

# THE SIERRA ANCHA EXPERIMENTAL FOREST, ARIZONA: A BRIEF HISTORY

Gerald J. Gottfried<sup>1</sup> and Daniel G. Neary<sup>2</sup>

The availability of adequate and reliable water supplies has always been a critical concern in central Arizona since prehistoric times. The early European settlers in 1868 initially utilized the ancient Hohokam Indian canal system which drew water from the Salt River. However, the river fluctuated with periods of drought and periods of high flows which destroyed the diversion structures. The settlers proposed a dam to store water and to regulate flows. In 1903, the Salt River Water Users Association was formed and an agreement was reached with the U.S. Government for the construction of a dam on the Salt River at its junction with Tonto Creek. The Salt River drains more than 4,306 square miles (mi<sup>2</sup>) from the White Mountains of eastern Arizona to the confluence with Tonto Creek. Tonto Creek drains a 1,000-mi<sup>2</sup> watershed above the confluence. The agreement was authorized under the Reclamation Act of 1902. The Theodore Roosevelt Dam was started in 1905, completed in 1911, and dedicated in 1911 (Salt River Project 2002).

The dam has the capacity to store 2.9 million acre-feet (af) of water. However, between 1909 and 1925, 101,000 af of sediment were accumulated behind Roosevelt Dam (Rich 1961). Much of it came from erosion on the granitic soils from the chaparral lands above the reservoir, and much of the erosion was blamed on overgrazing by domestic livestock. Water users were concerned that accelerated sedimentation would eventually compromise the capacity of the dam to hold sufficient water for downstream demands. The Tonto National Forest was originally created to manage the watershed above Roosevelt Dam and to prevent siltation.

The Summit Plots, located between Globe, Arizona, and Lake Roosevelt were established in 1925 by the U.S. Department of Agriculture to study the effects of vegetation recovery, mechanical stabilization, and plant cover changes on stormflows and sediment yields from the lower chaparral zone (Rich 1961). The area initially was part of the Crook National Forest which was later added to the Tonto National Forest. The Summit Watersheds consisted of nine small watersheds ranging in size from 0.37 to 1.23 acres (ac). Elevations are between 3,636 and 3,905 feet (ft). The treatments included: exclusion of livestock and seeding grasses, winter grazing, hardware cloth check dams, grubbing brush, sloping gullies and grass seeding. Protection from grazing did not pro-

duce changes in runoff or sedimentation. Treatments that reduced surface runoff also reduced erosion. Hardware cloth check dams reduce total erosion, and mulch plus grass treatments checked erosion and sediment movement. Runoff was reduced by the combined treatments (Rich 1961). The Summit Watersheds were integrated into the Parker Creek Erosion-Streamflow Station in 1932.

## THE SIERRA ANCHA EXPERIMENTAL FOREST

The Parker Creek Experimental Forest was established in 1932 and was expanded in April 1938 and renamed the Sierra Ancha Experimental Forest (USDA Forest Service 1938). It is one of 80 experimental forests and ranges administered by the Forest Service and dedicated to the study of environmental changes in natural and managed forest and rangeland ecosystems. The Sierra Ancha Experimental Forest (SAEF) includes 13,500 ac within the Tonto National Forest and is located on the western slope of the Sierra Ancha Mountains about 10 mi northeast of Roosevelt Dam. Elevations within the SAEF range from 3,550 to 7,725 ft. Average annual precipitation ranges from more than 33 inches (in) at the highest elevation at Workman Creek to 16 in at lower elevations near the Base Rock lysimeters. The Workman Creek precipitation gauge measured 11.42 in during a storm in September 1970, which is the highest measurement ever recorded in Arizona.

