Increasing Summer Flow in Small Streams Through Management of Riparian Areas and Adjacent Vegetation: A Synthesis

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Abstract.—Construction of small dams, suppression of woody vegetation in and adjacent to riparian zones, and removal of livestock from streamside areas have all led to summer streamflow increase. Potential may exist to manage small valley bottoms for summer flow increase, while maintaining or improving riparian habitat, range and watershed values.

INTRODUCTION

Techniques to increase streamflows through treatments in phreatophyte (i.e., riparian) zones depend almost exclusively on reducing evapotranspiration during the growing season (Satterlund 1972). At present, phreatophyte control to improve water yield has largely been abandoned, as a result of smaller than expected water savings and poor benefit/cost ratios stemming in part from potential loss of high-value riparian habitat (Graf 1980). Watershed and habitat improvement projects within riparian zones are, however, occasionally reported to increase summer streamflows without employing evapotranspiration control methods (Heede 1977, Jester and McKirdy 1966). Are there alternatives to currently accepted techniques? In an attempt to answer this question, this paper reports and interprets the results of a search for information pertaining to activities in or near riparian areas that have resulted in summer streamflow modification.

METHODS

Conventional literature search methods were used. In addition, researchers and field personnel were contacted to obtain unpublished information.

INFORMATION REVIEW

Information located relates primarily to small fluctuating streams, orders one through four (Strahler 1957). Three categories of activity were identified which can result in modification of summer streamflows: change in numbers of dams present, changes in vegetation in and near riparian zones, and changes in livestock grazing.

Beaver Dams

The effects of beaver dams on summer streamflow were observed on a small stream in Massachusetts after beaver, their dams and instream woody debris had been removed (Wilen et al. 1975). In the year beaver were removed, both experimental and control streams maintained perennial flow, but the control stream maintained the higher flow. The following spring, beaver unexpectedly reoccupied the experimental stream and built dams, while the control stream remained free of beaver. During the summer of the same year, the control stream went dry, but flow continued throughout the year at a station below the new dams on the experimental stream.

In a beaver study in Utah (Bates 1963), seepage into the stream in the study area was found to increase in the summer and decrease during the winter months. As a result, water budgets could not be determined with the instrumentation available. Analysis of streamflow data indicated that beaver did not, however, significantly affect overall consumptive use of water during the dry season by building dams and altering adjacent vegetation. Instead, consumptive use was shifted to earlier in the growing season in beaver pond areas, as compared to a stream section without ponds.

Reports of the effects of beaver ponds on streamflow are rare in the literature, but where reported tend to support the idea that beaver ponds augment summer streamflow. Beaver dams constructed after introduction of beaver on Ragg Creek in California in 1938 resulted in a small but steady flow throughout the summer in an area that normally was almost dry by mid-summer, and a similar finding was noted on another California stream (Tappe 1942). Serious economic losses were reported as the result of the loss of beaver on several streams in the Ochoco National Forest in eastern Oregon (Smith 1938, Finley 1937). Trout streams disappeared and hay crops in beaver pond areas were reduced by 90 percent, resulting in a loss at the time of $30,000 per year. Ranchers were either without recourse or had to drill
wells to water their stock. Downstream, lack of irrigation water resulted in reversion of cultivated land to desert. In Missouri, beaver in headwater streams reportedly restored permanently flowing water with resultant good fishing (Dalke 1947). Literature reviews by Call (1970) and Bates (1963) strongly support the idea that beaver dams help stabilize streamflow regimen and extend flows into the summer months.

Reid (1951) stated that enlarged water surfaces created by beaver dams in an Adirondack spring-fed stream increased evaporation rates and reduced the volume of streamflow by 50 percent. This observation is the only information located suggesting that the activities of beaver can reduce summer streamflow.

Check Dams/Gabions

The conversion of streams to perennial flow has been reported as a result of check dam and gabion installation in New Mexico, Oregon, Texas, and Colorado. The best-documented case was in Colorado in the Alkali Creek drainage (Heede 1977). In 1956, the drainage was fenced and cattle were excluded. In 1963, 132 check dams were installed in ephemeral gully networks for erosion control, and disturbed areas were reseeded. In 1967, livestock were reintroduced at a low stocking rate. In 1970, the rehabilitated gullies unexpectedly developed perennial flow. Old beaver dams exposed in the gully walls were observed during construction of the check dams, and since 1977 beaver have reoccupied a portion of the drainage just below the study area. Precipitation remained normal during the term of the study. Increases in ground cover and new sediment deposits in the gullies were believed to be responsible for change to perennial flow. Willow and rushes had become firmly established by 1977, yet perennial flow continued (Heede 1977).

