed on 80 acres and the area planted to perennial grass in 1958.

THE WORKMAN CREEK EXPERIMENTAL WATERSHEDS

by

Lowell R. Rich,[1] H. G. Reynolds,[1] and J. A. West[2]

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INTRODUCTION

The Workman Creek experimental watersheds lie within the humid forest type of central Arizona. Similar forested lands are the primary source of perennial streamflow that provides water for industrial, agricultural, and domestic uses at the desert elevation. Similar relations between watersheds and downstream land uses are found throughout the Southwest and elsewhere. Careful development of and attention to proper land management to maintain or improve streamflow from watershed lands are necessary. The Workman Creek watersheds are being used to test management techniques that will benefit water supplies consistent with other uses of the land.

Recent work stems from a cooperative agreement of 1953 between the Salt River Valley Water Users' Association and the Rocky Mountain Forest and Range Experiment Station. This agreement provides for determining the effects of timber cutting upon water yields and sedimentation for forest types such as those found on Workman Creek. This report states the objectives of the study, describes the first treatments, and summarizes preliminary results.

CHARACTERISTICS OF THE AREA

Workman Creek is about centrally located in the Salt River watershed system that provides runoff for the project lands around Phoenix, Arixona, (fig. 1). An appreciation of the desirability of proper watershed management can be obtained from a brief background account of the system and project.

SALT RIVER SYSTEM AND PROJECT

The Salt River system encompasses 12,898 square miles. The Verde and Salt Rivers are the main tributaries, with almost equal watershed areas. Median water yield of the system between 1913 and 1957 was 904,000 acre-feet annually. On the Salt River, the Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain Reservoirs have a storage capacity of 1,754,335 acre-feet. Bartlett and Horseshoe Dams on the Verde River have a capacity of

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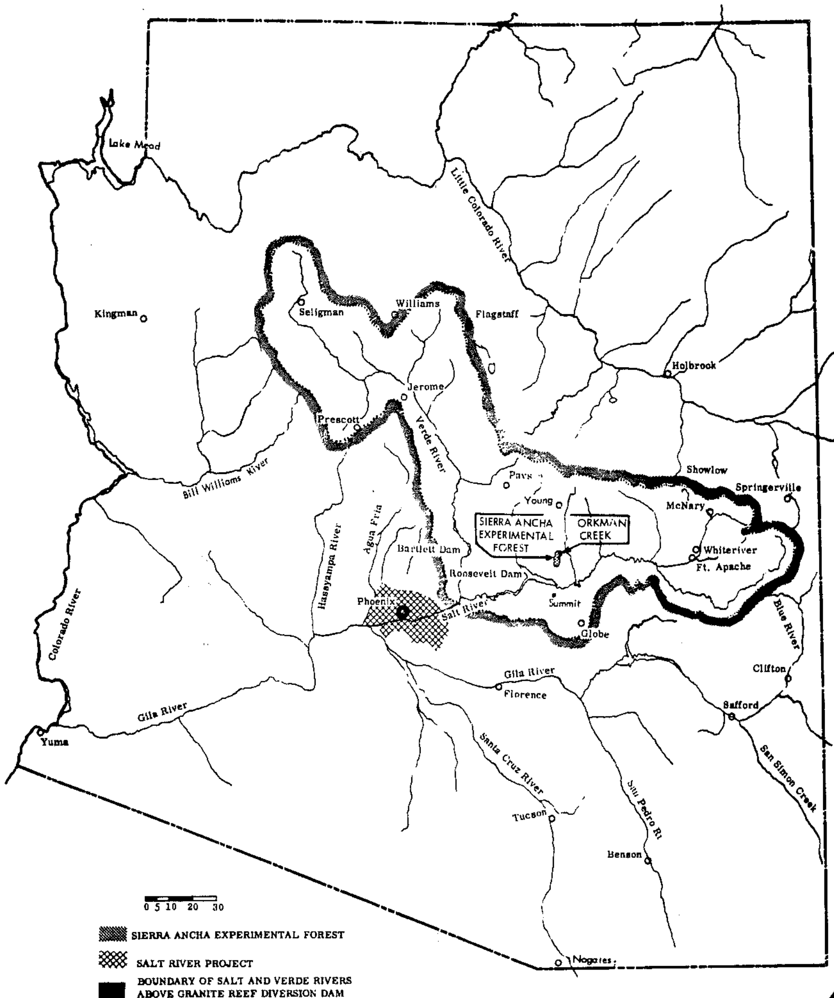

Figure 1.--Location of the Workman Creek watersheds in relation to the Salt River system and project.