The geology of the range is complex with sedimentary, metamorphic, and igneous rocks uplifted in a dome-like structure (Pase and Johnson 1968). Thick formations of Dripping Springs quartzite, dissected by deep canyons or with intrusions of diabase or basalt plugs and sills are common. Troy sandstone occurs at the higher elevations (Pase and Johnson 1968, Rich et al. 1961). Pase and Johnson (1968) recognized eight vegetation types within the SAEF including mixed conifer forests, mountain park, chaparral, oak woodlands, desert grasslands, desert shrub, and riparian. Fifty-seven percent of the SAEF supports chaparral vegetation. The untreated Upper Parker Creek watershed was proposed as a research natural area in 1987 because it contained vegetation that is representative of three important southwestern forest and woodland habitat types and a well-developed riparian area (Cochran and Laurenzi 1987).

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<sup>1</sup>Emeritus Scientist, U.S. Forest Service, Rocky Mountain Research Station, Phoenix, AZ

<sup>2</sup>Supervisory Soil Scientist, U.S. Forest Service, Rocky Mountain Research Station, Flagstaff, AZ.

In 1935, the headquarters complex at Parker Creek included cabins, bunkhouse, cook house, laboratory spaces, and assorted service buildings. Weirs, weather stations, lysimeters, and a variety of research facilities were constructed throughout the SAEF (Fig. 1). The Sierra Ancha Experimental Forest's initial mission was to study the effects of grazed and ungrazed vegetation on water yields and to learn more about water cycle relationships within the diverse vegetation zones that are represented in the Salt River Watershed (USDA Forest Service 1938).

### Short-Term Research

The Sierra Ancha Experimental Forest provides a unique research environment for conducting short-term and long-term studies on the basic hydrologic and ecological relationships in a variety of vegetation types extending along an elevation gradient. Some short-term studies tested erosion

control and revegetation techniques, the effects of grazing and wildfires on soil erosion, and the hydrology of headwater tributaries of the Salt River (U.S. Forest Service 1953). The consumptive use of range plants was studied and compared to evaporation from bare soil using a battery of small lysimeters. Other short-term studies examined the ecology of chaparral, oak woodland, and New Mexico locust (*Robinia neomexicana*); methods of shrub control; prescribed fire prescriptions for chaparral; pocket gopher (*Thomomys bottae*) food habits; riparian tree ecology; and plant and animal habitat preferences. Much of this research was reported in publications of the Southwestern Forest and Range Experiment Station, Rocky Mountain Forest and Range Experiment Station, and numerous professional journals.

Many of the original studies are described in a 1953 USDA Forest Service publication (USDA Forest Service 1953). The three undisturbed Base Rock Lysimeters, at the lower elevations, were used

