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Evapotranspiration losses from flood plains in the Agua Fria River drainage above Lake Pleasant, Arizona

By

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EVAPOTRANSPIRATION LOSSES FROM FLOOD PLAINS IN THE AGUA FRIA RIVER DRAINAGE ABOVE LAKE PLEASANT, ARIZONA

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ABSTRACT

The present (1970) evapotranspiration losses under the natural flow regimen and the maximum possible losses under an assumed perennial flow regimen that might result from upstream vegetation modification were estimated for the flood plains of the Agua Fria River and Humbug Creek above Lake Pleasant in central Arizona. The estimates were based on the relation between water use by mesquite, grasses, and bare soils and the depth to ground water. The estimated maximum annual consumptive-use rate is 48.5 inches in the lower reaches of the Agua Fria River. The estimated maximum possible water loss in the study reach of the Agua Fria River is about 8,900 acre-feet; about 5,500 acre-feet is being lost under present (1970) conditions. In the Humbug Creek reach, the present (1970) average annual loss is about 250 acre-feet, and it is possible that the loss may increase to about 680 acre-feet.

INTRODUCTION

Purpose and Scope of Investigation

In recent years many research projects have been undertaken to determine the probable or actual increase in runoff as a result of vegetation modification. The increase in runoff generally is measured at the downstream end of the test reach. Before any of the additional water can be used beneficially, it generally must travel some distance to a down stream storage and diversion system, and the increase in flow may be depleted gradually in the downstream direction, owing to an increase in use by plants or an increase in evaporation. Streamflow losses between the point of entry and the point of use of the water may be sufficiently large to affect seriously the benefit-cost ratio of vegetation-modification schemes.

The purpose of this investigation was to estimate the increase in transitory water losses that might occur in a part of the Agua Fria River drainage as a result of an increase in runoff expected from a proposed vegetation-modification program. Estimates were made of the existing evapotranspiration losses and of the possible increase in evapotranspiration losses assuming the maximum possible loss situation. The estimated increase in evapotranspiration losses may be compared with the anticipated increase in water yield as a result of proposed vegetation modification to assist in determining the feasibility of a vegetation-modification program.

An increase in losses from the system will be largely the result of increases in evaporation or evapotranspiration in response to shallower ground-water levels. The method of estimating the increase in losses is based on the relation between water use and the depth to ground water for soils and vegetation typical of those along the stream channels in the Agua Fria drainage. The evapotranspiration estimates were made by multiplying the area covered by vegetation by the average water use. The estimate of the increase in water loss was based on empirical data; therefore, the values can be considered only as approximations.

The vegetation-modification program is only in the discussion stage, and, therefore, a test reach has not been selected for treatment. For this study, loss estimates were made for the main stem of the drainage system—the Agua Fria River—from the gaging station at Sycamore damsite downstream to Lake Pleasant, a distance of 44.2 miles. Estimates also were made for Humbug Creek, which drains part of the south slope of the Bradshaw Mountains and flows directly into Lake Pleasant. Humbug Creek drains an area that is typical of those being considered for vegetation modification, and the stream is typical of the other streams that drain the Bradshaw Mountains and are tributary to the Agua Fria River.

Physical and Geological Setting

The Agua Fria River flows generally from north to south (fig. 1), and above Lake Pleasant the drainage area is 1,459 square miles, most of which is in Yavapai County in central Arizona. Waddell Dam and Lake Pleasant are the diversion and storage system for flow in the Agua Fria River; the water is used for irrigation within the Maricopa County Municipal Water Conservation District No. 1.

The Agua Fria River drainage basin is elongated in a north-south direction and is about 25 miles wide and 60 miles long. The river is near the central axis of the basin and is about 80 miles long within the area. The altitude of the drainage basin ranges from about 8,000 feet above mean sea level in the Bradshaw Mountains to about 1,600 feet at Lake Pleasant. In the Agua Fria River drainage basin the amount of precipitation varies greatly and generally increases with altitude; the average annual precipitation ranges from about 12 inches at the lower altitudes to as much as 28 inches at the highest altitudes (U.S. Weather Bureau, issued annually).

(PAGE 6 FOLLOWS)

At the present time (1970), only a small amount of water is used for domestic and agricultural purposes in the drainage basin. The amount of land under cultivation above Lake Pleasant probably is less than 1,000 acres, and most of the irrigation water is pumped from the ground-water reservoir. Water for domestic and stock use also is supplied by wells.

