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## MANAGEMENT OF EPHEMERAL STREAM CHANNELS<sup>a</sup>

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### INTRODUCTION

Almost all runoff from semiarid rangelands in the Southwest results from highly variable, intense, thunderstorm rainfall of a limited areal extent (3). Most stream channels are dry over 90% of the year, with occasional late afternoon and nighttime flows during the summer rainy season. For typical ephemeral stream channels on the USDA, ARS Walnut Gulch Experimental Watershed in southeastern Arizona, most of the water from occasional flows is infiltrated into the channel alluvium, often in relatively short reaches within the watershed. In the large channels, some of the infiltrated water may replenish ground-water storage, but for the channel system as a whole, it is mostly lost to evaporation from the channel surfaces, and transpiration from channel and bank vegetation. Management of this highly variable resource requires a knowledge of the amounts and distribution of water moving into, through, and out of a channel system, and a knowledge of potential changes in flood wave movement, peak discharge amounts and frequencies, durations and flow volumes, and channel equilibrium. Flood wave movement and possible changes in sediment transport resulting from the upsetting of channel equilibrium are particularly important upstream from populated areas where greater flood damage can occur.

In this paper, records from the Walnut Gulch Experimental Watershed are used to estimate losses in ephemeral channels and to estimate potential added usable water from a management of these channels. Added water yield is tied

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to general and specific management practices. Questions of management effects on channel equilibrium, and flood amounts and frequencies are considered. Estimates based on Walnut Gulch data are extrapolated to suggest the potential of ephemeral stream channel management in a river basin.

#### WALNUT GULCH EXPERIMENTAL WATERSHED

The Southwest Watershed Research Center of the Agricultural Research Service operates the 57.7-sq mile (148 km<sup>2</sup>) Walnut Gulch Experimental Rangeland

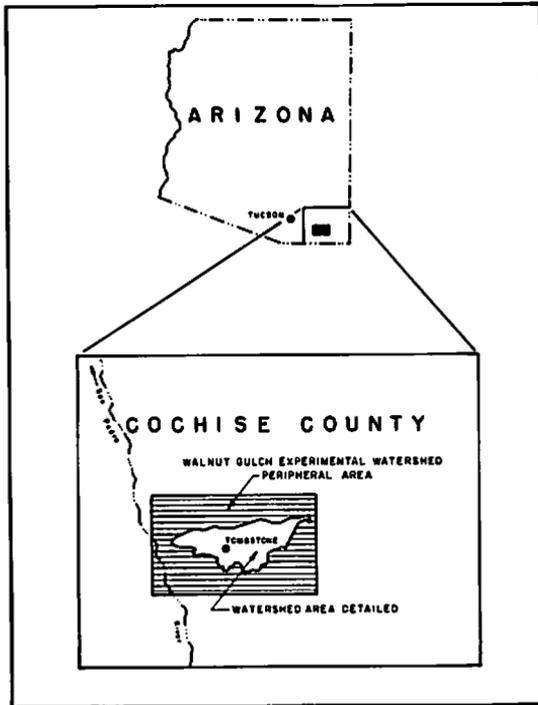


FIG. 1.—Location Map of Walnut Gulch Experimental Watershed in Southeastern Arizona

Watershed in southeastern Arizona (Fig. 1). There are 95 recording rain gages and 11 major runoff-measuring stations on the watershed. Channel abstractions are estimated from differences between runoff records from successive stations. The hydrologic research being performed includes the use of small plots for establishing rainfall-runoff relationships as well as the use of natural watersheds on various drainage area sizes with varying soil, vegetation, and geology to facilitate mathematical modeling of the total hydrologic cycle and various components. For a more detailed description of the hydrology of Walnut Gulch see Ref. 4.

#### CURRENT STUDIES

Some work has been done in increasing runoff from very small watersheds

for on site water uses such as stock watering. For example, the USDA Water Conservation Laboratory in Phoenix, Ariz., has developed several methods for collecting on site runoff. One method is to seal an area of several thousand square feet and collect runoff in stock watering tanks. Another is to construct lined ditches parallel to a very small channel to catch and collect runoff before it can be lost in the channel alluvium. This particular method has shown promise on a small scale, since runoff from extreme events simply overflows the lined ditches and runs down the natural channel, as would occur normally.

More has been done to estimate losses in the larger (greater than about 1-sq mile) ephemeral channels on Walnut Gulch, than in the far more numerous small channels. This is primarily because of the belief that the larger channels are more easily managed and also are more important in studies of flood wave movement and channel equilibrium.