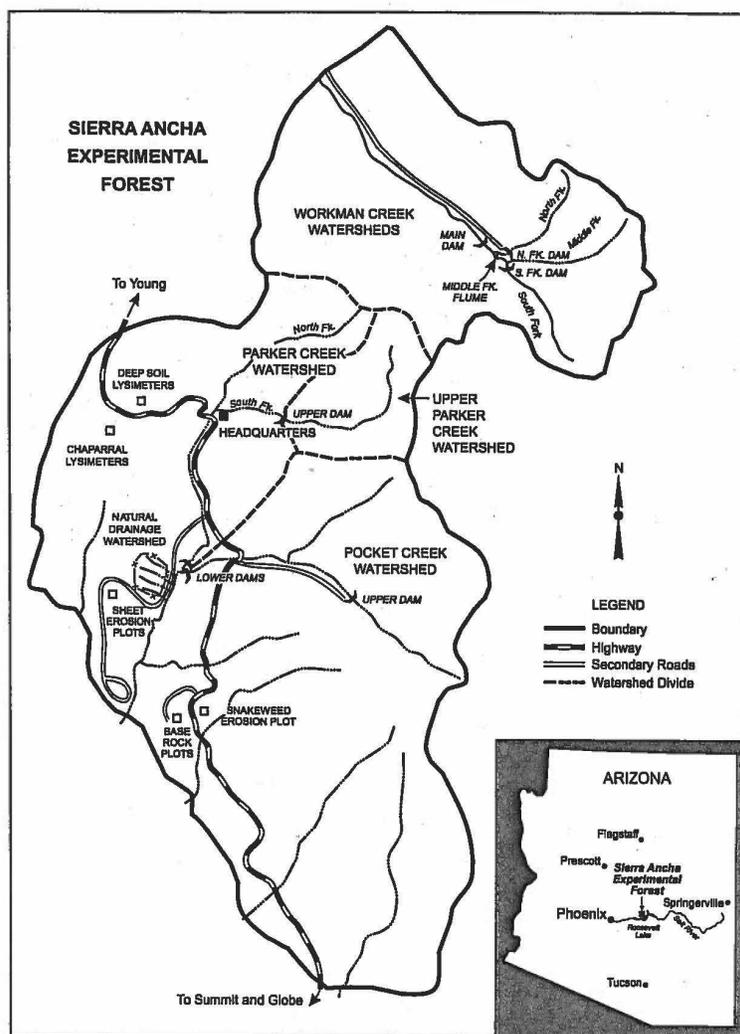


Figure 1. Early map of the Sierra Ancha Experimental Forest showing the watersheds, hydrologic structures, and research sites (USDA Forest Service 1953). Many of the research plots and sites are no longer being monitored.

to test the impacts of over-grazing, standard grazing, and a control on surface runoff, subsurface runoff, and sedimentation (Fig. 1). The treatments used sheep to achieve the desired grazing effects. The lysimeter which was reserved as a control, with good ground cover, produced the most subsurface runoff and the least surface runoff and erosion. The lysimeter with the poorest cover produce the opposite result while conservative grazing produced an intermediate effect. In one storm which produced 6.8 in of rainfall, soil loss from the control lysimeter was 44 tons/mi<sup>2</sup> while it was 1,114 tons/mi<sup>2</sup> from the lysimeter with poor groundcover (USDA Forest Service 1953).

There were other experiments concerned with steep-slope erosion and with grazing effects and methods of reducing erosion (Fig. 1). One study used rows of prickly pear cactus (*Opuntia* spp.) planted across the slope to reduce surface runoff and erosion. Other studies within the Parker Creek camp complex used small lysimeters of 121 square inches of surface area to measure transpiration and evaporation from individual plants and from bare soil (USDA Forest Service 1953). The finding was the transpiration and evaporation by plants is only slightly greater than evaporation from bare soil. Water use by shrubs and half-shrubs is greater than for higher forage-yielding grasses.

## WATERSHED STUDIES

### Natural Drainage Watersheds

The four watersheds were established on Parker Creek in a chaparral area located at 4,600 ft in elevation (Fig. 1). This watershed experiment was one of the first in the Central Arizona Highlands to evaluate grazing effects. The watersheds ranged from 9 to 19 ac in size and each contained a 90° V-notch weir. The soils were derived from quartzite and diabase, which predominates on the upper slopes of the watersheds. The intent of the initial study was to study the effects of livestock grazing upon vegetation, runoff, and erosion (Rich and Reynolds 1963). The treatments were 80% utilization or 40% utilization during a spring-fall grazing season by cattle and horses, and two control watersheds. Although there were some small differences in runoff and sedimentation, results were not statistically significant. The conclusion was that proper grazing in the chaparral type had no measurable effect on water production or erosion (Rich and Reynolds 1963).

A second experiment designed to determine the effects of chaparral cover manipulations on streamflow was initiated in 1954 (Ingebo and Hibbert 1974). The chaparral cover was suppressed on two watersheds by treating with herbicides while two watersheds were maintained as control areas. Grass

cover increased on the quartzite soils within the treated areas. No changes in grasses were measured on the diabase soils but forbs and half-shrubs increased on all soils. The combined data from the treated watersheds yielded a streamflow increase of 22% or an increase of one-third of an inch (Ingebo and Hibbert 1974).