In the Fremont National Forest in Oregon, the installation of 34 rock check dams on Shoestring Creek in 1974 resulted in perennial flow below a mile-long erosion control project (Anon. 1979). Livestock grazing patterns remained unchanged. Recovery of bank vegetation and use of the water by trout and waterfowl where none had existed for years was reported.

Brown (1963) reported the results of a water conservation program undertaken on the Flat Top Ranch, Texas, in which all major drainage areas were converted to perennial flow. Dams were constructed to accelerate infiltration into sandy banks. Water storage in banks was also increased by diversion channels to spread water and promote infiltration and storage. Development of upland areas into grasslands, to retard runoff and promote storage, was also undertaken.

In New Mexico, Jester and McKirdy (1966) reported that installation of check dams in Taos Creek resulted in perennial flow within 10 years, and that trout were subsequently stocked in the stream. On another stream, Las Huertas Creek, within three years of installation of 25 gabion structures, streamflows were extended each spring by a month or more. The improved stream section was lightly stocked with trout, and some fishing was provided.

Streamside Vegetation

The information reported here has been limited to situations where streamflows have been measured at gaging stations, or where flow changes have been observed in the field, following treatment of valley bottom vegetation. A large part of the literature on water yield improvement via suppression of phreatophytes has involved estimation of potential water savings (Horton and Campbell 1974). Predicted water savings, however, have often been more than actual savings, as determined by field measurement. Few studies meeting the above criteria have been reported (Sopper 1971). No literature was located reporting streamflow modification by use of anti-transpirants in riparian zones.

In a paired-watershed experiment, Rowe (1963) reported that removal of 4 acres of riparian and 34 acres of woodland vegetation along Monroe Canyon, California, resulted in variable but significant water savings that ranged from 0.4 to 1.2 acre-feet per acre treated. Perennial flow from the treated stream section also resulted. The greatest water savings were attributed to removal of peripheral, deep-rooted woodland species that were able to tap the capillary fringe and saturated valley bottom soils through a layer of aerated overburden. The smallest savings in water was thought to occur along the stream channel where free water and wet soil surfaces, within the capillary fringe, were subjected to the direct effects of wind and solar radiation. Evaporation from such areas was estimated to be about the same as evapotranspiration loss from areas with an undisturbed riparian cover.

Ingebo (1971) reported that removal of streamside chaparral from Whitespar B watershed in Arizona resulted in perennial flow from a previously intermittent stream. Water savings ranged from 0.35 to 0.55 acre-feet annually per acre treated.

Rich and Thompson (1974) reported that removal of alder and bigtooth maple adjacent to streams, springs and seeps in the North Fork of Workman Creek drainage in Arizona resulted in no significant changes in water yield during the riparian growing season, and that diurnal fluctuations in streamflow were not changed. Less than one percent of the basal area of trees in the 248 acre watershed were removed from riparian areas. Later, the removal of 80 acres of adjacent nearby moist-site conifer resulted in a 45 percent increase in annual water yield.

Bowie and Kam (1968) reported that after the eradication of cottonwood, willow and seepwillow
along a 1.5 mile section of Cottonwood Wash, Arizona, a water savings amounting to 6 percent over inflow occurred during the growing season. Riparian vegetation was eradicated on 22 acres of floodplain and water savings amounted to 1.7 acre-feet per acre treated. Reduced water savings later in the study were attributed to the reestablishment of seepwillow. Increased evaporation from exposure of riparian soils to wind and sun was postulated as the reason for less than expected savings.

Small increases in dry-season streamflow have been reported after removal of riparian vegetation from streamside by Dunford and Fletcher (1947) in North Carolina, by Nanni (1972) in South Africa, and by Biswell and Schultz (1958) in California.

Streamflows increased in five small Oregon drainages where juniper cuttings were performed for understory release. Livestock were excluded from the treated drainages. Each drainage was reported to have undergone conversion from a dry, erosive, juniper-dominated valley to one containing a true riparian system. Increased release of groundwater was attributed to the juniper cuttings. At each site, extension of flows in both time and distance downstream occurred, and riparian vegetation also developed. Along one of these once intermittent drainages (Skull Hollow, Crooked River National Grassland, Oregon), perennial flow was present throughout a mile-long study area and for 0.3 miles downstream four years after treatment.