Diskin and Lane (1) developed a stochastic model for individual runoff events for watersheds of 3 sq miles to 57.7 sq miles ( $8 \text{ km}^2$  to  $148 \text{ km}^2$ ) in which the distribution parameters used to describe the runoff are based on watershed characteristics, with drainage area by far the most significant parameter. They showed that while the number of runoff events increased for increasing watershed size, the unit runoff volume per storm decreased as watershed size increased. They also related the standard deviations of both the number of events and the storm volume to watershed size, and used these relationships to generate synthetic data having a temporal distribution described by the beginning of the runoff season, the interval between storm events, and the flow beginning time within a particular day.

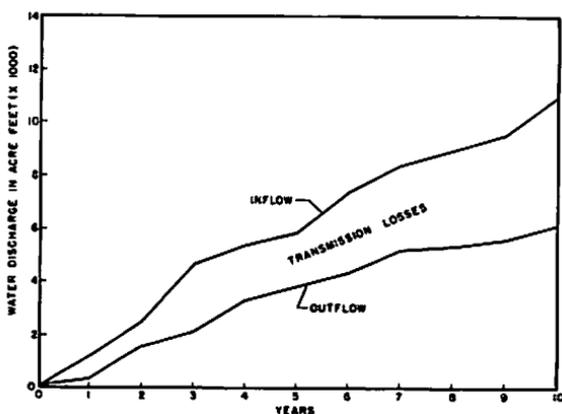


FIG. 2.—Cumulative Inflow and Outflow of Water in 36,200-ft Reach on Walnut Gulch (1 acre-ft =  $1,233 \text{ m}^3$ )

Ten years of inflow and outflow data for the 6.8-mile (11-km) channel reach on Walnut Gulch were generated by using the Diskin-Lane model, and the results are summarized in Fig. 2. The line labeled "inflow" was computed by totaling the discharge for each tributary to the reach, plus the inflow at the upper end of the reach. Outflow was that generated using the Diskin-Lane model for the outlet of the watershed. Thus, the difference between the two

graphs represents the cumulative absorption of the reach alluvium. The 480-acre-ft/yr (590,000-m<sup>3</sup>) average loss shown by this graph was highly variable, as might be expected.

If the statistics of the true population (actual data) are preserved by the synthetic data (an assumption for which there is no answer because of the many unmeasured tributaries), the loss represents about 13.3 acre-ft/1,000 ft of channel (5,400 m<sup>3</sup>/100 m of channel)/yr. In an average channel width of 100 ft (30 m), the loss represents about 3.8 ft (1.2 m) of water per unit area wetted per year.

### POTENTIAL SALVAGEABLE WATERS

Two types of ephemeral channels could be managed so as to increase the water yield. The first and most numerous type is the very small (possibly 1st or 2nd order) channels in which flows are very brief (often less than 1 hr), and from which almost all infiltrated water is subsequently lost to evaporation or transpiration. In other words, water abstracted in these channels is truly lost and does not reach ground-water storage. Although very small, these channels generally have considerable coarse alluvium and abstract significant amounts of water because of the large numbers of such channels.

The second type includes the channels with deep alluvium where some of the infiltrated water may reach ground-water storage and, therefore, may be a potentially usable water source. This type of channel can be subdivided into reaches with possible deep percolation and those without. Obviously, the fraction of water reaching storage varies widely within and between channel reaches, primarily because of geologic differences along the channel perimeter. Knowing which reaches or what conditions best support ground-water recharge is necessary to determine whether a specific reach should be managed.

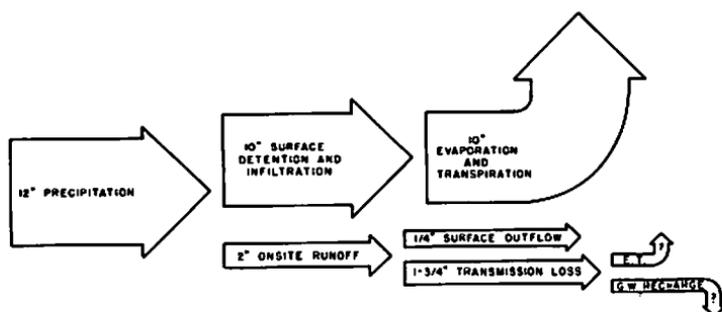


FIG. 3.—Water Balance of 57.7-sq mile (148-km<sup>2</sup>) Walnut Gulch Watershed (1 in. = 25.4 mm)

Managing the numerous small channels may be potentially less profitable because of the probable high treatment costs. These channels do, however, dramatically affect the water yield of an area and must be considered in management studies.

For example, Renard (4) showed that the average annual runoff per unit area for Walnut Gulch decreases with increasing area, according to

$$Q = 1.54 A^{-0.151} \dots \dots \dots (1)$$

in which *A* = the drainage area, in acres; and *Q* = the annual runoff, in inches. He further indicated that the hydrologic balance (as shown in Fig. 3) of the 57.7-sq mile (148-km<sup>2</sup>) Walnut Gulch watershed results in an average transmission loss of 1-3/4 in. or 5,400 acre-ft/yr (44 mm or 6,700,000 m<sup>3</sup>).