### Workman Creek Watersheds

A major project was conducted on the Workman Creek watersheds to evaluate the hydrology of higher elevation mixed conifer forests and to determine the changes in streamflow and sedimentation from manipulating the forest vegetation (Rich and Gottfried 1976). Elevations range from 6,600 to 7,724 ft. There are three gauged watersheds on Workman Creek-North Fork, Middle Fork, and South Fork (Fig. 1). Streamflow on South Fork and North Fork are measured at 90° V-notch weirs and a combination 90° V-notch and 7-ft Cipolletti weir (Main Dam) measures flows from all watersheds. Middle Fork runoff is calculated by subtracting South Fork and North Fork records from Main Dam records. Perennial streamflow was measured continuously from 1938 through 1983 and from 2000 to the present. Most runoff is generated by winter storms. Annual streamflow average about 3.3 in for the three watersheds prior to any treatments. The mixed-conifer forest consists of Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and ponderosa pine (*Pinus ponderosa*). Gambel oak (*Quercus gambelii*), New Mexico locust, and quaking aspen (*Populus tremuloides*) are common. The riparian area also contains Arizona alder (*Alnus oblongifolia*), bigtooth maple (*Acer grandidentatum*), and Arizona walnut (*Juglans major*). The average stand basal area was 193 ft<sup>2</sup>/ac on Middle Fork.

### Initial experiments

The research design was to treat North Fork and South Fork and to hold Middle Fork as the hydrologic control. The first treatment on North Fork was to remove broad-leaved trees adjacent to the stream channel (Rich and Gottfried 1976). The treatment which only covered a small part of the watershed, did not affect streamflow. The second treatment on North Fork in 1958 (Rich and Gottfried 1976) involved clearcutting all of the forest on the moister sites and seeding perennial grasses. This cut removed the forest from 32% of the watershed and resulted in a significant increase in streamflow of 42±10% or 1.26 in.

Starting in 1953, the stands on South Fork were harvested according to a single-tree selection prescription which removed 46% of the merchantable timber. The harvest plus a 60-acre wildfire on the

upper end of South Fork resulted in a significant runoff increase of  $7\pm 6\%$  or 0.23 in (Rich and Gottfried 1976). The significant increase was related to the heavy precipitation during the 1966 water year. The wildfire resulted in an increase in sedimentation (Rich 1962).

### Subsequent experiments

A second set of watershed treatments were initiated in 1967 (Rich and Gottfried 1976). The North Fork treatment removed about 100 acres of dry-site forests, mainly ponderosa pine, and seeded grass. The treatment was adjacent to the areas cleared earlier. The result was a  $31\pm 9\%$  (1.32 in) increase in runoff over the increase from the moist-site cut. The combined moist-site and dry-site treatment produced an increase of  $84\pm 10\%$  or 2.70 in. A subsequent analysis using an additional six years of streamflow data indicated that the increase for the combined treatments was  $72\pm 22\%$  or 2.65 in (Hibbert and Gottfried 1987). It should be emphasized that these treatments were experimental to determine the potential for water yield increases from an extreme forest treatment and were definitely not intended as possible forest management options.

The next South Fork treatment was designed to thin and develop a ponderosa pine stand to 40 ft<sup>2</sup>/ac which should optimize both forest growth and water yields. Trees were harvested or thinned to the desired density; about 2.9 million board ft were removed. Cleared areas, where sufficient tree density did not remain, were planted with 2-yr-old ponderosa pine seedlings. A total of 191,000 seedlings were planted by contract and Forest Service crews. The treatment resulted in an increase in water yields of about  $111\pm 16\%$  or 3.67 in. The later analysis showed an increase of  $110\pm 29\%$  or 4.20 in (Hibbert and Gottfried 1987).

The results from Workman Creek indicate that removal of forest vegetation in significant areas and amounts will substantially increase water yields (Rich and Gottfried 1976). The challenge is to integrate this information into forest management planning to be able to predict how silviculture prescriptions affects both the stand, watershed condition, wildlife habitats, and other economic and esthetic values.

