About This Brochure

Coconino National Forest managers and Rocky Mountain Forest and Range Experiment Station scientists have prepared this brochure to describe a program of forest and range management research in the Beaver Creek area of the Coconino National Forest in central Arizona.

For those unable to visit Beaver Creek, this brochure provides a summary of accomplishments and current work, printed in the type style you are now reading. *Additional details are printed in italics.*

For those planning a visit, the enclosed map will serve as a field guide. Suggested stops noted on the map are keyed to descriptions in this brochure and to numbered sign posts along the tour route.

NOTE: A self-addressed card is enclosed. Use it to request more information and to tell us of your reactions to what you read in this brochure or see during the tour.

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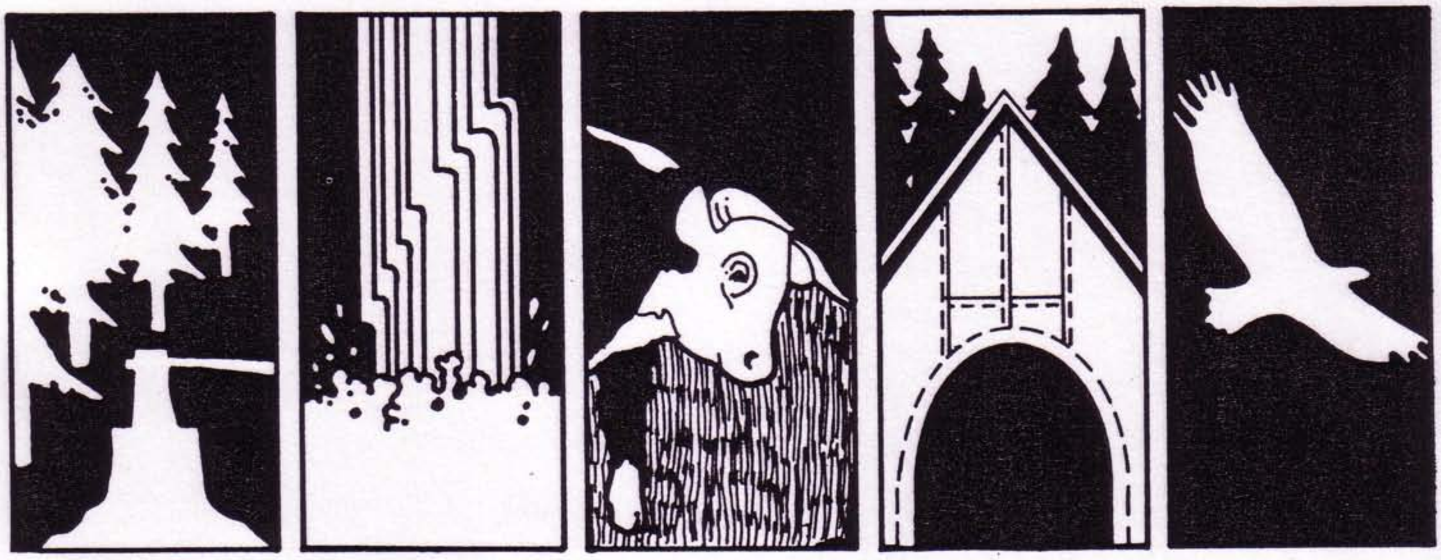
About The Program

Americans look to their public forest and rangelands to fill many of their basic needs for water, food, energy, shelter, and clothing. Demands for these goods are more intense and diverse than ever before. At the same time, more and more people turn to public lands for recreation, relaxation, and educational experiences.

Public land managers must respond to people's needs while maintaining the quality and productivity of the environment. Consequently, better ways are being sought to assess and select management practices that will yield reasonable combinations of products such as wood, water, or livestock forage; as well as provide other values such as wildlife habitat, scenic beauty, and recreation opportunities. For example, practices that emphasize water and forage production may reduce wood supplies and compromise the quality of habitat for some animals. Emphasizing timber production might lower scenic beauty, but improve habitat for big game animals.

The goals of the Beaver Creek Program are to provide land managers with: (1) essential facts about the biological, physical, social, and economic effects of multiresource management actions in ponderosa pine forests and pinyon-juniper woodlands; and (2) better ways to predict, display, and evaluate differences among the probable results of management alternatives before actions are initiated.



A Cooperative Effort

Many organizations are involved in this program, including several Forest Service research and management units, other federal and state agencies, universities, foundations, and private concerns. Their varied skills and expertise are vital to its success.

Program Evolution

In the summer of 1955, several ranchers met with a Forest Service representative and an officer for the Salt River Project, an organization of water users in southern Arizona. The ranchers and the water users' agent were concerned that increasing numbers of trees and shrubs were reducing the flow of streams and the supply of livestock forage on watersheds in the State.

As a result, the University of Arizona was commissioned to investigate the potential for improving water yield from the State's forests and ranges. University findings, titled RECOVERING RAINFALL, better known as the Barr Report, suggested that surface water runoff from mountain watersheds might be increased by replacing high water-using plants, such as trees and shrubs, with low water users, such as grass.

Based on this report, the Forest Service began to test theories for increasing the flow of mountain streams. By 1960, studies dealing with ponderosa pine and pinyon-juniper lands had evolved into the Beaver Creek Watershed Evaluation Program. Its emphasis was to determine how much water yield could be increased using various methods for altering the vegetation. Changes in livestock forage, timber production, wildlife habitats, recreational values, and soil movement also were to be studied.

Similar projects were undertaken by other Forest Service units in areas of mixed conifer, chaparral, and streamside vegetation elsewhere in Arizona. Results of studies conducted to date at Beaver Creek, and other locations, show that changes in plant cover can produce substantial streamflow increases from some vegetation types, but not all. The impacts of watershed management practices on other range and forest resources also have been assessed.

Why Beaver Creek?

The Beaver Creek area is a large watershed encompassing 275,000 acres upstream from the junction of Beaver Creek and Verde River. It is part of the Salt-Verde Basin, a major river drainage in central Arizona. The Salt and Verde Rivers provide much of the water for Phoenix and other communities in the heavily populated Salt River Valley. This watershed was selected for research because it is representative of extensive areas of pinyon-juniper woodlands and ponderosa pine forests in Arizona and the Southwest.

What is a watershed? Think about measuring the flow of water at a certain point in a stream. All the land upstream which could contribute to the streamflow at that specific point is a watershed. It can be as small as a few square yards, or as large as thousands of square miles.

Beaver Creek Watershed includes plateaus, sloping mesas and breaks, and steep canyons. Elevations range from 3,000 to 8,000 feet above sea level.

Woodlands of intermingled pinyon pine, Utah juniper, and alligator juniper grow between 4,500 and 6,500 feet elevation as they do on some 51 million acres in the Southwest.