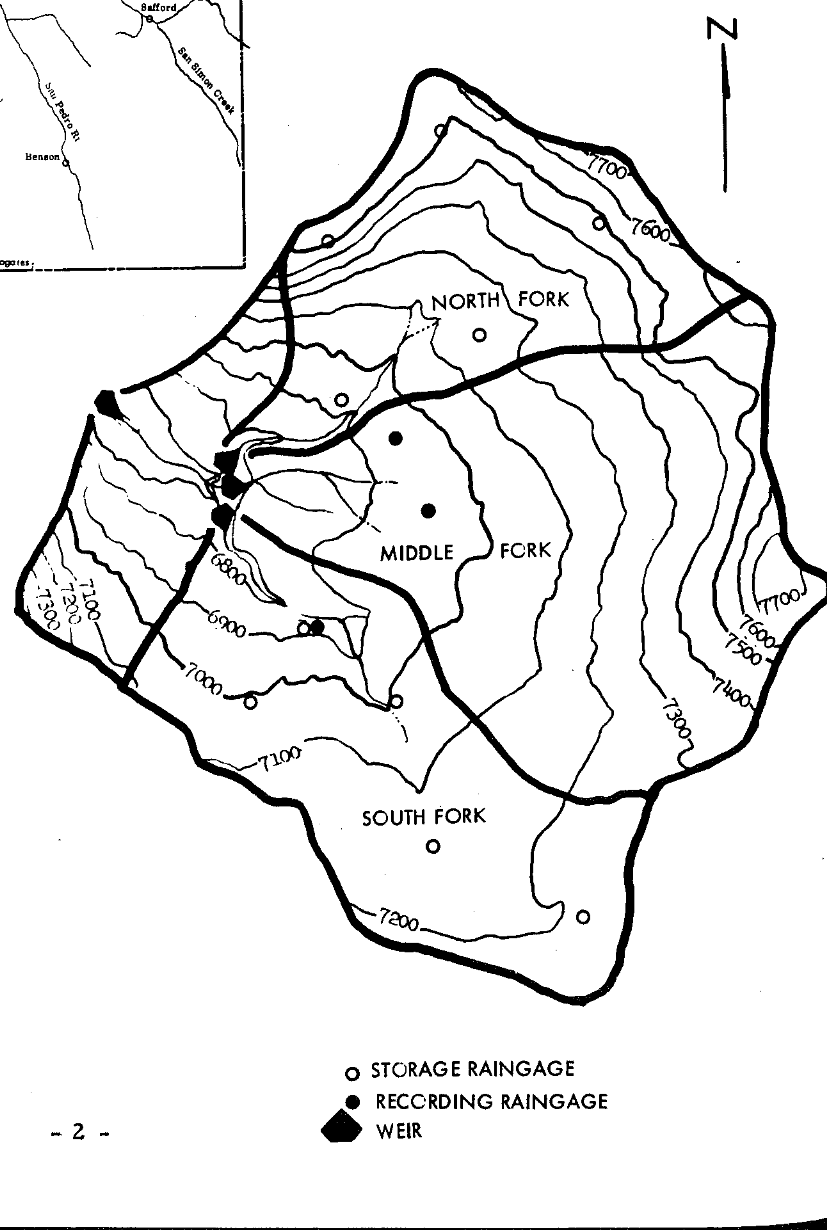

Figure 2.--
The experimental watersheds showing contour lines and gages.

322,378 acre-feet. Dams on the Salt River are equipped to develop hydroelectric power. Responsibility for the administration and allocation of power and water lies with the Salt River Valley Water Users' Association.

About 242,000 acres of land are under the Salt River Project. Water for these lands serves industrial, domestic, and agricultural uses. About 48,000 acre-feet of water were supplied to 381,000 people in the greater Phoenix area in 1958 for industrial and domestic purposes. Demand for water for such uses may double by 1975, if the present rate of population increase continues. The remaining water from the system is delivered to agricultural lands. Runoff and pump water in 1958 was sufficient to produce a gross crop value of $52,145,374. About 50 percent of this income was from cotton; the remainder was about equally divided among grains and forage crops, truck crops, and citrus.[3]

THE WORKMAN CREEK WATERSHEDS

Location and General Characteristics

The Workman Creek watersheds are located about 50 miles north of Globe on the Young Highway. They are on the Sierra Ancha Experimental Forest, a part of the Tonto National Forest, selected for the study of streamflow.

Gaging stations were established on Workman Creek in 1938 to measure streamflow from an area covered by a forest of ponderosa pine, Douglas-fir, white fir, and Gambel oak. Elevations are between 6,590 and 7,724 feet for the bowl-like basin that drains to the west. The major basin is divided into three forks, each with a perennial stream. The North Fork watershed contains 248 acres, Middle Fork 521 acres, and South Fork 318 acres (fig. 2).

Geology and Soils

All watersheds are underlain by Dripping Springs quartzite rock that has been intruded by diabase, and basalt plugs and sills. Troy sandstone outcrops on the upper part of the watersheds. Most of the formations are level, except for some local flexures caused by intrusions.

Surface soils are of loam to clay-loam texture, with either granular or crumb structure. Subsoils are mostly layered and vary in texture from clay loams to clays. Soils depth varies from a few inches to more than 15 feet.

Precipitation

Precipitation is measured by recording and storage rain gages located throughout the watersheds (see fig. 2). Recording gages chart amount of precipitation in relation to time. Storage gages are read on May 31 and September 30 each year.

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[3] From records compiled by the Salt River Project.

Average annual precipitation on the experimental watersheds is 32 inches. Highest annual precipitation since 1938 occurred in 1940-41 and was 53 inches, or 166 percent of the average (fig. 3). Lowest precipitation measured was 20 inches in 1954-55 (62 percent of average). About 69 percent of the annual precipitation falls during the winter (October through May).

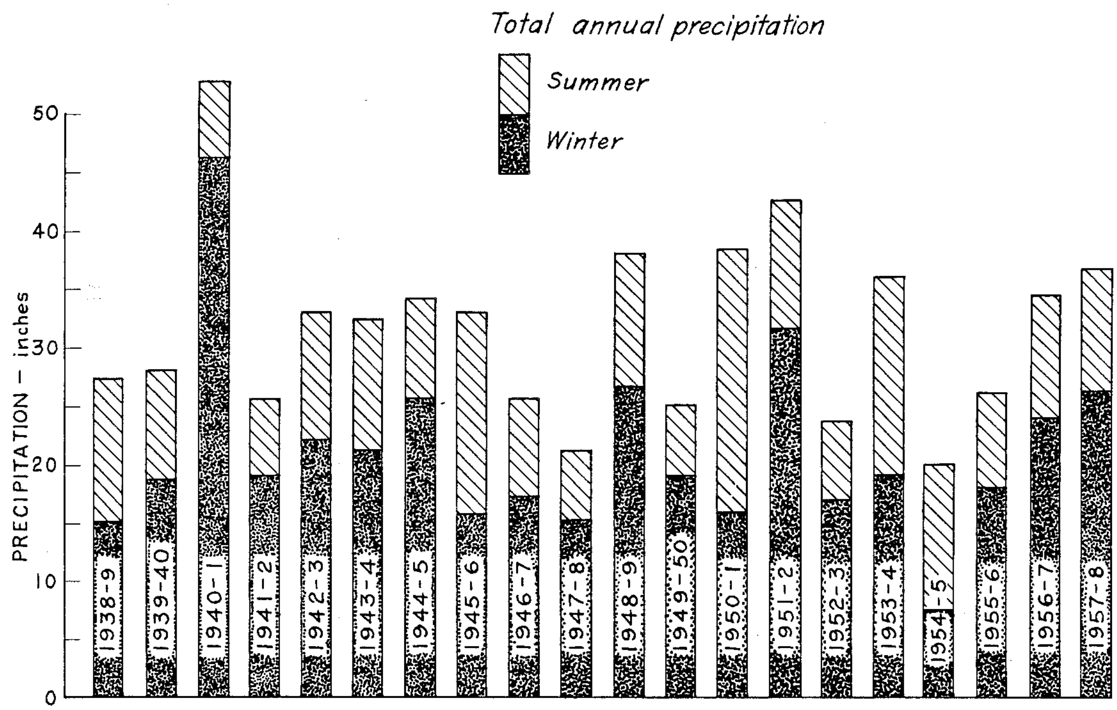

Figure 3. --Annual and seasonal rainfall on the Workman Creek watersheds.

The largest storm on record was the 10.65 inches which fell between August 26 and 29, 1951. The most intense storm was 3.41 inches in 3 hours on July 16, 1957, with 2.20 inches of the storm falling in a period of 30 minutes. The longest period without precipitation was 80 days, between April 9 and June 28, 1943.

Vegetation

Sites for plant growth vary from the dry southern exposures of North Fork to the moist sites on the northern exposures of South Fork. Middle Fork, with a westerly aspect, is intermediate between the two.