If annual runoff losses in the lower 6.8 miles (11 km) (the most likely recharge channel) are about 480 acre-ft (590,000 m<sup>3</sup>), then theoretically, about 4,900 acre-ft (6,100,000 m<sup>3</sup>) are available for recovery by management of the other channels within the watershed. Losses are divided roughly between those in the very small (1st and 2nd order on a Horton-Strahler type analysis) and those in the small to intermediate channels (3rd and 4th order). The 4,900 acre-ft (6,100,000 m<sup>3</sup>) of water is lost to the atmosphere and is not a usable resource at this time. Obviously, this is an oversimplification, since some of the water goes to sustain plant growth, which indirectly reduces erosion rates and flood damage. The deeper question, of course, is how channels can be managed so they can increase water yield or change water use without damaging or critically changing the delicate ecological balance of the arid rangelands. Also, the management must be economical, which necessitates a practical approach.

**POTENTIAL OF CHANNEL SEALING**

The possibility of sealing selected reaches of alluvial channels to increase water supply for downstream surface and ground-water storage in such arid and semiarid regions as southern Arizona has been considered for years. However, so little is known about channel equilibrium and ground-water recharge that schemes for sealing channels have been largely speculative.

Recently, a new sealant for coarse materials was used on an experimental scale at Walnut Gulch. The cost of the sealant in place for a minimum treatment is advertised at about 10¢/sq yd (11¢/m<sup>2</sup>) or \$480/acre (\$1,200/ha), but the cost for adequate sealing of the coarse alluvial channels, such as are on Walnut Gulch, may be two to three times greater.

If about 2 acre-ft (2,500 m<sup>3</sup>) of water were saved per acre of channel sealed, the cost on a 1-yr basis would range from about \$250/acre-ft to \$750/acre-ft (\$200/m<sup>3</sup> to \$600/1,000 m<sup>3</sup>) of water. Obviously, if the method is to have any value, the sealant must last for some years. At present, the life of the sealant is unknown. If, the sealant lasts for 10 yr, the cost per acre-foot of water salvaged, amortized at 5% for a 10-yr life, would be between \$40 and \$120 (\$32 and \$100 per 1,000 m<sup>3</sup>). At present, most urban communities obtain water for considerably less. Thus, even with a 10-yr life, this sealant probably is not economically feasible. However, these rough estimates do suggest that channel sealing may be a feasible alternative for satisfying increased urban water needs in the Southwest and other arid lands in the near future, since the cost of water is rising rapidly in regions where less expensive sources of water are being depleted.

Furthermore, the preceding figures may be somewhat conservative. Most watersheds, including Walnut Gulch, contain some channel reaches with perma-

nent impervious layers or rock near the surface and would not need sealing. Sealing reaches that offer the best returns could increase the amount of water saved per dollar.

#### **INCREASED FLOOD POSSIBILITY**

Because the greatest potential for management of ephemeral channels appears to be increased water supply for downstream urban use, the possibility that such management would increase flooding must be considered.

Many small and medium-sized runoff events that would normally be lost or nearly lost in the channels would be expected to reach the watershed outlet. There would be more flows and a greater runoff volume from the small and medium-sized flows. Obviously, downstream water users would need to be prepared to store greater volumes of water, because such a project would explicitly increase runoff.

Sealing channels would have little effect on major peak discharges. For extreme events, essentially all channel abstractions are accounted for in the rising limb of the hydrograph. Therefore, although runoff volumes would be significantly greater, maximum peak discharges probably would not be.

The extreme events in arid lands move the largest volumes of sediment. Since channel sealing would not appreciably increase the extreme peaks, increased reservoir sedimentation may not be as important a deterrent to increasing runoff as was initially believed. Also, overbank flooding would not increase. However, degradation downstream from the sealed channel may be significantly greater. Therefore, more study is needed on the problems of channel stability and sediment transport before such a program is realized.

#### **MANAGEMENT POTENTIAL FOR RIVER BASINS**

Estimates of potential usable water from Walnut Gulch were extrapolated for the San Pedro River Basin. There are 2,870 sq miles (7,450 km<sup>2</sup>) of drainage between Palomas on the Mexican border, and Mammoth near the confluence with the Gila River. On the assumption that Walnut Gulch is typical of most of this drainage, and that 4,900 acre-ft (6,100,000 m<sup>3</sup>) of water theoretically could be saved from that 57.7-sq mile (148-km<sup>2</sup>) watershed, more than 200,000 acre-ft/yr ( $2.5 \times 10^8$  m<sup>3</sup>/yr) would be available for salvage in basin channels. This estimate excludes the lower reaches of Walnut Gulch and similar watersheds where enough of the abstractions reach ground-water storage to preclude management until more is known about deep percolation in the relatively wide and deep alluvial channels. At present, the 2,870 sq miles (7,450 km<sup>2</sup>) produce about 20,000 acre-ft/yr ( $2.5 \times 10^7$  m<sup>3</sup>/yr) of surface flow in the San Pedro Basin, or about 1/10 the potential added water.