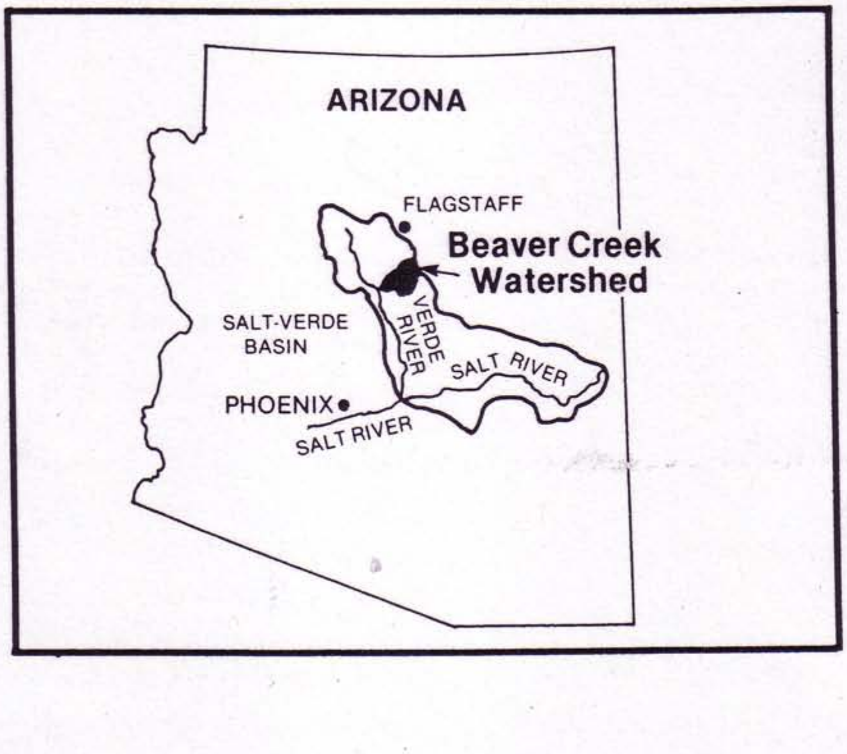
Ponderosa pine forests, characteristic of 11 million forested acres in the Southwest, dominate the hillsides and plateaus above 6,500 feet. Scattered through the ponderosa forests are clumps of Gambel oak, the predominant deciduous tree at Beaver Creek. Oaks are valued for the food and shelter they provide to wildlife.

There are many species of wildlife common to the Southwest within the Beaver Creek Watershed. Songbirds, birds of prey, vultures, and numerous small animals such as squirrels and rabbits are abundant. Beavers frequent the streams at lower elevations. An occasional bear may be found in the pine forests, and mountain lions and bobcats prowl the rocky canyons.

Deer, elk, and turkeys are the major game species. Deer occur at all elevations in summer, whereas elk prefer the higher forests. When winter snows come, both deer and elk move lower. Turkeys stay in the pine forests all year.

These patterns of wildlife use are repeated in mountain areas throughout the Southwest.

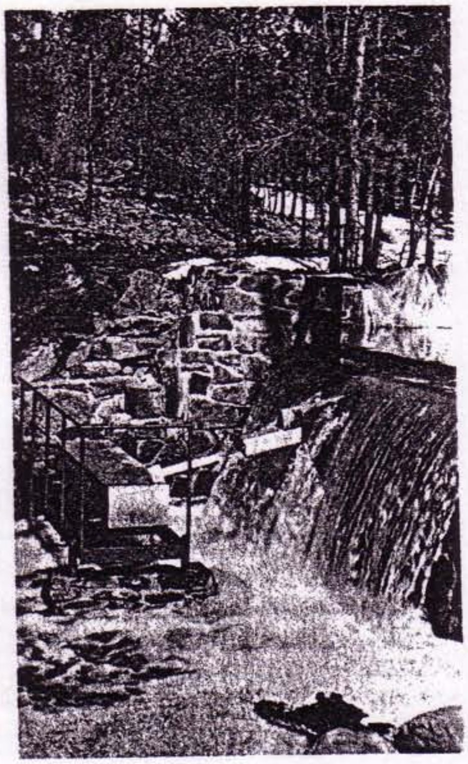
Annual precipitation on the Beaver Creek Watershed varies. On the average, the pinyon-juniper woodlands receive 18 to 20 inches, and the ponderosa pine forests receive 20 to 25 inches of water a year from rain and snowfall.

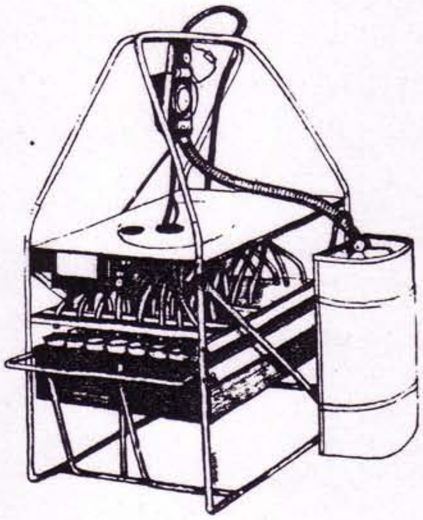


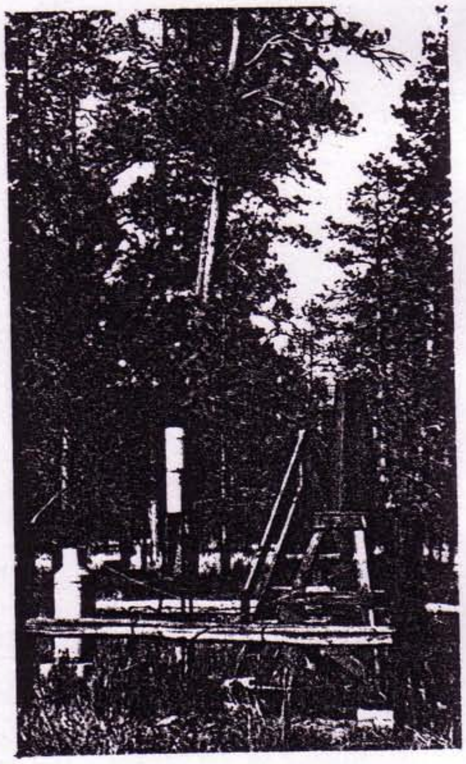
Getting Project Rolling

Between 1957 and 1962, 20 specific watershed study units within the Beaver Creek area were designated to test the effects of several vegetation management practices on water yield and other resources. Of the 20, 18 were watersheds from 66 to 2,036 acres where specific vegetation modifications could be tested on a pilot basis. The other two — encompassing 12,100 and 16,500 acres — were watersheds set aside to demonstrate the effects of management practices on areas of the size forest managers work with daily.

Recently, 24 smaller watershed units, each having uniform soil, plant life, and topography, were defined in areas of diverse ecological characteristics. Information from these units helps refine and verify findings — from studies on the larger watersheds — for use over a wide range of conditions.







Each of the 44 study watersheds requires instrumentation and maintenance. Gaging stations measure changes in streamflow caused by modifications in upstream vegetation. On selected watersheds, devices are installed to estimate the amount of soil and nutrients carried by runoff water. A network of weather stations completes the instrumentation.

Measuring Results

Before any vegetation was changed, runoff from each watershed was measured for several years to determine streamflow variations under pretreatment conditions. During this time, the quantity and quality of other natural resources also were inventoried.