Ponderosa pine dominates the area. Gambel oak is common as an understory. The driest and hottest aspect is occupied by several species of oak. On the more moist sites, Douglas-fir and white fir are important elements of the composition. Along stream channels, bigtooth maple, Arizona alder, Arizona walnut, and aspen are found sparingly.

Proportions of the most abundant trees on the three forks are as follows:

	Ponderosa pine	White fir	Douglas-fir	Gambel oak	Other
	- - - - - - - - - - (Percent)	- - - - - - - - -			
North Fork	52.2	20.1	4.1	22.2	1.4
Middle Fork	46.4	20.2	10.1	21.8	1.5
South Fork	59.4	25.5	5.8	8.0	1.3

Average basal area per acre for all trees 1 inch and over in 1953 was 174 square feet on North Fork, 193 square feet on Middle Fork, and 201 square feet on South Fork. Volume of sawtimber per acre (conifers 12 inches and over) was 13,000 board feet on North Fork, 15,000 board feet on Middle Fork, and 21,000 board feet on South Fork.

In Middle Fork there is a 20-acre meadow, and in South Fork one of about 2 acres. Elsewhere grass and herbaceous plants cover less than 1 percent of the ground surface.

Streamflow

Streamflow is measured by 90° V-notch and Cipolletti weirs (fig. 4). Water-level recorders measure continuous height of water at the weir. Records of height of flow are converted to discharge rates by appropriate rating tables. Ponds above the weir dams trap sediment.

Average annual streamflow for the period 1938 to 1952 was 3.19 inches for Middle Fork, 3.38 inches for North Fork, and 3.42 inches for South Fork. About 77 percent of the streamflow comes between December and April; it varies from 64 percent on South Fork to 85 percent on Middle Fork. Streamflow was usually lowest in early July just before the summer rains. Streamflow during July, August, and September amounted to only 5 percent of the annual yield on Middle Fork, 7 percent on North Fork, and 12 percent on South Fork. Seasonal distribution of streamflow for the three watersheds is shown in figure 5.

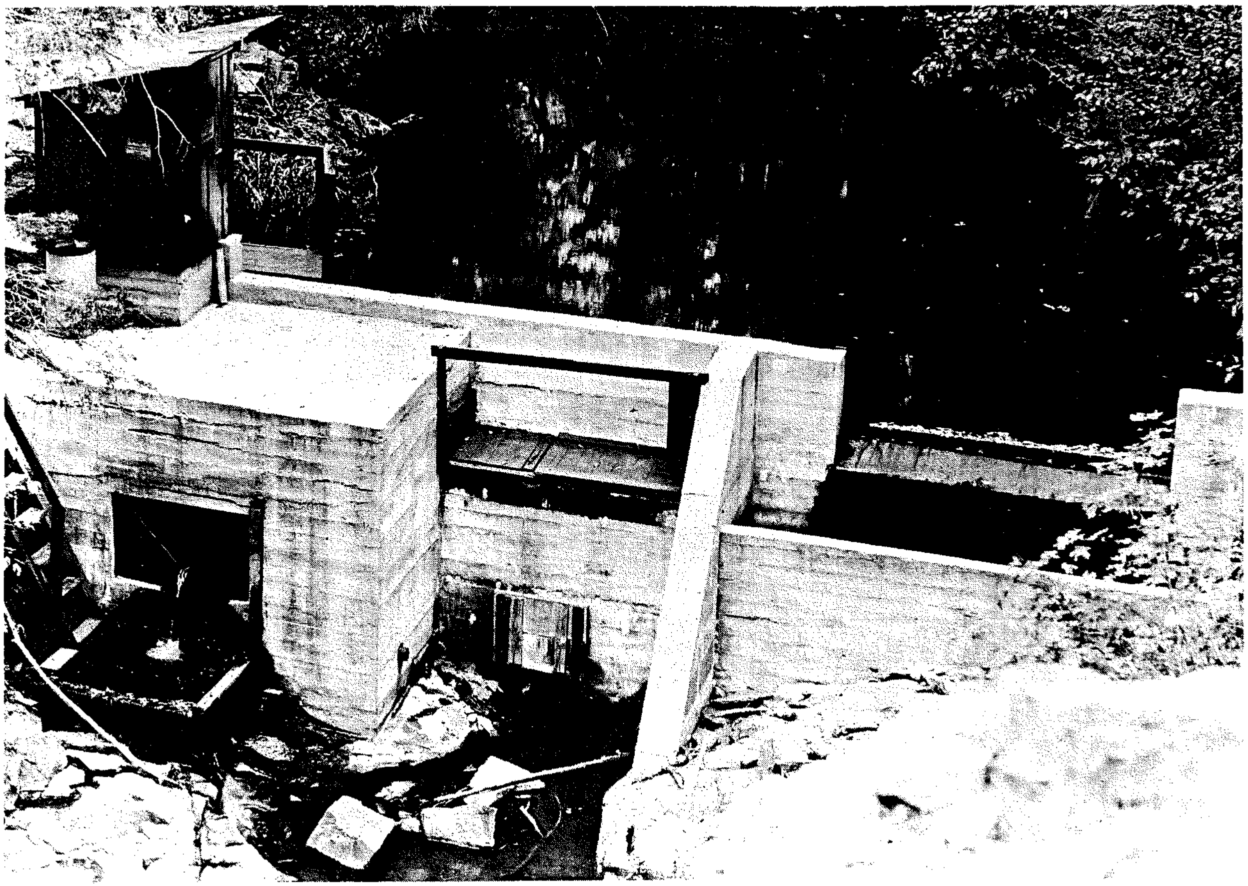

Figure 4. --The 7-foot Cipolletti weir (on the right) for high flows, and the 90° V-notch weir (on the left) for low flows, are used to measure total streamflow from the entire Workman Creek watershed.

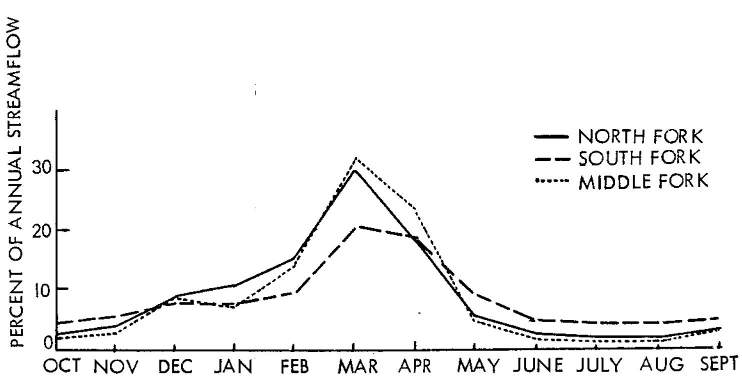

Figure 5. --Average monthly distribution of streamflow for the three Workman Creek experimental watersheds.

