Chapter 3

Providing Water and Forage in the Salt-Verde River Basin

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Introduction

The Salt-Verde River Basin, covering about 8.4 million acres of the Central Arizona Highlands, supplies most of the water for the Salt River Valley in addition to providing other multiple use values. Mixed conifer, ponderosa pine forests, and a portion of the pinyon-juniper woodlands predominantly occupy the higher-elevation watersheds. Chaparral shrublands occupy a wide range of elevations, experience varied annual precipitation amounts, and overlap major portions of the pinyon-juniper woodland and semidesert grassland types (figure 2). Management of these shrublands for increased forage and water production, and reduction in sediment production and its subsequent transport into Roosevelt Reservoir, has been of major interest to people in the Central Arizona Highlands and Salt-Verde River valley since the early 1900s.

Research And Management

The importance of the chaparral shrublands resulted in the establishment of research and management programs that used permanent study areas devoted to long-term demonstration and monitoring. Research watersheds were located on the Three-Bar Wildlife Area (figure 5) and the Natural Drainages watersheds on the Sierra Ancha Experimental Forest (see Gottfried et al. Chapter 2 of this publication). A demonstration management project was also established in the 1960s at Brushy Basin, located about 10 mi west of the Three-Bar experimental watersheds, to test the effectiveness of chaparral control methods.

Potential erosion and sedimentation problems were a major concern in the Salt-Verde River Basin because of the possibly that eroded materials from hillslopes would fill Roosevelt Reservoir (Rich 1961). Therefore, management of plant cover on upland watersheds was important. There was also interest in increasing forage production for livestock and wildlife, while maintaining wildlife habitat diversity.

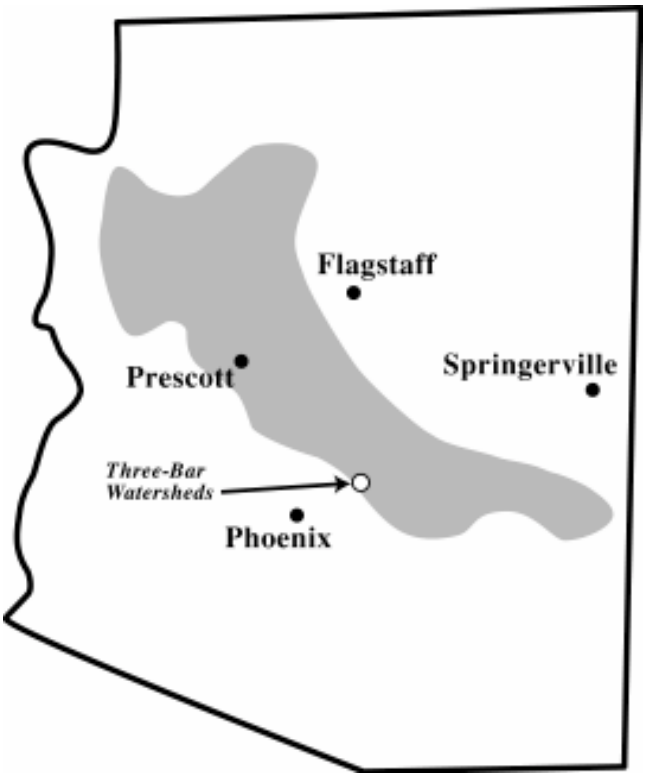

Figure 5. Three-Bar Watersheds in the Central Arizona Highlands.

Three-Bar Experimental Watersheds

The research program on the Three-Bar watersheds represented the first major experimental watershed program in Arizona chaparral shrublands. Four watersheds (A, B, C, and D) were established and instrumented in 1956 on the Three-Bar Wildlife Area west of Lake Roosevelt. This area supported dense chaparral stands and had not been grazed since 1947. All of the watersheds had been burned by a wildfire in June of 1959. After the burn, watershed A was abandoned and watershed F was instrumented in June 1963 to replace it. All 4 watersheds (B, C, D, and F) are north-facing, at elevations of 3,350 to 4,250 ft, on soils derived from granite, with the upper slopes exceeding 70%.

Previous studies on chaparral had been conducted at the Natural Drainages watersheds on the Sierra Ancha Experimental Forest (see Gottfried et al. Chapter 2 of this publication). However, the Three-Bar location, provided a better opportunity for evaluating the maximum water yields that might be expected from shrub-to-grass conversions because of its higher yearly precipitation and dense chaparral cover (>60% crown cover). The dense stands were highly productive areas. Experimental watersheds were subsequently established in medium density chaparral (40% to 60%) on the Whitespar watersheds and in low density cover (<40%) on the Mingus watersheds. These watersheds are in north-central Arizona (Yavapai County) in the Central Arizona Highlands (DeBano et al. Chapter 4 of this publication). The range of densities at Three-Bar, Whitespar, and Mingus were representative of most of Arizona's chaparral shrublands and allowed researchers and managers to better identify chaparral shrublands that could be economically treated to obtain increased streamflow.