In addition to the main watershed studies, other research at Workman Creek evaluated New Mexico locust and mixed conifer root systems (Gottfried and DeBano 1983), pocket gopher food habits (Gottfried and Patton 1984), and snow-runoff relationships based on the Natural Resources Conservation Service's (NRCS) Workman Creek snow course and SNOTEL data (Gottfried et al. 2002). A significant relationship with an  $r^2=0.70$  was developed between the NRCS SNOTEL site and the

Middle Fork Flume. Arizona State University utilized the Parker Creek Camp and the adjacent forest and streams for summer classes for several years and graduate students continue to conduct research on the Forest. The Workman Creek installations were mothballed from 1983 to 2000, but long-term hydrologic, climatic, and vegetation records, reports, and publications are on file at the Rocky Mountain Research Station in Flagstaff. An archive of historical photographs of research at the SAEF is available at <http://www.fs.usda.gov/rds/imagdb/> (Golson, W., 2015, pers. corresp.).

### Coon Creek Wildfire

The value of the Workman Creek information and installations became apparent in 2000 when the Coon Creek Wildfire, which started on the east side of the Sierra Ancha Mountains, crossed the Workman Creek area, eventually burning 9,200 acres. The Middle Fork with its untreated forest was severely burned and the other two watersheds were less severely impacted. There are many questions about the impacts of wildfires on streamflow peaks and volumes, soil erosion and sedimentation, and vegetation recovery, especially after a wildfire that produced different levels of severity. The Rocky Mountain Research Station and the Tonto National Forest and its volunteers were able to repair and open the weirs at Workman Creek and to reestablish the plant inventory points to study fire effects. Data on post-fire streamflow, sedimentation, and vegetation recovery continue to be collected and analyzed to determine the fire effects of different fire severities (Neary et al. 2006). Analyses of the immediate post-fire period indicated that a monsoon storm in June 2000, with a 15-min intensity of 2.6 in/hr, produced a peakflow of 2,023 cubic feet per second (cfs), seven times greater than the previously recorded high peak. Sediment yields of 1,982 ft<sup>3</sup> were estimated from measurements at Main Dam for the 20 months after the wildfire (Gottfried and Neary 2003). Most of the sediments probably originated from the severely burned Middle Fork watershed.

### New Studies

In addition to research related to the Coon Creek Wildfire, two other studies were started on the South Fork. One study started in 2011, is part of the International Cooperative Program on Assessment and Monitoring of Air Pollution Effects on Forests (SAEF-ICP II) (Koestner et al. 2012b). The study is designed to understand causal relationships impacting forest ecosystems and determine the effects of different stressors on forest conditions. A wide range of data are being collected on forest conditions, soil chemistry, meteorology, and ozone depo-

sition. The South Fork site is ideal because of its location at a high elevation east of metropolitan Phoenix. The second new study is evaluating log decomposition of tree boles on the soil surface or standing vertically. The study, which originated at Duke University in North Carolina, showed that increased tree growth and changing soil chemistry can be used to model how forests will react to elevated carbon dioxide levels (Koestner et al. 2012a). Answers from this study should help with climate change research.

### CONCLUSIONS

The research at Sierra Ancha Experimental Forest has contributed and continues to contribute to the knowledge of hydrology, watershed management, and basic ecology for almost 80 years. Many concepts that managers and researchers now consider self-evident were first described and analyzed at Sierra Ancha. While the interest in generating increases in streamflow through vegetation manipulations has declined, the research at Sierra Ancha continues to provide useful information to researchers and land managers. The wealth of meteorological and hydrologic data available from Sierra Ancha can be used in future evaluations of the effects of a changing climate on common southwestern vegetation types. The knowledge gained at Sierra Ancha and at other forest research sites in Arizona can provide managers with knowledge about how currently proposed treatments could affect the multiple forest and woodland resources. The Sierra Ancha Experimental Forest continues to be a location for research to answer present and future questions.

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