As previously mentioned, the losses above the lower 6.8-mile (11-km) reach on Walnut Gulch are about evenly divided between that from the very small channels (1st and 2nd order) and that from the small to intermediate channels (possibly 3rd and 4th order). The small to intermediate channels have the greatest potential for management to increase yield. The potential is something over 100,000 acre-ft/yr ( $1.25 \times 10^8$  m<sup>3</sup>/yr) for about a 3,000-sq mile (7,800-km<sup>2</sup>) drainage.

Obviously, there is variability between and within basins in the Southwest. However, Osborn (2) pointed out the high correlation between summer rainfall and annual runoff in the San Pedro Basin, and similar correlations exist for other arid and semiarid drainages. These correlations could be used to transfer results from Walnut Gulch and the San Pedro River Basin to other southwest basins with a reasonable degree of confidence.

As is the case of Walnut Gulch, sealing selected tributary reaches of the San Pedro River would increase the number and volume of summer flows and, most likely, increase winter ground-water flow, but should have little effect on the extreme peaks from the widely scattered, summer thunderstorms. The chance of winter runoff would be greater as well, but winter storms, although covering larger areas, are relatively low-intensity events and runoff would most likely be lost in the unsealed lower reaches of the tributaries. In fact, the principal effect of sealing on winter runoff might be to increase ground-water recharge by supplying more water to the recharge reaches of the tributaries during periods when the channels are almost always dry, and when potential evaporation and transpiration are low.

#### CONCLUSIONS

Sealing of ephemeral channels to increase the downstream water supply does not appear economically feasible at this time for semiarid regions such as the Southwestern United States. However, estimated costs for potential increases in water supply from channel sealing suggest that sealing may be feasible, or at least should be considered as an economic alternative, for meeting growing urban water demands in the Southwest in the future. The potential water yield increase by selective channel sealing for a 3,000-sq mile (7,800-km<sup>2</sup>) drainage area appears to be over 100,000 acre-ft ( $1.25 \times 10^8$  m<sup>3</sup>), with the cost depending primarily on the effective life of the sealant. For this reason, investigations of management methods and potentials for ephemeral channels are continuing.

Preliminary studies of the effects of ephemeral channel sealing on channel equilibrium, sediment transport, and flood frequencies and magnitudes suggest that sealing may not have the adverse effects that were once feared, but further studies are needed and are continuing in these areas.

#### ACKNOWLEDGMENT

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#### APPENDIX.—REFERENCES

1. Diskin, M. H., and Lane, L. J., "A Basinwide Stochastic Model for Ephemeral Stream Runoff in Southeastern Arizona," *International Association of Scientific Hydrology Bulletin*, Vol. 17, No. 1, Apr., 1972, pp. 61-76.
2. Osborn, H. B., "Comments by a Hydrologic Engineer on Cloud Seeding in Arizona," *Proceedings, Third National Conference on Weather Modification*, Rapid City, S.D., June, 1972.
3. Osborn, H. B., and Hickok, R. B., "Variability of Rainfall Affecting Runoff from a Semiarid Rangeland Watershed," *Water Resources Research*, Vol. 4, No. 1, 1968, pp. 199-203.

4. Renard, K. G., "The Hydrology of a Rangeland Watershed," *ARS-41-162*, United States Department of Agriculture, 1970, pp. 26.

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**KEY WORDS:** Drainage; Ephemeral streams; Flood peaks; Hydrology; Irrigation; Runoff; Small watersheds; Transmission loss; Watershed management

**ABSTRACT:** Most runoff from small arid land watersheds in the Southwest is abstracted by ephemeral channels before reaching perennial streams. Some of the abstracted water reaches ground-water storage, but most is lost to evaporation and transpiration. Records from the USDA-ARS Walnut Gulch Experimental Watershed in Southeastern Arizona are used to estimate channels abstractions and to provide estimates of potential added usable water for increased downstream urban water demands. Estimates of salvageable water based on Walnut Gulch data are extrapolated to suggest the potential of ephemeral channel management in a river basin, and questions of management effects on channel equilibrium, sediment transport, and flood frequency and magnitude are considered.

**REFERENCE:** Osborn, Herbert B., and Renard, Kenneth G., "Management of Ephemeral Stream Channels," *Journal of the Irrigation and Drainage Division, ASCE*, Vol. 99, No. IR3, Proc. Paper 10005, September, 1973, pp. 207-214