Research Objectives

The Three-Bar Experimental Watersheds were established to determine the effects of chaparral shrub-to-grass conversions on increasing water yields (figure 6), on dissolved chemical constituents and sediment, and of fire and herbicide applications in controlling shrub re-growth.

While these research objectives provided a framework for treatment of Watersheds B, C, and F, other research agendas evolved as the understanding of chaparral response to treatment increased. Foliar sprays, initially used to control chaparral shrubs, inadequately eliminated all of the shrubs and required repeated application (Hibbert et al. 1974). Because of this inadequacy, soil-applied herbicides in subsequent treatments of Watersheds C, B, and F were tested. Above-normal nitrate levels were discovered in stream water as a result of earlier herbicide treatment on Watershed C. These high nitrate responses led to studies on water quality and nitrogen losses as a result of shrub treatments.

The treatment pattern changed from treating entire watershed areas (Watersheds C and F) to selectively controlling shrub plants in a mosaic pattern to provide protection from erosion on steep slopes, better habitat diversity for wildlife, and maintenance of increased streamflow (Watershed B). The mosaic treatment pattern of chaparral control was ultimately tested on the Whitespar watersheds (DeBano et al. Chapter 4 of this publication).

Brushy Basin Management Demonstration Area

Brushy Basin (8,100 acres) was the site of a chaparral management project initiated by the Tonto National forest on the west slope of Mazatal Divide, 2 mi northwest of Four Peaks (figure 7). The objective was to demonstrate how fire and herbicides could be used to control chaparral shrubs and to improve forage resources (Courtney and Baldwin 1964). The treatment consisted of a prescribed burn followed by a maintenance plan. The maintenance plan included continuous and complete herbicide treatment of the highest water-yielding sites with the exception of a hardwood-riparian area, occasional spraying

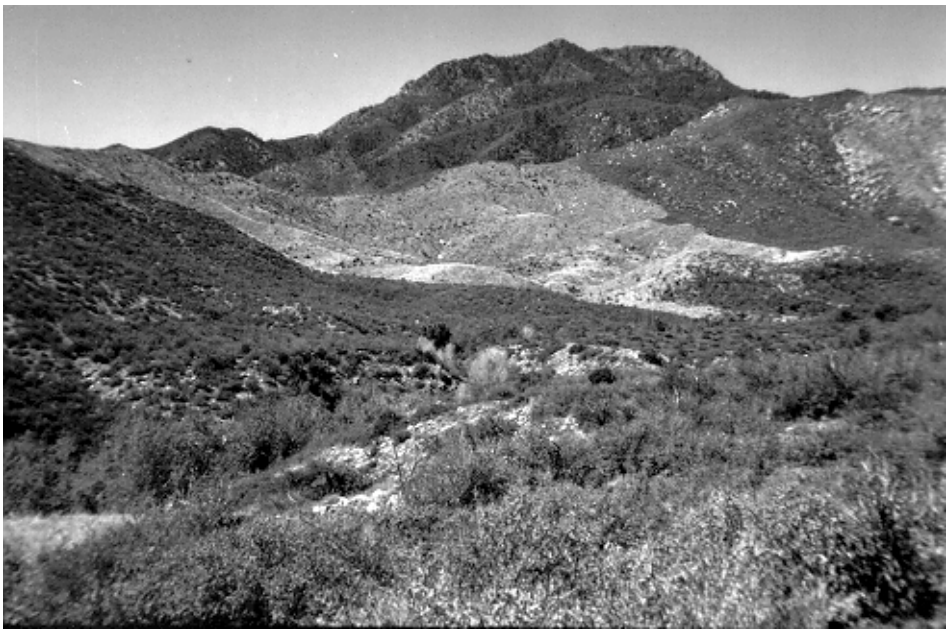

Figure 6. A shrub-to-grass conversion water yield improvement treatment on a Three-Bar Experimental Watershed.

with foliar herbicides to lower the density of brush on the moderate water-yielding sites, and retention of cover on steep and rocky sites (Suhr 1967).

Broadcast burning consumed about 80% of the canopy on about 5,000 acres over 3 yr. This burning program represented the first large-scale burning on national forest land (Moore and Warskow 1973). The burned areas were re-seeded with a mixture of grasses (Suhr 1967). Portions of Brushy Basin have been heavily grazed since this treatment, and erosion was particularly severe on some grazed areas during heavy rains in October 1972 (Ffolliott and Thorud 1974). Follow-up maintenance with herbicides was not implemented because of the environmental concerns associated with pesticide use, particularly foliar herbicides.