Annual streamflow at Main Dam, which measures all streamflow from North, South, and Middle Forks, has varied from 11.4 inches in 1940-41 to less than 1 inch in 1955 (fig. 6). Water yield during 1940-41 was markedly above average and significantly increased the average for the period of record. Runoff for most years has been between 2 and 4 inches.

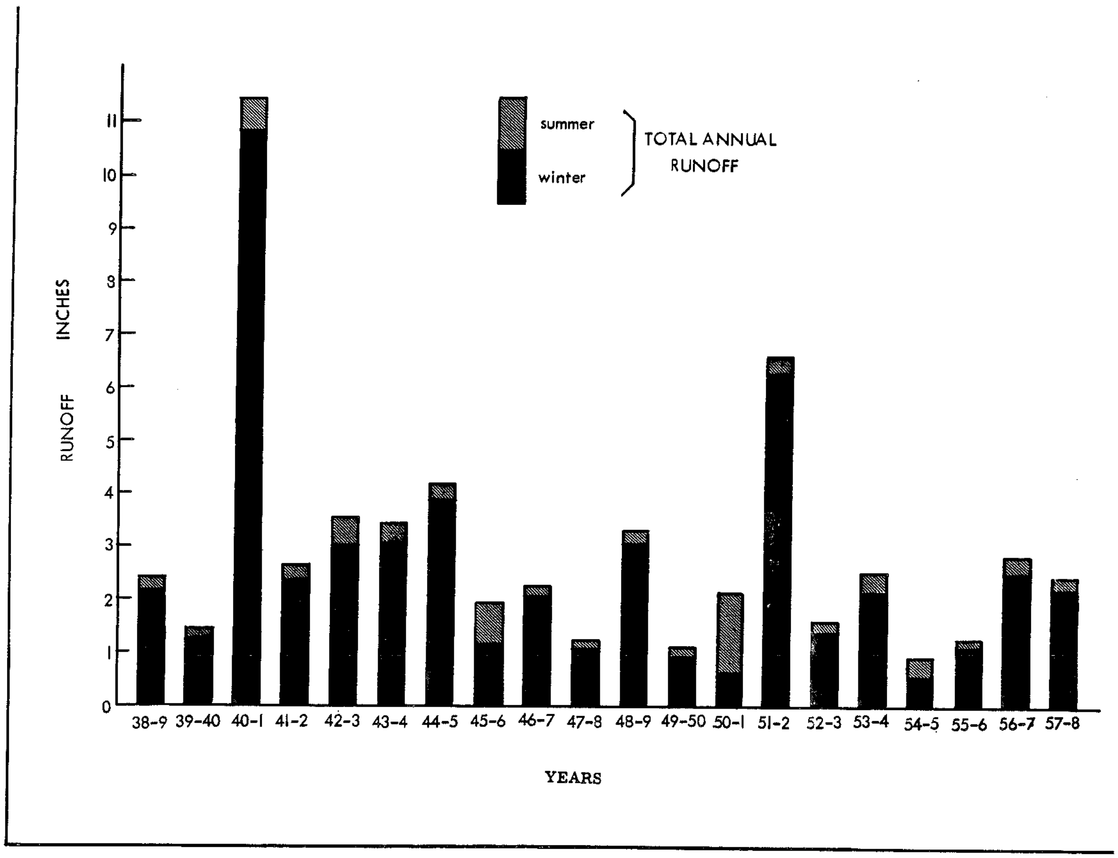

Figure 6. --Annual runoff at Main Dam of Workman Creek, which is the combined total runoff from the three experimental watersheds.

THE RESEARCH PROGRAM

OBJECTIVES

Research on the Workman Creek watersheds involves these main objectives:

1. To determine the hydrology of watersheds covered with natural mixed conifer forest. Measurements taken are precipitation, streamflow, and sediment movement.

2. To determine what changes in hydrology are associated with:

   a. Progressive changes from tree cover to grass and shrubs.
   b. Timber management practices of harvest cutting, thinning, and road building.

EXPERIMENTAL DESIGN

Of the three watersheds available, one is reserved as a control to determine treatment effects on the other two. The years 1938-39 through 1951-52 were the calibration period. Streamflow records during this period established a relation between the control watershed (Middle Fork) and the two treatment watersheds (North and South Forks).

Measurements since treatment are compared with the calibration period. Departure from the established relation measures the effect of treatment. Amount of departure is tested mathematically. Large differences caused by treatment can be detected in a much shorter period than small differences. Hence, length of time for studying the effects of a treatment may vary.

The North Fork watershed is used to evaluate changes in water yield and sedimentation resulting from removing or changing cover types. The first step was to cut and poison all broadleaved trees along the stream channel. The second step was to remove and replace with perennial grass all trees (mainly Douglas-fir and white fir) growing on moist bottom sites.

South Fork is being managed for the production of high-quality timber to determine the effect such management has upon water yields and sedimentation. The first cut, in 1953, removed about 50 percent of the merchantable volume and was followed by an improvement cut to accomplish: (a) mistletoe control on pine, (b) release of pine poles by elimination of Douglas-fir and white fir, and (c) hardwood removal. Basal area was reduced 35 percent.

Another cut is planned for about 1965. It will remove approximately 25 percent of the remaining merchantable volume plus improvement cuttings and pine thinnings to create a high-quality, repidly growing pine stand.

Table 1 summarizes the treatments that have been completed, those that are anticipated, and their probable timing.

TREATMENTS COMPLETED

Riparian Cut of Broad-leaved Trees (North Fork)

All Arizona alder and bigtooth maple adjacent to springs, seeps, and streams, on North Fork were cut during August 1953. Stumps were poisoned with ammate to prevent sprouting. The cut included: 158 alders varying in diameter from 1 to 33 inches, and 946 maples varying from 1 to 11 inches. The total basal area of these trees, 271 square feet, was approximately 0.6 percent of the total basal area of all trees on the 248-acre watershed.

Table 1.--Schedule of treatments for the Workman Creek watersheds.

Year and treatment	North Fork	Middle Fork	South Fork
Completed:			
1938-52	Calibration	Calibration	Calibration
1953	Riparian cut of broadleaf species	Control	Start of logging
1954			Continued logging
1955			Completed logging
1956			Completed improvement cut
1958	Convert moist site (mostly Douglas-fir and white fir) to grassland	Control	
Anticipated:			
About 1965		Control	Second logging and improvement cut

Conversion of Moist-site to Grassland (North Fork)

Eighty acres of moist-site forest, dominately white fir and Douglas-fir, were cleared during September and October 1958 (fig. 7). The cleared area was then planted to perennial grass.