With pretreatment measurements completed, six watersheds — Bar-M and Nos. 2, 5, 13, 15, and 18 — were designated as untreated "controls." They were shown to respond to environmental influences in a manner similar to the watersheds where experimental treatments would be applied.

Measurements continue on both experimental and control watersheds for several years after treatments are applied. Streamflow, sediment production, and water quality are monitored regularly, and other resources are reinventoried periodically. Changes caused by the management practices applied to the experimental units are evaluated by comparing posttreatment values with pretreatment data, and with data from the untreated "control" watersheds.

Pinyon-Juniper Treatment & Results

The pinyon-juniper experiments were among the first conducted in the Beaver Creek area. Prior to these studies, many woodland managers thought pinyon-juniper removal would improve both streamflow and forage production. Large areas throughout the Southwest had been cleared expecting these benefits. However, results at Beaver Creek show that substantial forage increases are possible, but that changes in water yield are not likely to be significant.

Three techniques were used to remove pinyon and juniper trees from Watersheds 1, 3, and 6 — uprooting, herbicide spraying, and cutting, respectively. Herbicide spraying on Watershed 3 was the only treatment to yield a significant streamflow increase. However, the government carefully controls the use of herbicides for environmental reasons, limiting the general use of this technique. Mechanical removal, such as uprooting or cutting, is the primary means for converting pinyon-juniper woodlands to other types of vegetation.

Increased grass is the most noticeable change triggered by pinyon-juniper removal. However, the cost of removal usually is more than the value of livestock forage gained unless the trees can be sold for fenceposts and firewood.

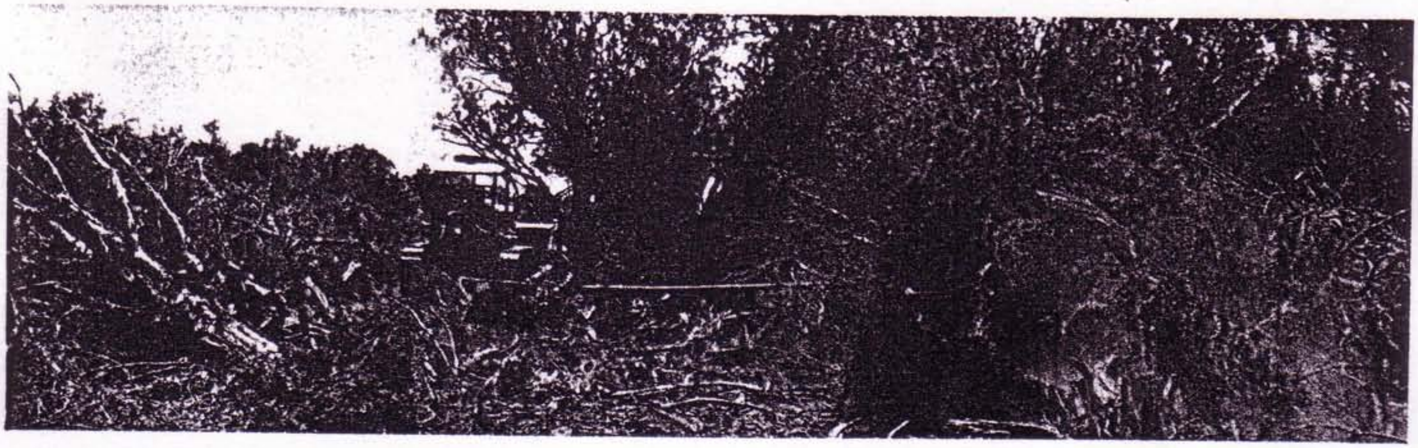
Pinyon-juniper removal also causes wildlife changes, particularly among small mammals and birds. For example, birds that feed in trees are replaced by ground feeders. The predominant game animal — the mule deer — is affected little by tree removal when woodland cover is left not far from the openings. However, more forage is made available in early spring when deer often need additional nourishment.

Records from the pinyon-juniper watersheds show that erosion rates and sediment loads in the streams have varied sharply with the intensity of storms. A heavy storm soon after the trees were removed from one watershed washed away much soil. In the long run, however, average sediment loads from the treated watersheds do not exceed those from the control watersheds significantly.

On Watershed 3, herbicide residues found in small amounts in streamflows the year following application soon disappeared. On all three watersheds, changes in water quality have been minor.

The following descriptions provide additional details about the treatments applied to each experimental watershed.

Watershed 1 *(306 acres)*



Large pinyon pine and juniper trees were uprooted in 1963 by pulling a cable between two crawler tractors. Small trees were cut by hand, all trees were piled and burned, and the area was planted to grass.

This treatment improved livestock range conditions markedly. Average annual livestock forage production increased 180 pounds per acre, or 300 percent above pretreatment levels. However, the increase in streamflow was insignificant — about 3 percent. The soil pits left by the uprooted trees trapped some of the runoff, probably contributing to the small change in streamflow.

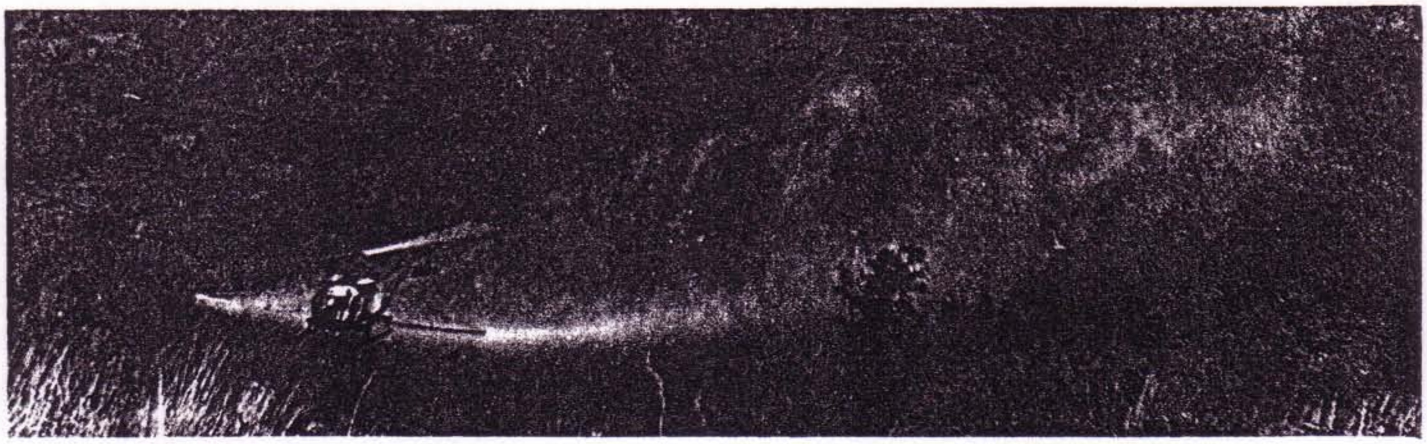
Watershed 6 *(100 acres)*

Trees were cut with power saws in 1965 to overcome the soil pitting problem experienced on Watershed 1. Felled trees were left in place. Shrubs were killed by hand-sprayed herbicides, and tree stumps were sprayed to stop sprouting.

Water yield increase resulting from this treatment was minor — .38 inch or 14 percent per year. However, the average annual livestock forage yield rose 130 pounds per acre, or 45 percent above pretreatment levels.