Cooperators

Interest in chaparral management evolved into a research and management program involving several agencies and organizations. The Tonto National Forest was responsible for managing much of the chaparral areas in the Central Arizona Highland. USDA Forest Service research was conducted by the Rocky Mountain Forest and Range Experiment Station and was assigned to the Forestry Science Laboratory at Tempe. Most of the Forest Service research addressed hydrologic and vegetative evaluations. Scientists with the Arizona Game and Fish Department provided wildlife evaluations on the Three-Bar Wildlife Area. Cooperative studies were also carried out with the University of Arizona, Arizona State University, and Colorado State University. Personnel from the Salt River Project and Arizona Water Resources Committee provided support and guidance in many of the watershed evaluations. Streamflow was gaged on some watersheds by the U.S. Geological Survey of the Department of Interior.

Results

Earlier status-of-knowledge publications presented the results of increasing water yields and other multiple use values in chaparral shrublands through the early 1970s (Brown, T. C. et al 1974, Hibbert et al. 1974). These results have been refined and, in some cases, expanded upon in subsequent publications. A brief discussion of the results is presented below; details are found in the cited literature.

Three-Bar Watersheds

After a wildfire in 1959, Watershed D recovered naturally to be used as a control and Watershed B, Watershed C, and Watershed F received chemical treatments. Results of the treatments (Hibbert et al. 1974) were:

- The effect of the wildfire on streamflow was short-lived. A sharp increase in overland flow occurred in the first few years after the wildfire, especially during the first summer rains.

Figure 7. Overview of the Brushy Basin Management Demonstration Area.

- Stream flows increased on all the watersheds. However, after the third year, the crown cover on the control watershed (D) was dense enough to prevent any increased water production.

Following the treatment on Watershed C:

- Streamflow increased 4-fold (5.8 area-inches of water) over 11 yr when compared with flow from the control Watershed D.
- Foliar herbicides killed about 40% of the shrub live oak and 70% of the birchleaf mountainmahogany. Because of the poor rate of shrub control, the remaining shrubs were treated individually with soil-applied herbicides in 1965 and 1968. This treatment reduced the shrub crown cover to less than 3% by 1969.
- Annual forage production averaged 1,200 lb/acre and provided a ground cover that maintained high infiltration rates.
- The increase in streamflow, particularly yearlong streamflow, allowed riparian vegetation to become established below the gaging station (DeBano et al. 1984).
- Bird populations flourished in the newly created riparian areas, but were reduced in the areas converted to grass (Szaro 1981).

Results from Watershed B were:

- Nitrates in streamflow rose to relatively high concentrations (about 85 ppm) and were exported from the watershed in amounts up to 125 lb/acre/yr, in comparison to a control watershed value of about 1 lb/acre/yr. High concentrations of nitrates in the streamflow lasted longer from the 2-stage treatment on Watershed B than from the 1-stage treatment on Watershed F. High nitrate concentrations (44 to 373 ppm) were found in soil solutions from 5, 10, and 15 ft depths on the converted watershed compared to low nitrate concentrations (0.2 to 6.2 ppm) on an adjacent undisturbed area (Davis 1987a, Davis and DeBano 1986).
- Herbicide (picloram) concentrations in streamflow were higher (360 to 370 ppb) during the initial 3 months following treatment than thereafter. After 14 months and 40 inches of accumulated rainfall, picloram could not be detected in the streamflow (Davis 1973).
- Surviving chaparral shrubs were re-treated in 1968 and again in 1978 (Davis 1987a). These additional 2 treatments reduced the shrub cover to about 8%.
- Annual grass and forb production averaged 690 lb/acre on the treated areas as compared to 300 lb/acre on nearby untreated slopes.

Results from Watershed F were:

- Nitrate concentrations in streamflow from the control (Watershed D) remained less than 1 ppm, while nitrate from the treated watershed increased to a maximum concentration of 56 ppm during the first posttreatment year, with an annual average concentration of 16 ppm (Davis 1984, 1987b, 1989).
- Shrub crown cover was reduced from 55% to less than 5% the first year after treatment. Shrub kill increased to more than 95% after 2 years.
- Runoff efficiency (the ratio of streamflow-to-precipitation) was increased to 2.3 times the efficiency of the control watershed (D), an increase of 1.5 area-inches of streamflow.