A break in topography between the flatter dry sites above to the steeper moist slopes delineated the area for clearing in many places. Where topography was not delimiting, composition of the forest was used as a basis for separating forest types. The area was classed as moist site wherever white fir and Douglas-fir stems 4 inches and larger made up more than 50 percent of the forest stand. Moist-site vegetation was found along both sides of the main stream channel and two contributing forks in the upper reaches of the watershed.

Trees larger than 10 inches d.b.h. were cut with power saws and removed from the area. Smaller trees were pushed over with a bulldozer. Unmerchantable material was piled into windrows suitable for burning. Most of the forest litter and debris was also pushed into the slash piles (fig. 8). This left an ideal seedbed between the windrows for seeding to perennial grass.

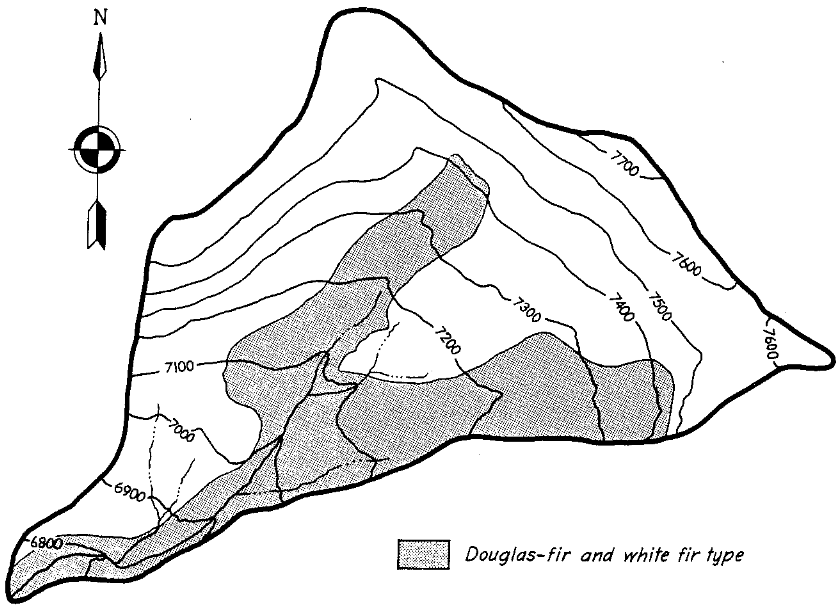

Figure 7. --Area of moist-site forest (dominately white fir and Douglas-fir) converted to grassland on North Fork of Workman Creek watershed.

Figure 8. --Clearing of moist-site vegetation in North Fork of Workman Creek watershed showing slash piles prior to burning.

Ground between the slash piles was seeded immediately to a mixture of 40 percent slender wheatgrass, 40 percent Kentucky bluegrass, and 20 percent orchard grass, with cyclone hand seeders at the rate of 6-2/3 pounds per acre. An oak log about 20 inches in diameter and 16 feet long was dragged crosswise over the area by tractor to cover the seed. Then an additional 3 1/3 pounds of seed per acre was sown over the area. Redtop was planted along stream channels and seeps at the rate of 10 pounds per acre.

Slash was burned in March 1959 to reduce fire hazard and to provide a seedbed for completing the grass planting. In most places, material smaller than 6 inches d. b. h. was completely consumed. Larger material was charred but not completely burned.

Suppression of hardwood sprouts, removal of conifer reproduction, and spot seeding to insure an adequate stand of grass are conducted as necessary.

Timber Management Cut (South Fork)

The first cut on South Fork was started in June 1953 and was completed in November 1955. The gross volume of timber cut was 3 million board feet; net volume, after allowance for defect, was 2 million board feet.

The first harvest cut removed approximately 46 percent of the merchantable timber (conifers 12 inches and over). Total reduction of basal area of trees 1 inch and over was 24 percent. Logging damage, access roads, and skid trails reduced basal area by an additional 6 percent (fig. 9).

Stand improvement was completed during the summer of 1956. This consisted of poisoning undesirable elements in the forest composition with ammate. In small areas of pine infested with mistletoe, all trees were poisoned. Larger areas of infestation were isolated by poisoning a 60-foot border around the area of infestation. Gambel oak and New Mexico locust, which overtopped the pine reproduction, were also poisoned. In addition, where the composition was a mixture of pine and fir, firs were poisoned to favor growth and reproduction of pine. This improvement work reduced basal area by an additional 6 percent.

Slash was piled and burned along the main access roads. Roads, skid trails, and landing areas were seeded to perennial grass.

On July 6, 1957, a wildfire burned 60 acres of the upper southeast portion of the watershed. The fire burned the most level part of the area where stream channels are not well defined and where there is no perennial streamflow. Based on sample plots, the fire destroyed about 5,400 square feet of basal area on the 60, or about 9 percent of the basal area on the entire watershed. Thus, total basal area reduction by logging, road construction, improvement measures, and fire was 45 percent.

Figure 9. --South Fork of Workman Creek after logging in an area dominately of white fir. About 46 percent of the merchantable volume was removed.

RESULTS TO DATE

North Fork Riparian Cut of Broad-leaved Trees

Five years (1954 to 1958) of annual water yields from North Fork following the removal of broad-leaved trees along the stream showed no significant increase when compared with water yields from the control watershed (Middle Fork). Annual water yields for the individual years and the regression between Middle and North Forks are shown in figure 10. Yearly averages since treatment are about equally dispersed around the average regression line. To be detected in the 5-year period of measurement, the annual increase would have had to exceed 1.03 area inches.

The water year ending September 30, 1954 was characterized by heavy March precipitation and summer precipitation that averaged 186 percent of average. The years of 1955 and 1956 were among the driest sampled since the study was started. The years 1957 and 1958 were nearly average.

Since riparian trees are deciduous during the winter, the riparian cut was also tested for effect on growing season (summer) streamflow (fig. 11).