Young oaks and alligator junipers are flourishing as the effects of spraying wear off. As these plants increase in size and quantity, forage production will decline.

Watershed 3 ***(360 acres)***



All but 20 acres of this watershed were sprayed with an herbicide mixture of picloram and 2,4-D in 1968. Most of the watershed was sprayed by helicopter, while the edges were sprayed from the ground to prevent herbicide drift onto adjacent areas. This treatment killed 83 percent of the trees, but left them standing. Growth of some weeds and grasses was slowed temporarily but soon recovered.

This was the only pinyon-juniper treatment to produce a meaningful increase in water runoff. Annual water yields rose .45 inch or 65 percent above pretreatment levels. Researchers concluded that standing dead trees, which use no water, shield the soil from drying wind and sun. With ample moisture remaining in the soil, less rain and snowmelt will soak in, and more will become runoff. The average annual livestock forage increase was minor, only about 65 pounds per acre.

Many of the standing dead trees have been cut and sold for firewood in recent years. Scientists are monitoring subsequent changes in water and grass production.

Ponderosa Pine Treatment & Results

Results from the ponderosa pine studies have been encouraging. They show that a variety of management approaches — prudently applied to thin dense pine stands — can improve outputs of forest products such as wood, water, and forage, as well as amenity values such as scenic beauty and wildlife habitat.

Forest plants grow faster as a result of intensive management. Trees may produce two to three times more wood each year than when they are excessively crowded. Grasses and other plants foraged by livestock and big game may increase 200 percent or more. On the other hand, habitat for turkeys, squirrels, and certain other small animals may deteriorate if the forest is opened up too much.

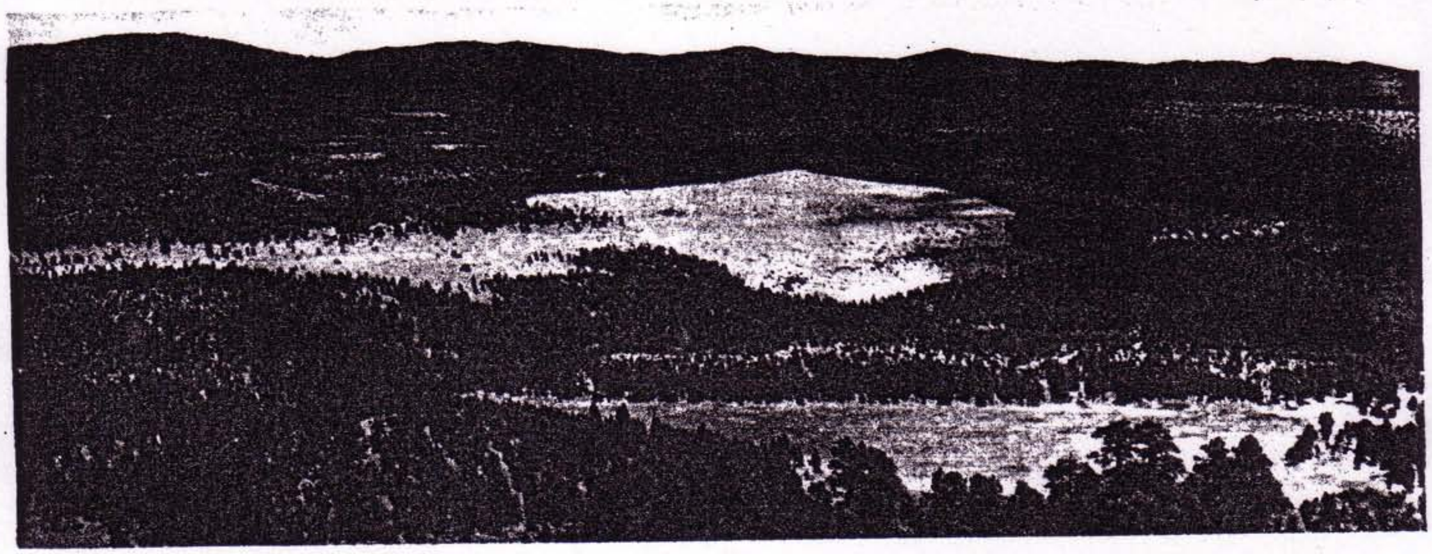
A variety of techniques can be used to manage forest density. The appropriateness of these depends on management goals and the natural productivity of the site. Uniform thinning throughout the stand, harvesting small patches or irregular-shaped strips, or combinations of these approaches, may be used.

What about appearance following harvest? Researchers working at Beaver Creek and elsewhere developed a "scenic beauty index" for predicting the visual impacts of different timber management methods. In the process, they found that carefully harvested stands, where logging residue is cleaned up, frequently rank as high or higher than unmanaged areas in the opinion of forest visitors.

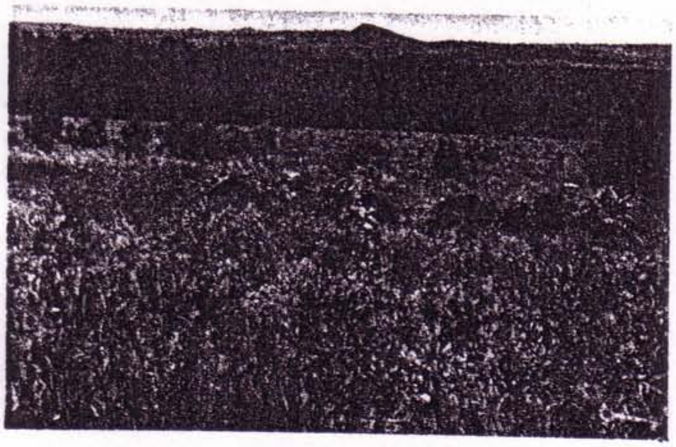
The pine harvests caused a slight deterioration in water quality, adding sediment and chemicals to the runoff. These changes were most noticeable immediately following harvest. However, long-term changes have been minor, and water quality still meets acceptable standards.

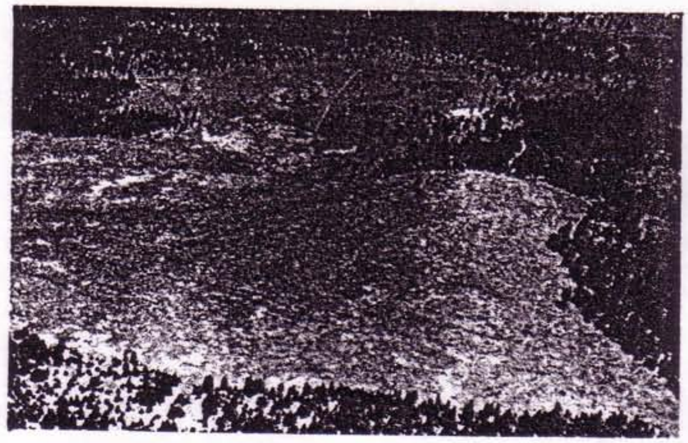
Analyses show that proper management can be profitable, too. In fact, if harvesting is carefully planned and supervised, intensive forest management can enhance both economic and environmental values.