Other Studies

Results of other studies near the Three-Bar experimental watersheds, and conducted elsewhere in the chaparral shrublands in the Salt-Verde River Basin, are summarized below. In addition to testing of the effectiveness of herbicides for shrub control, studies using prescribed fire and a biological control (goat browsing) were tested:

When using fire, more than half the chaparral canopy should be eliminated and prevented from becoming reestablished to obtain relatively high levels of seeded grass production (Pase 1971 and Pond 1961a). However, burning can also result in an increase in undesirable plant species (Pase 1965).

Goat browsing reduces total cover in chaparral stands, particularly when in conjunction with initial brush-crushing (Severson and DeBano 1991). Goat browsing to control chaparral shrubs can result in the consumption of the same plant species preferred by cattle, deer, and elk (Knipe 1983). Successful use of goats to control shrub cover requires an intensive level of animal management.

The root system of a shrub live oak (figure 8) was excavated to characterize its mass (Davis and Pase 1977). It was determined that:

- The root system included a taproot, many deep-penetrating roots, and profuse lateral roots.
- The shrub live oak root system effectively depletes both ephemeral surface and deeply stored soil moisture.

A study was conducted at El Oso west of Lake Roosevelt and north of the Three-Bar Wildlife area, to measure the temporal and spatial sediment delivery to and within a

stream network following a wildfire in chaparral shrublands. This study indicated that:

- Severe erosion following a wildfire deposited large amounts of hillside soil and debris in the channel system (Heede 1988).
- As vegetation recovered after fire, sediment delivery from the watershed practically ceased.
- Relatively clear water, upon entering the channel, caused degradation of the sediment deposited in the tributaries and delivered this sediment into the main channel for years after active hillslope erosion had ceased.
- The delayed sediment delivery made it difficult to interpret the effect of current management activities on erosion responses.

Mule (*Odocoileus hemionus*) and white-tailed deer (*O. viginianus*) and black bear (*Ursus americanus*) were studied on the Three-Bar Wildlife Area by the Arizona Game and Fish Department. These studies indicated that:

- Mule and white-tailed deer select a variety of plants for food including forbs, dwarf and half-shrubs, mast and other fruits, and evergreen browse of both chaparral and desert shrub (McCulloch 1973, Urness 1973, Urness and McCulloch 1973).
- While conversion treatments increased forage production for cattle and deer, loss of cover adversely effected deer, particularly when conversions of large areas or entire watersheds were implemented (McCulloch 1972).
- Cover and food for black bear are enhanced in habitats composed of shrubs and low trees interspersed with a few forest species in the major drainages. This arrangement provides numerous mast- and fruit-producing species (LeCount 1980).
- Leaving areas of adequate size as escape cover and providing a number of seral stages of postburn vegetation should benefit both game and nongame wildlife species (Pase and Granfelt 1977). Less than half of any area should be converted (Reynolds 1972).

An inventory of 139 chaparral sites totaling almost 335,000 acres was accomplished in the early 1970s (Brown et al. 1974). The cost of converting portions of chaparral shrubland areas that met crown cover, slope, and managerial criteria for conversion to grass, and maintaining these conversions over 50 yr, was compared with the benefits to society of increased water yield and forage for livestock and reduced fire-fighting costs. It was shown that:

- Using fire as the main conversion tool, 96 of the inventoried sites (69%) had a benefit-cost ratio greater than 1. Using a soil-applied herbicide, 72 sites (52%) had a benefit-cost ration greater than 1.
- Proper management would favorably affect soil movement, wildlife habitat, an esthetics. Recreation use would be unaffected in most treated areas.

Implications

Information has been obtained on how chaparral shrubland ecosystems function for land management deci-

Figure 8. Root system of shrub live oak excavated to a depth of 21 feet.

sion making. Past research has contributed information on shrub control techniques, watershed and soil responses to shrub control, water quality, wildlife habitat changes, and economics. The most important management implication of this research is the ability to determine how to control chaparral shrubs to enhance the production of water and forage and to maintain wildlife habitat diversity.

If chaparral shrub suppression is desired, burning must be combined with other control methods such as applications of soil-applied herbicides or mechanical control methods. A problem associated with mechanical equipment is that it is limited to slopes with less than a 10% grade on rock free soils. One advantage of using prescribed fire is that the environmental changes created are similar to those occurring during the natural evolution of fire-adapted ecosystems (Axelrod 1989). A disadvantage of using prescribed fire is that shrub control is temporary (Hibbert et al. 1974). Therefore, a management objective is often the suppression of shrubs rather than their eradication.

Current Status

Hydrologic evaluations on the Three-Bar watersheds were discontinued in 1983. The Three-Bar Wildlife Area remains ungrazed and provides a study site for current wildlife studies and for monitoring by the Arizona Game and Fish Department.