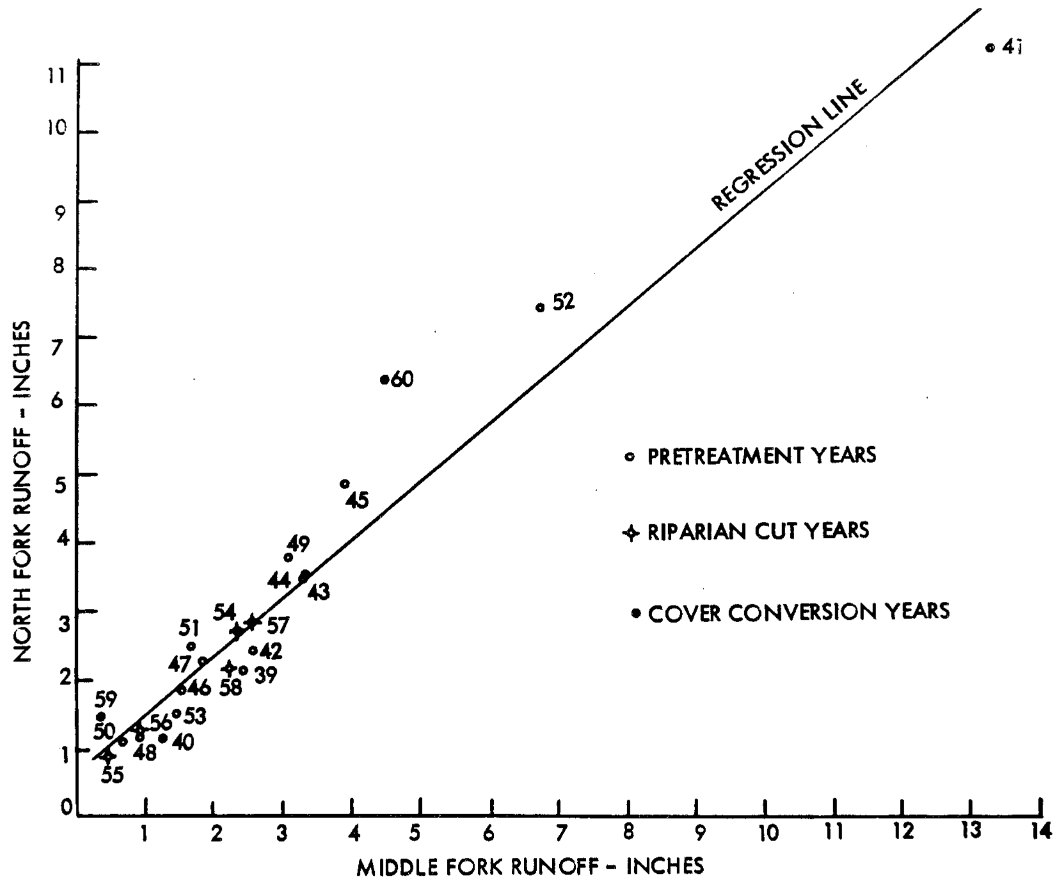

Figure 10. --Annual water yields from North Fork and Middle Fork of Workman Creek, showing none of the riparian cut years departing significantly from the pretreatment regression line.

Posttreatment years do not depart significantly from pretreatment years. The data again indicate that the effect of removing riparian vegetation along the stream was too small to be picked up by the instrumentation and statistical control employed.

Other watershed studies have shown that diurnal fluctuations of streamflow are changed by removing riparian vegetation. A comparison of hydrograph charts preceding, during, and following the removal of broad-leaved trees on North Fork indicates no changes in diurnal fluctuations (fig. 12).

Riparian trees were cut during three weekends, August 8 and 9, August 16 and 17, and August 29 and 30, 1953. Except for irregularities caused by rainfall, hydrograph charts for days preceding, during, and after the cuts are essentially the same. Rainfall of 0.25 inch essentially eliminated diurnal fluctuation on July 31. Rain of 0.67 inch on August 9 and 10, and 0.52 inch on August 27 and 28 caused significant increases in streamflow. Rain of 0.10 inch or less of August 8, 10, 14, 15, and 18 caused only small changes in streamflow.

The conclusion is that removal of the broad-leaved trees along this channel had no effect on annual and growing season streamflow, or on diurnal fluctuations.

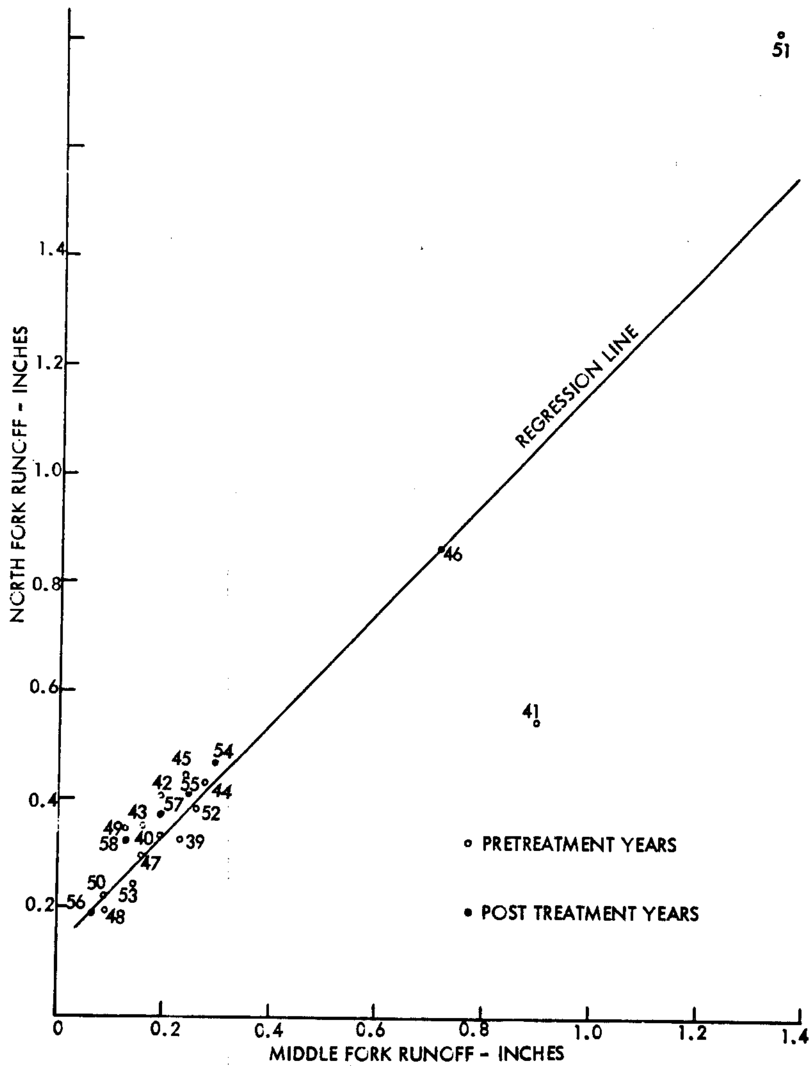

Figure 11. --Summer water yield from North Fork and Middle Fork of Workman Creek before and after removal of broad-leaved riparian trees showing that posttreatment years do not depart significantly from pretreatment years.

North Fork Moist-site Cut of Douglas-fir and White Fir

Water Yields

Water yield increased 0.5 inch during the first water year (October 1958 through September 1959) following replacement of 80 acres of forest with perennial grass. (Expected streamflow, based on the pretreatment regression, was 0.9 inch; actual measured streamflow was 1.4 inches.) The difference was not statistically significant (see fig. 10).