The following descriptions provide additional details about the treatments applied to eight experimental watersheds. Commercial quality trees removed from these units were sold for lumber, pulpwood, poles, and house logs.



Watershed 11 **(178 acres)**



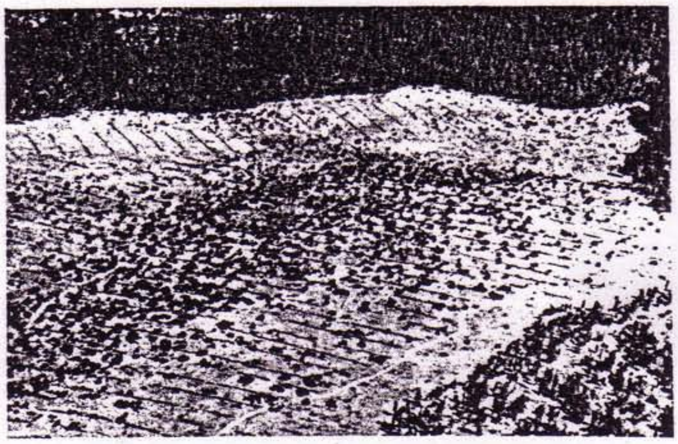


The first treatment of a pine watershed cleared Watershed 11 of all woody vegetation in 1958. Slash, the residue left from harvesting, was piled and burned, and grass was planted. However, testing did not begin until a good stand of grass was established.

Between 1967 and 1972, cattle grazing was permitted during the spring and fall. Grazing stimulated water production by 8 percent — not enough to be meaningful. The amount of sediment carried by runoff from the watershed was not significantly affected by grazing.

No significant changes occurred in grass production during the experiment, but deer and elk use declined. This was the only treatment that appeared to have a negative effect on use by these animals.

Watershed 12 (455 acres)



Watershed 12 was cleared of all trees in 1967. Logging slash and oaks not sold for firewood were piled in windrows. The windrows were positioned to trap blowing snow, much as snowfences do, and to shade snowdrifts until spring temperatures caused rapid melting, thereby increasing surface runoff.

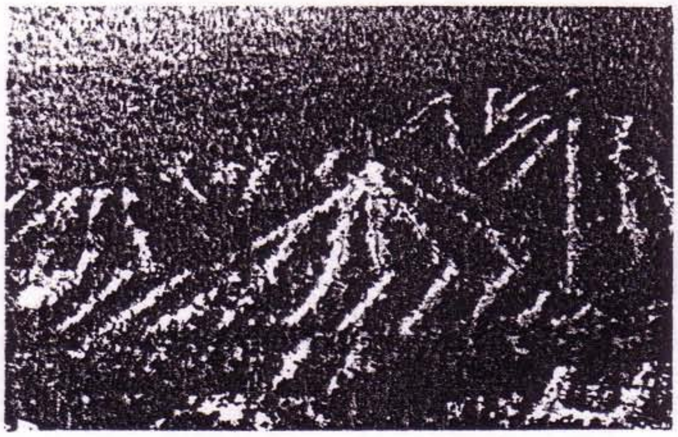
Many forest visitors protested the appearance of this treatment — the most severe applied to a pine watershed — during the first years following harvest. However, it was needed as a base for comparing other treatments.

As expected, average annual water runoff increased significantly — 1.7 inches, or 30 percent. The amount of sediment carried by the runoff rose 200 percent from an average 40 pounds per acre per year to 120 pounds. Even so, this is not a surprising change considering the severity of the treatment.

Livestock forage improved considerably, averaging 240 additional pounds per acre annually. That's more than twice the level of pretreatment conditions. Deer forage increased 120 pounds per acre — up 175 percent, and deer use has risen substantially.

Trees of commercial value no longer exist and will not reappear until long after a new generation of pines becomes well established. Meanwhile, noncommercial trees such as Gamble oaks are growing vigorously and providing abundant food and cover for wildlife. In time, the pine forest will return. Even now, an average of 135 pine seedlings per acre can be found growing throughout the area.

Watershed 9 **(1121 acres)**



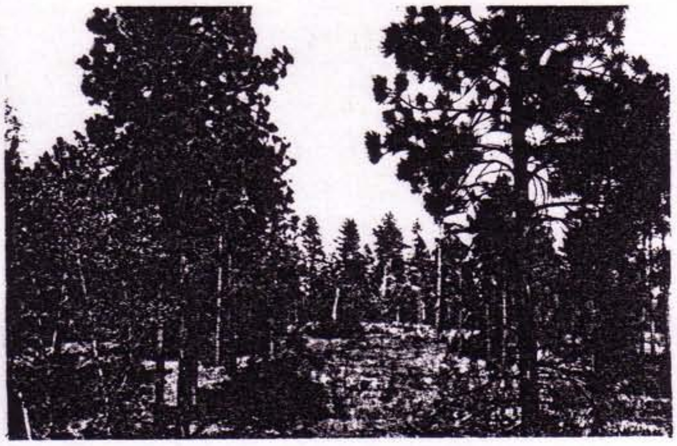
On Watershed 9, uniform strips 60 feet wide were cut from the forest in 1967. The total area cut equaled one-third of the watershed. These strips were oriented downslope to direct surface runoff into drainage channels. Harvest slash was piled in these aisles and partially burned. The strips of remaining forest, averaging 120 feet wide, were undisturbed.

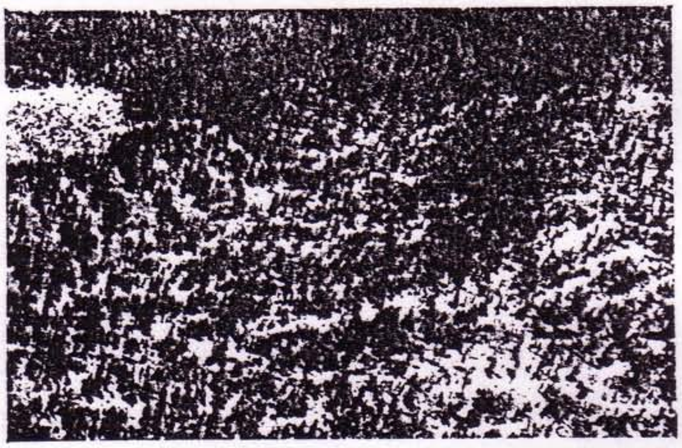
The average annual water runoff has increased by 1 inch since cutting — up 16 percent. Volumes of sediment washed from the watershed have been minor.

Forage for livestock and for deer and elk was scarce before harvesting. Though production has increased 40 percent for livestock and 100 percent for big game since treatment, total forage levels remain low. Consequently, increases in deer and elk use have been slight.

If this experimental management method were to be permanently maintained, strips covering one-third of the watershed would be harvested every 40 years, with each set of strips reharvested on a 120-year cycle.