Livestock Grazing

Six years after fencing 7 miles of Willow Creek in the Crooked River National Grasslands in Oregon, flows changed from intermittent to perennial. While Willow Creek for 5 miles above and below the exclosure remained dry in the summer, there was perennial flow within the exclosure. Riparian vegetation recovered, but beaver had not constructed dams within the exclosure. Fencing of McMeen Springs and the creek below (a tributary to Willow Creek) also resulted in development of perennial flow. A similar finding was reported on Camp Creek in Crook County, Oregon. By 1974, 4 miles of Camp Creek had been fenced from cattle. As a result, dramatic increases in wildlife utilization, pronounced buildups of soil within the stream channel, and substantial increases in the amount of riparian vegetation occurred (Winegar 1977). During the droughts of 1977 and 1981, the West Fork of Camp Creek, which is the main source of flow in Camp Creek, became dry. Downstream, however, just within the exclosure, flow began and persisted for four miles and then disappeared just outside the exclosure. Camp Creek now supports fish and beaver, although none were present at the time of fencing.

Change from intermittent to perennial flow on three small, spring-fed Texas streams was observed after elimination of cattle grazing. Big game species were not removed. Riparian vegetation grew abundant at about the same general time that perennial flow developed. It is unknown if flow from springs increased.

DISCUSSION

The research studies that were located generally pre-date the development of modern concepts of streamflow generation from headwater catchments. Specifically, the principles of the variable source area concept (Sattlerlund 1972) have not been used to help interpret riparian water yield improvement research, although this research has almost exclusively been performed in headwater catchments.

Summer flow increases after small dam construction indicates that the potential for water storage and enhanced summer streamflow within small valleys is often unrealized. Enough water can be stored, as a result of a high density of dams, to provide enough water for increases in consumptive water use by riparian plants and for change from intermittent to perennial flow (Heede 1977, Jester and McKirdy 1966, Anon. 1979). By providing materials for debris jams, dams, and instream obstructions, woody riparian species may partly mitigate for water losses through high rates of transpiration during the growing season. Beaver often construct and maintain dams in areas where there would otherwise be few dams, because of the lack of woody debris of sufficient size and abundance to form instream obstructions. Wood brought to the stream by beaver may also later become part of instream obstructions.

Management geared to increase the number of dams on small, low flow streams may have good potential for summer flow augmentation, even in relatively humid areas as demonstrated by findings in Massachusetts (Wilin et al 1975). Small dams often have beneficial effects on fish and waterfowl and can improve watershed values by stabilizing stream channels and trapping sediment. As an alternative to removing woody riparian vegetation to improve water yield during the growing season, the placement of small dams in the channel is especially attractive from a fish and wildlife habitat maintenance standpoint.

The means by which small dam can increase summer streamflow may be postulated. Small dams may increase the size of the zone saturation, or the saturated wedge, contained within the valley bottom. The most striking change in streamflow reviewed, in which check dams installed in gullies of the Alkali Creek drainage resulted in changes from ephemeral flow to perennial flow (Heede 1977), may have been the result of creating a saturated zone within the sediment trapped behind check dams (Heede and DeBano 1984). Small dams may be especially effective in increasing summer flow in stream channels in which channel downcutting has occurred and resulted in a greatly reduced saturated wedge. Peterson (1950) reported that

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gullying on San Simon Creek, Arizona, was accompanied by change to ephemeral flow, and channel aggradation has occurred on several streams where summer streamflow increases have been reported (Winegar 1977, Anon. 1979). The possibility that channel downcutting itself may favor loss of summer flow, without change in climate, should be seriously considered.

The removal of nonriparian vegetation, such as chapparal or conifer, from streamsides and valley slopes near the riparian zone has resulted in increases in summer streamflow (Ingebo 1971, Rich and Thompson 1974, Rowe 1963). In several cases, removal of juniper has apparently resulted in the release of enough water to provide for developing riparian vegetation and change from ephemeral to perennial flow. These findings demonstrate that in some cases the presence of riparian vegetation is not the most important factor governing summer streamflow, and that nonriparian vegetation removal and conversion to grass may be a management alternative to riparian removal for summer streamflow augmentation in small streams (orders 1-4) which comprise over 85 percent of the stream mileage on a worldwide average (Windell 1971, Winegar 1977, Anon. 1979). The removal of nonriparian vegetation, such as chapparal or conifer, from streamsides and valley slopes near the riparian zone has resulted in increases in summer streamflow (Ingebo 1971, Rich and Thompson 1974, Rowe 1963). In several cases, removal of juniper has apparently resulted in the release of enough water to provide for developing riparian vegetation and change from ephemeral to perennial flow. These findings demonstrate that in some cases the presence of riparian vegetation is not the most important factor governing summer streamflow, and that nonriparian vegetation removal and conversion to grass may be a management alternative to riparian removal for summer streamflow augmentation in small streams (orders 1-4) which comprise over 85 percent of the stream mileage on a worldwide average (Windell 1971, Winegar 1977, Anon. 1979).