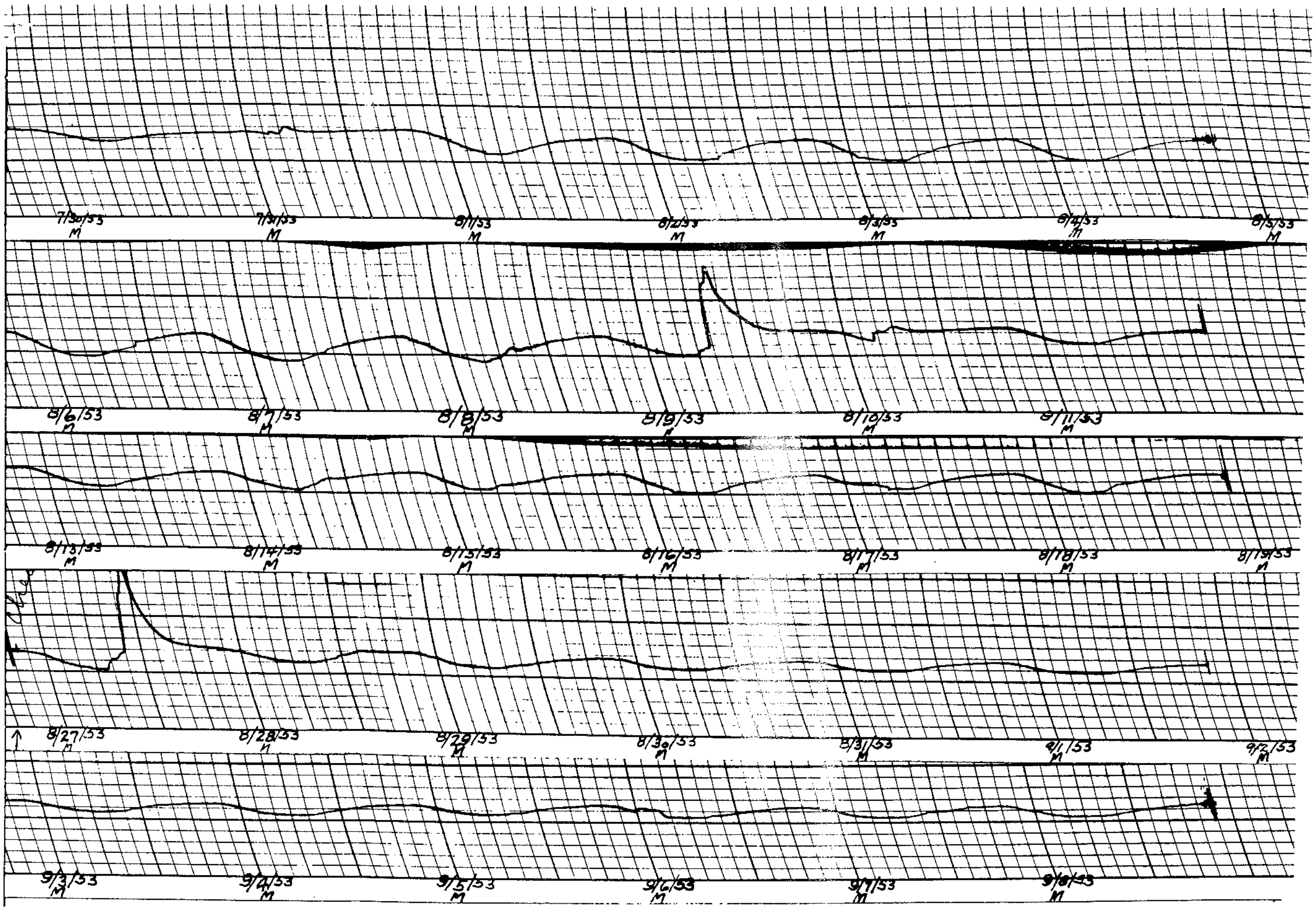

Figure 12. --Charts of streamflow preceding, during, and following the time riparian trees were cut on the North Fork of Workman Creek. Cutting started August 8, 1953 and was completed by August 30, 1953. Diurnal fluctuations continued unchanged during August 31 to September 8, 1953, after the broad-leaved trees were cut.

Annual precipitation in 1958-59 was 23.8 inches, which was 75 percent of the pretreatment average. Winter precipitation was only 54 percent, and summer rainfall (June through September) was 120 percent of average. Annual streamflow was 48 percent of average. Winter streamflow was only 28 percent of average, but summer streamflow was 128 percent of average.

Water yield the second water year after treatment (October 1959 through September 1960) increased significantly (fig. 10). Expected streamflow was 4.4 inches; actual streamflow was 6.4 inches--an increase of 2.0 inches.

Annual precipitation in 1959-60 was 43.0 inches, which was 136 percent of average. Winter precipitation was 158 percent and summer rainfall was 93 percent of average. Annual streamflow was 211 percent of average. Winter streamflow was 223 percent and summer streamflow was 128 percent of average.

Additional years of measurement, which include points between these two observed years as well as additional above-average water yields, will be required for adequate evaluation of treatment. Thus, the increased water yields are indicative and not conclusive.

Sediment

Sediment from North Fork, as measured in the weir basin, averaged about 3.5 cubic yards annually during the pretreatment years. Sediment was moved during larger storms; at other times, water was essentially clear.

During the first year after treatment, two summer storms (July 30 and August 19, 1959) deposited a total of 21.1 cubic yards of sediment in the weir basin. Except for storm peaks, streamflow carried less than 50 parts per million of suspended sediment. Storm peaks were not unusual compared to storm peaks during pretreatment years. Highest peak discharge in the first year was 13.6 cubic feet per second, about 35 cubic feet per second per square mile.

During the second year, two winter storms (November 2 and December 24, 1959) deposited a total of 57.1 cubic yards of sediment in the weir pond. Highest peak discharge was 23.7 cubic feet per second, about 61 cubic feet per second per square mile, an amount that had been exceeded during pretreatment years.

South Fork Timber Management Cut

Annual water yields following the first harvest cut on South Fork show no significant change when compared with yields from the control watershed. Streamflow data for South Fork for years during and after timber harvest (solid circles) fall among pretreatment years (open circle) (fig. 13).

Analyses of pretreatment data indicated that relatively large increases in water yields would be necessary to establish statistical significance in a few years. Ten years was anticipated as the minimum time to establish statistical significance, consequently more years of record will be necessary to establish mathematically the influence that this type of timber harvest has on water yields. For the period of record (1953 to 1958), water increase would have had to exceed 0.74 area-inch to be significant.