Watershed 14 *(1349 acres)*





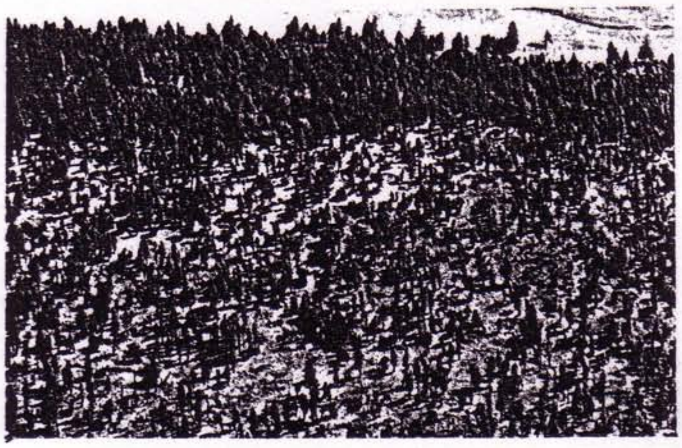
The treatment applied here consisted of irregular strips cut through the forest in 1970. Each strip varied from 30 to 120 feet wide, with pines cleared from one-third of the area. Additional trees were thinned from the stands between the strips to stimulate growth of the remaining trees. In total, half the timber on the watershed was removed. All slash was piled and burned in the cut strips, and seedlings were planted. Gambel oaks were left in the cut strips to provide acorns and cover for wild animals, and to soften visual impacts.

As on Watershed 9, harvest strips were oriented to direct runoff into drainage channels. Irregular cutting patterns and thorough slash cleanup were designed to make the appearance of these strips better than those on Watershed 9. Visitors polled during research to evaluate esthetic preferences indicated they considered this managed forest to be quite appealing.

This experiment has caused the average annual water yield to increase 0.6 inch or 13 percent above the years prior to harvest. Minor increases occurred in sediment flow. Deer and elk use has increased since treatment.

Sufficient time has not passed on any of the treated pine watersheds to permit sustained changes in forest growth to be verified by actual measurements. However, scientists have devised a mathematical model that imitates, or simulates, how the forest might respond to various management practices. With this model, scientists can predict future growth rates using available data. If the management method tested on Watershed 14 were continued, the remaining trees would be thinned again in 1990. Then, in 2010, after trees were well established in the cut strips, new irregular strips covering another third of the watershed would be cut. If Watershed 14 continues to be managed in this manner, scientists predict the volume of timber harvested in the next 120 years will change from 1100 to 3300 cubic feet per acre, a 200 percent increase above pretreatment conditions.

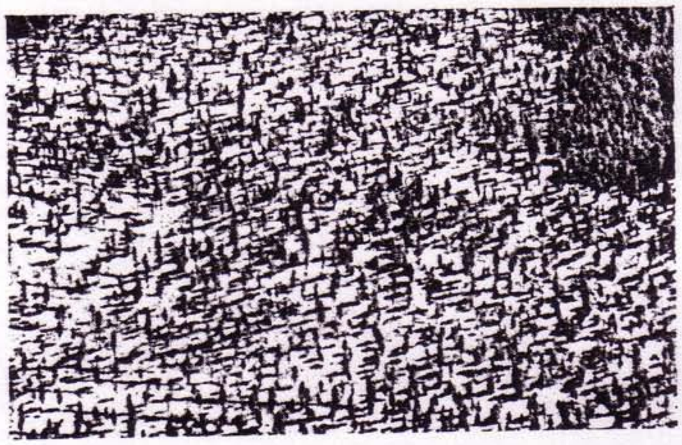
Watershed 16 *(252 acres)*



In 1971, this watershed was treated in a manner similar to Watershed 14, but with 65 instead of 50 percent of the tree cover removed through a combination of irregular stripcuts and thinning. The cut strips covered one-half of the area, making it the heaviest treatment of this type. Gambel oaks were left standing for wildlife food and shelter, and logging slash was piled and burned.

Insufficient time has passed since treatment to collect enough data to conclusively determine resource responses.

Watershed 17 **(299 acres)**



A thinning treatment — the removal of selected trees throughout the forest to enhance the growth of remaining trees — was applied to Watershed 17 in 1969. Heavy thinning reduced the forest to 25 percent of its original density. Small oaks were left for use by wildlife, but large oaks, except for nesting trees, were cut. Residual debris was piled in windrows similar to those on Watershed 12.

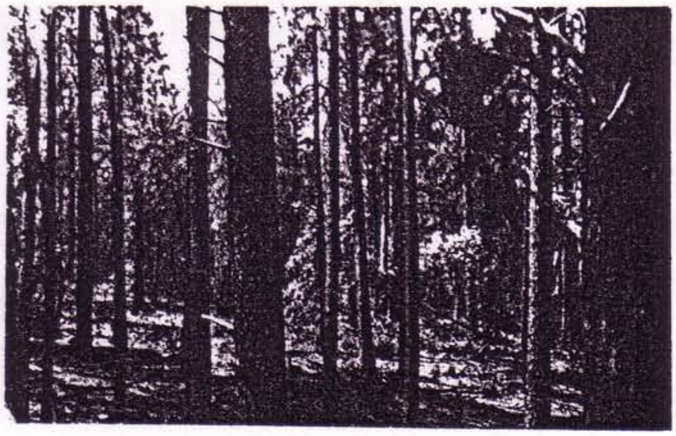
Using the model mentioned in the description for Watershed 14, scientists predict the volume of timber harvested in the next 120 years will rise from the pretreatment level of 1400 cubic feet per acre to 3900 — a 175 increase — if this management approach is continued.

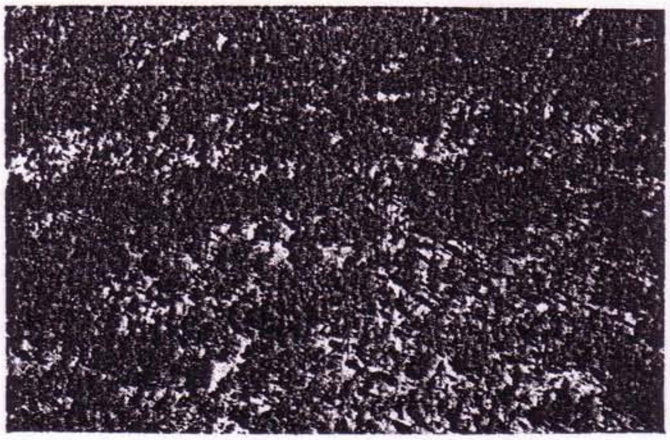
The average annual water yield has increased significantly — 1.3 inches or 19 percent. Modest amounts of sediment accompanied the increased streamflow. Most came the first year after harvest; then sediment declined in succeeding years.

Changes in forage still must be analyzed. However, deer and elk use has increased substantially, indicating that vegetation changes on the watershed appeal to these animals.

Many forest visitors consider this a rather severe management practice, but do not find it nearly as unattractive as clearcutting.