Advantages to this approach include increase in forage production through control of vegetation not likely to resprout. Disadvantages could include potential destabilization of valley slopes and in many cases the need to remove livestock for a short time after treatment.

It is hypothesized here that the downslope movement of water, or subsurface flow, can be intercepted and transpired by vegetation on valley slopes to a greater degree than presently believed, and that removal of deep-rooted valley slope vegetation can reduce transmission losses as water moves toward the saturated zone in valley bottoms. Diurnal fluctuations in downslope subsurface flow have been measured and are shown to correspond to diurnal fluctuations in streamflow (Burt 1979). During the day, movement of water was toward slope surfaces, and at night downslope movement of water towards the valley bottom augmented in small and Shultz (1958) reported that removal of deep-rooted vegetation upslope from springs resulted in immediate increases in spring flow. Although diurnal fluctuation in streamflow and water tables is often attributed solely to riparian evapotranspiration, vegetation on valley slopes may also play a role. Lewis (1961) reports that diurnal fluctuations in streamflow have been detected before the riparian growing season, and suggested evaporation from riparian zones may play a more important role in controlling streamflow than previously supposed. Diurnal fluctuations in the zone of saturation in response to diurnal fluctuations in subsurface flow could also explain this phenomenon, since valley slope vegetation can begin transpiring earlier in the year than woody riparian vegetation.

Studies involving removal of woody riparian vegetation have shown that summer streamflow can be increased as a result of removal of this vegetation alone, but that savings have been at most moderate. The best water savings after eradication of woody riparian vegetation yet achieved (Bowie and Ram 1968) amounted to 1.7 acre-feet of water saved per acre of the floodplain treated. This savings, however, represented less than half the total evapotranspirative water losses measured before treatment. After treatment, evaporation and transpiration by untreated vegetation amounted to over 50 percent of the total losses of water found prior to treatment. Substantial increases in evaporation loss were postulated (Bowie and Ram 1968).

Besides shading and maintenance of a moist microclimate, riparian vegetation provides structural materials for beaver dams and debris jams, and also the most important foods for beaver. Other suggested water-conserving functions of true riparian vegetation include building organic soils better able to retain soil moisture (Marcuson 1977), and stabilizing stream channels and prevention of channel degradation and loss of the water table. During overbank flows, riparian vegetation helps slow and spread flows and may encourage better streambottom aquifer recharge. Although removal of riparian vegetation may result in small increases in summer streamflow over the short term, the elimination of woody riparian vegetation and debris over the long term may result in eventual loss of summer streamflow, especially along stream reaches susceptible to gullying.

Livestock are seldom removed from large, intermittent stream sections where unexpected flow increases would be likely to be noticed visually. This may explain why more reports of streamflow increases after removal of livestock are not available. Mechanisms by which summer flow increase might result upon removal of livestock may be hypothesized. Combined utilization of riparian vegetation by beaver and livestock can lead to the virtual elimination of wood, beaver and their dams. Upon removal of livestock, beaver and woody riparian vegetation often reestablish. In gully situations, recovery of riparian vegetation may lead to channel aggradation, improved channel morphology, and improved storage capacity. Beaver may in turn help the situation by colonizing when more water and structural material becomes available. Removal of livestock may result in increased ground cover and reduced compaction in areas contributing to streamflow, resulting in increased infiltration and water storage. As the results from Willow Creek indicate, there may be unknown flow maintenance functions of the riparian zone which may come into play when livestock are removed.

Summer streamflow can be influenced by a large number of interacting factors within the areas contributing to streamflow in small valleys. Information reviewed suggests that riparian vegetation may not be as detrimental to summer streamflow maintenance as is generally supposed, and that there may well be, depending on the situation, management alternatives that would allow for both increasing summer flows and for maintaining or improving riparian zones and other values.

Without including ephemeral channels, small streams (orders 1-4) comprise over 85 percent of the stream mileage on a worldwide average (Windell 1980). Information reviewed, however, suggests
that the complexities of streamflow generation and maintenance in these streams during the dry season are not fully understood. Particularly where dry-season water is at a premium, improved knowledge of summer streamflow generation could be beneficial in many ways.

LITERATURE CITED