South Fork Burn

Prior to July 1957, disturbance of the watershed from felling, skidding, and yarding had no effect upon sediment accumulated at the gaging station, although some sediment had moved into stream channels from roads and other disturbed areas. As a result of the wildfire on July 6, 1957, there was noticeable soil movement following the first summer rains. The most intense storm on record, 3.41 inches in 3 hours, occurred on July 16.

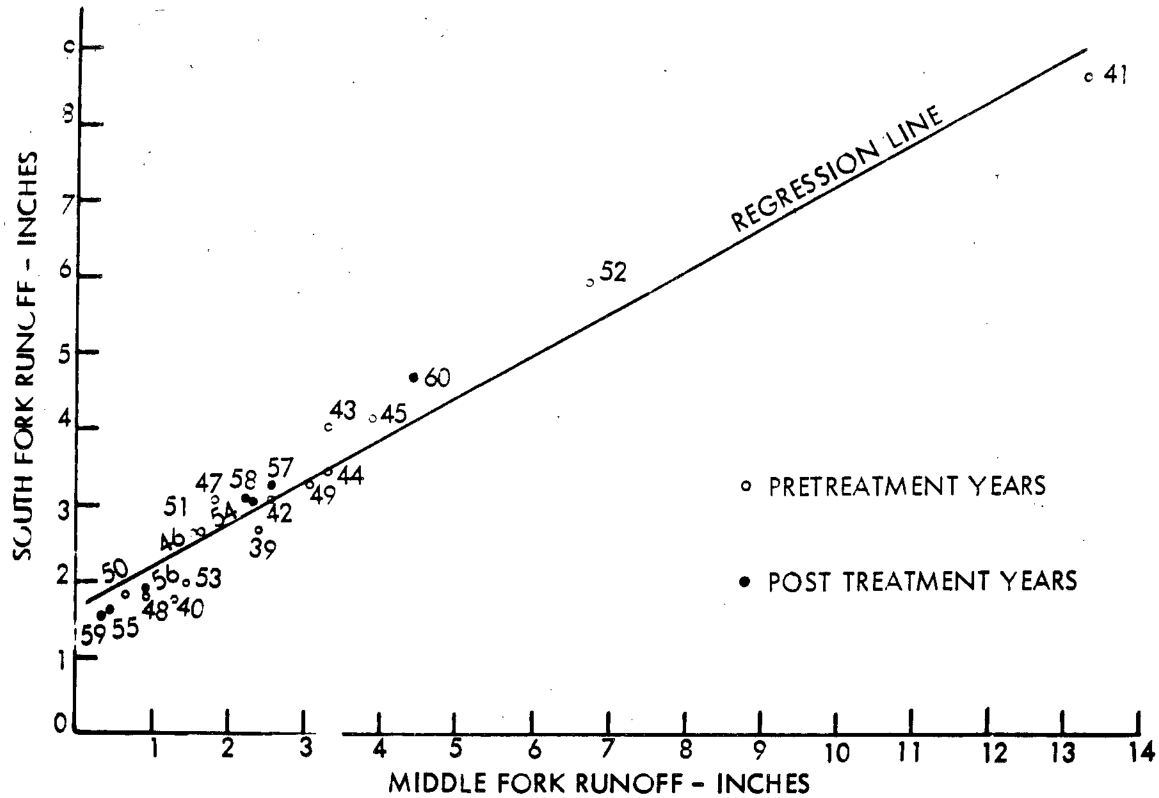

Figure 13. --Annual water yields of South Fork before treatment compared with yields since logging.

Surface soils within the fire area are medium texture, 0-3 inches deep, granular structure, dark brown in color. Subsoils vary from clay loams to clays, and soil depths vary from a few inches to more than 15 feet. Parent material is diabase. Prior to the fire there was $1\frac{1}{2}$ inches of well-decayed organic matter, and erosion was slight.

Steepest slopes in South Fork are in the lower part of the watershed on north slopes immediately above the weir. Above this steep section the watershed levels out to where slopes vary from less than 1 to about 10 percent with only occasional slopes as high as 15 percent. The fire was confined to these gentle slopes dominated by ponderosa pine where neither perennial streams nor well-defined channels occur.

Immediately after the fire, the elevation of the ground surface was determined at 1,600 randomly located points within the burned area. After the summer rains, remeasurement of these points indicated an average loss in elevation of 0.016 foot. Applying this value to the 60 acres in the burn gives a total movement of 0.96 acre-foot of soil and ashes.

Eighteen randomly spaced cross sections were measured along the stream channel in the South Fork watershed. The upper section, just below the burn showed enlargement. The other 17 sections had an average net decrease in area of 4.8 square feet. The quantity of sediment in the channel and weir basin was 0.41 acre-foot or about 43 percent of the 0.96 acre-foot estimated to have been moved on the burned area.

The material not reaching the main channel was largely deposited on flatter areas between the channel and the burn. Eight major areas of deposition were located and were covered with a total of 0.44 acre-foot of sediment. These areas and the channel deposits account for 89 percent of the total volume moved from the burned area.

Sediment movement on this burn emphasizes the importance of maintaining an adequate plant cover for soil stabilization. Normal logging operations over the entire watershed had little effect upon soil movement. When the cover was destroyed by fire upon about one-sixth of the watershed, soil movement increased greatly.

That a part of the experimental watershed burned is unfortunate. However, the burn will not vitiate the results of the study. Soil movement and recovery of vegetation are being measured on the burned area. The effects of fire will be evaluated as a part of the overall study.

FUTURE RESEARCH

The Workman Creek watersheds are just beginning to provide research dividends. The calibration period from 1938 to 1953 has defined some of the streamflow characteristics of the mixed conifer forest type. These data can be used in classifying and predicting the characteristics of similar areas in the Southwest. Also, they are an essential base for the treatments already applied and for those anticipated in the future.

The riparian cut on North Fork suggests strongly that removal of a few broadleaf hardwoods along streams in mixed forest stands at high elevation does not result in increases in water yields. Such information is valuable in the planning of watershed improvement programs for these high-elevation forests.

The effect that commercial timber harvest and changing from a moist forest to a perennial grass type has upon water yield and sedimentation must await further years of record. Additional measurements of water yields must be obtained before conclusions are mathematically sound. Each year of record will add to our knowledge.

Future work of the Workman Creek watersheds is an investment in better watershed management and better land use. Proper management of our watershed lands requires an understanding of the products, such as water, timber, and forage from these lands; and how they can be used in combination to give maximum sustained returns from the land. Knowledge of the relation between different vegetation types and water yield, and the effect that forest management has upon water use are important first steps in achieving this objective. Future results and studies on the Workman Creek watersheds will supply some of this much needed information.

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