Watershed 8 ***(1802 acres)***



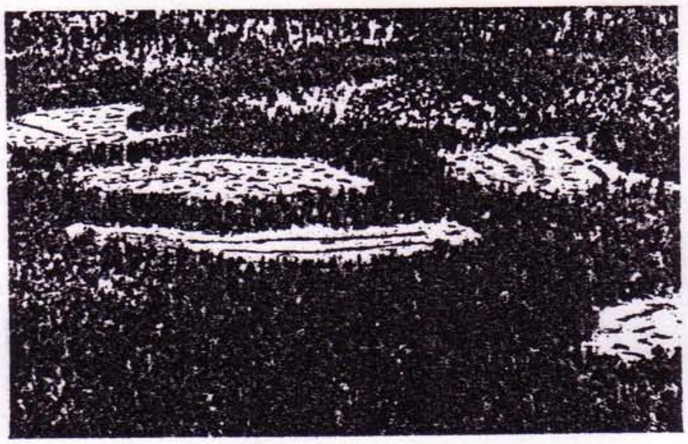


In 1974, this forest was thinned to 70 percent of its original density. Slash and small trees that could not be sold were piled and burned.

This management technique is designed to stimulate tree growth and maximize future timber yields. For that purpose, periodic thinning harvests would be scheduled every 20 years, with new trees naturally replacing those removed. When enough facts are collected and analysed, it is anticipated that this treatment will show greater timber yield potential than those applied to Watersheds 14 and 17.

Some increases in water yield and livestock forage also are anticipated, but several more years of data are needed to determine actual trends in the responses of these resources.

Watershed 10 **(571 acres)**

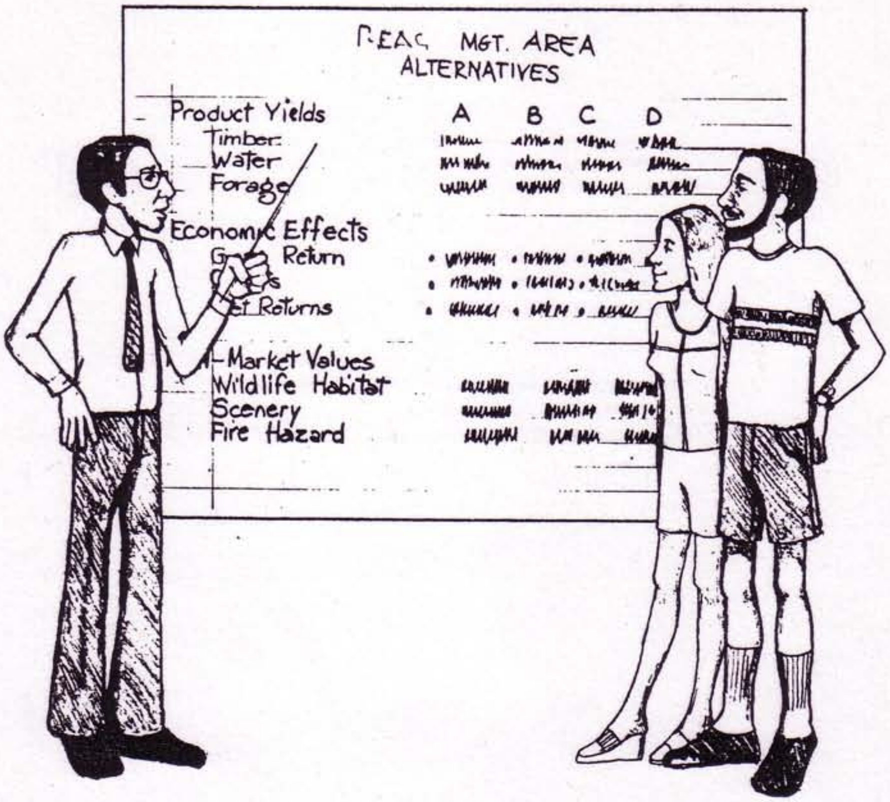


Cut in 1974, Watershed 10 features 17 cleared patches, each covering 8 acres or less, scattered over the area. These openings, comprising approximately one-sixth of the watershed, have irregular borders to give them a relatively natural appearance.

Logging slash was piled and burned in half of the openings, while slash piles were left on the remaining ones to provide cover for small animals such as rabbits, squirrels, and turkeys. Each opening was seeded with grasses preferred as food by deer and elk.

The purpose of this management experiment is to improve habitat for certain wildlife species while maintaining a reasonable level of timber production. With this approach, new openings would be cut every 20 years. By the time the final sixth of the watershed would be harvested, trees that had grown up in the initial openings would be nearing harvest age, and the whole process would start over again.

Insufficient time has passed since applying this treatment to measure and assess results.



Current Research & Results Testing

To determine which combinations of forest and range products best meet differing public demands, land managers need reliable tools to predict and assess the effects of management actions on the resources and the people. For example, clearcutting, harvesting small patches or strips of timber, or selectively harvesting individual trees might all be acceptable approaches to producing wood from a specific forest tract. But, other important questions must be answered before decisions are made.

"What are the probable effects of each management approach on future water yield and quality? On wildlife habitat? On harvesting and management costs? On scenic values? On recreation opportunities? On air quality? On erosion? On livestock forage? On fire hazard? On nutrient cycles? On economic and social structures in local communities?"

Land managers must be able to show the economic, social, and environmental effects of different management options in a way that the public can understand. Tradeoffs among products and amenity values to be gained or lost must be clearly displayed for each option. With this kind of information, managers are better able to obtain public views and combine them with professional experience to make wiser decisions about the allocation and use of limited resources.

Beaver Creek researchers and their cooperators are developing, evaluating, and improving prediction and assessment techniques and tools to help meet these needs. Most of them use modern computer technology. Some consist of intricate sets of mathematical equations, called models; others are simple thought processes. All must be useful under varying management situations and levels of complexity.

The goal is to provide managers and planners with a wide range of models and methods that can be readily learned and used in whatever combination best fits the specific situation. The cost of using these tools also must be reasonable. One such tool is PIPO — a computerized technique for simulating the growth and management of ponderosa pine forests. PIPO enables managers to better understand, describe, predict, and control behavior of forest stands under various management and climatic conditions.

A number of computer-based models already have been developed at Beaver Creek and elsewhere in the United States following years of inventorying resources, analyzing research findings, and assessing management practices. Several of these models are being tested and refined in projects now underway at Beaver Creek.

Scientists also are analyzing the ability of selected models to simulate the effects of management in forest ecosystems that differ from those at Beaver Creek. For example, candidate methods for predicting water yield changes resulting from various management practices in mixed-conifer forests have been tested with data from Thomas Creek, an experimental site on the Apache-Sitgreaves National Forest in southeast Arizona.

To achieve their ultimate goal, Beaver Creek personnel and their cooperators are devising modular systems or "families" of models. Most individual models are only capable of predicting a narrow range of consequences that might result from a management action, ignoring many of nature's interdependencies. But compatible models, coupled in "families," can simulate a variety of interactions in the environment. For example, the basic PIPO model mentioned earlier is capable of describing the effects of various management schemes on tree reproduction, growth, mortality, and wood yield. One version of PIPO has been coupled to other models which describe the movement of water and soil, and changes in forage and wildlife habitat. As a result, the forest manager can use the model "family" to assess the effects of different management programs on a wider varietv of resource values and products than just trees and wood.

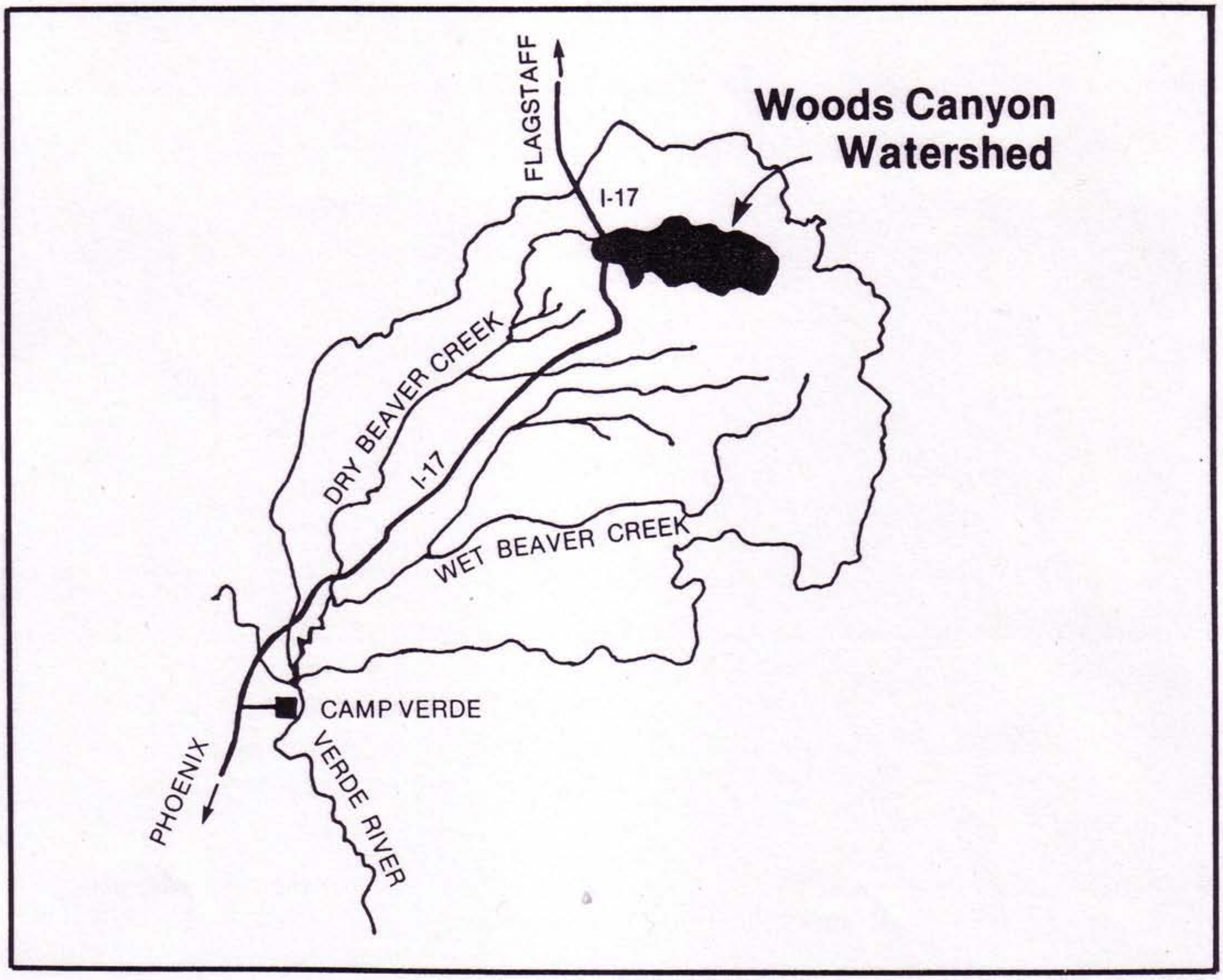
Economic analysis plays a major role in multiple-use management decision making. It helps to identify and explain the important plusses and minuses among alternative approaches to forest management by pulling relevant information on diverse resources and activities into a common economic perspective.

Economists are formulating ways to describe and display the biological, physical, and social consequences of different management programs in terms of: manpower, material, and machinery costs; potential monetary returns from market-valued products such as lumber, water, and livestock forage; and potential changes in local economic conditions.

And, economists are developing better ways to describe and evaluate the differences among proposed actions on nonmarketed resources and conditions such as scenery and safety from fire. For example, how do changes in scenic values affect enjoyment by forest visitors? Or, how is the safety of residents in mountain subdivisions affected by changes in the kinds and amounts of fuel in surrounding forests?

Woods Canyon (12,100 acres)

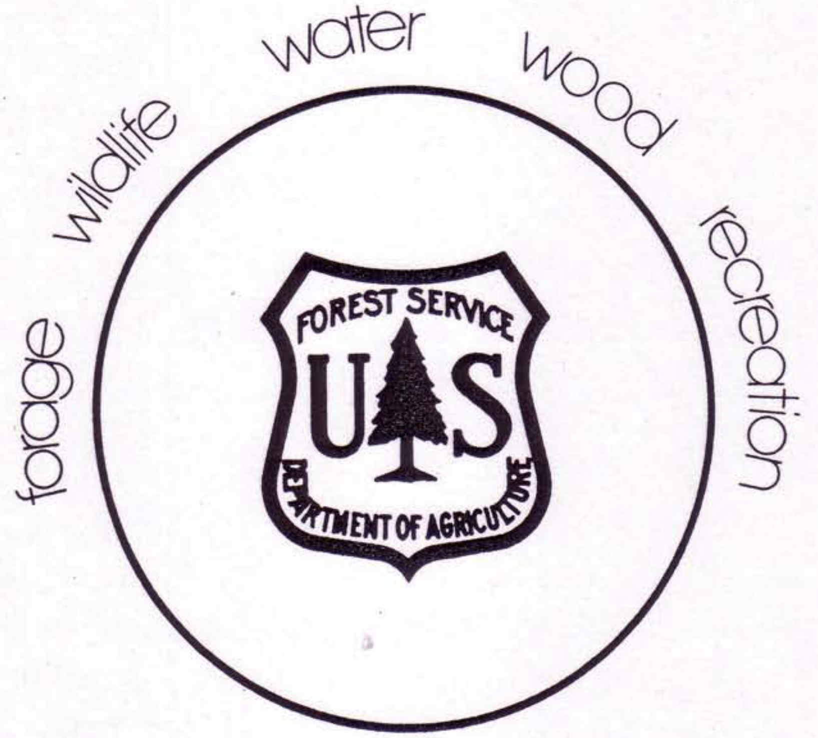
Woods Canyon, a large drainage within the Beaver Creek area, is a principal research application site. Here scientists and resource managers are making an operational-scale evaluation of the most promising planning and management methods and tools developed at Beaver Creek and elsewhere. This includes testing the accuracy of models developed for predicting the quantity and quality of resources that can be produced on an area, and the environmental, social, and economic consequences of alternative management practices.



Conclusion

The work centered at Beaver Creek is one example of the Forest Service responding to changing public and environmental needs. Basic knowledge about environmental interactions continues to flow from the watershed experiments begun years ago. Resource management planning methods being developed and tested are helping public land managers to better assess the status and future of the resources under their supervision, and to plan and implement appropriate management programs.

Results from this research and testing program should provide continuing assistance to natural resource agencies and industries as they respond to America's changing demands for forest and range products and outdoor experiences.



Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.

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