Geologically, the drainage basin may be divided into eastern and western parts. Along the west side of the area, the Bradshaw Mountains are composed mainly of Precambrian granite and schist. Topographically, the west part of the area is very rugged and has deep canyons and steep slopes. Gold and silver mining have been extensive in the area. In the eastern part of the area, the surface material is mainly basaltic lava flows and associated rocks of Quaternary and Tertiary age underlain by Precambrian granite and schist. The area contains many broad gently sloping mesas separated by deeply incised steep-sided canyons. The Agua Fria River has cut a trench as much as 1,000 feet deep through the volcanic rocks into the Precambrian granite and schist. Although the unconsolidated alluvial deposits along the streams are small in areal extent, the deposits constitute the principal areas for an increase in streamflow losses because they have the capacity to store additional water and have large stands of phreatophytes. The deposits may form small discontinuous pockets or large alluvial areas. The unconsolidated alluvium is composed of thin layers of sand and gravel deposited in depressions in the hard rock.

Drainage Network and Streamflow

The flow in the Agua Fria River, the principal stream in the basin (fig. 1), has been measured at Sycamore damsite since 1940 and has been estimated at Lake Pleasant on the basis of changes in storage since 1934. Streamflow data for the Sycamore damsite are published annually by the U.S. Geological Survey as Agua Fria River near Mayer, Ariz. The flow measured at the Sycamore damsite is the total outflow from the 588-square-mile area above the gaging station and includes the tributary flow from Ash, Sycamore, and Big Bug Creeks, which are just above the gaging station. In the summer, flow at the Sycamore damsite is mainly from ground water; downvalley ground-water flow discharges at the hard-rock outcrop about 4 miles upstream from the gage. The Agua Fria River flows year round at the gaging station, except during prolonged dry periods or when all the flow is being diverted for irrigation.

In the reaches downstream from the gaging station to a point near Black Canyon City, the Agua Fria River flows through a deep canyon cut in basalt, and tributary inflow is small. The tributary drainage in this area is characterized by broad relatively flat mesas and deeply incised canyons that generally drain to the west. Squaw Creek is tributary to the Agua Fria River in the area where the river leaves the confines of its canyon and enters the alluvial area at Black Canyon City. This 3-mile reach of the river is of prime concern because it has the greatest potential for an increase in evapotranspiration losses. During times of low flow in the upstream and downstream reaches, there is no streamflow in the 3-mile reach; the periods of no flow usually occur when the base flow at the Sycamore damsite gage declines to about 3 cfs (cubic feet per second) and there is no tributary inflow in the intervening reach. Farther downstream, the downvalley ground-water flow again discharges at a bedrock outcrop at the old highway bridge at Black Canyon City.

Below Black Canyon City, the Agua Fria River is joined by Black Canyon Creek, an ephemeral stream that drains the east slopes of the Bradshaw Mountains. In the reach downstream from this junction to Lake Pleasant the Agua Fria River is perennial, except in a few segments where relatively wide or deep deposits of sand are present. The major tributary to the Agua Fria River is Boulder Creek, an ephemeral stream that drains part of the south slopes of the Bradshaw Mountains. Boulder Creek joins the Agua Fria River about 13 miles upstream from Waddell Dam.

The rest of the area is drained by Castle and Humbug Creeks; the creeks are ephemeral and flow directly into Lake Pleasant. Castle Creek drains a desert-shrub area southwest of the Bradshaw Mountains, and Humbug Creek drains an area on the south slopes of the Bradshaw Mountains. The upper part of the Humbug Creek watershed, which is in the chaparral zone, is being considered for vegetation conversion.

Humbug Creek is typical of the major streams that drain the east and south slopes of the Bradshaw Mountains—Turkey and Poland Creeks, which join Black Canyon Creek, and Boulder and Humbug Creeks. The streams extend from near the tops of the mountains into the desert zone and pass through all vegetation zones. The streams have relatively steep gradients and flow over hard rock and scattered pockets of sand and gravel. Humbug Creek flows over hard rock for almost its entire length. The hard rock is granite in the upper reach and tightly cemented conglomerate in the lower reach. Although small pockets of sand and gravel are interspersed throughout the channel, most of the ground-water storage and most of the phreatophyte growth occur in the alluvial area just above Lake Pleasant. The base flow of Humbug Creek is of short duration, and the creek is dry throughout most of its channel during most of the year.

Vegetation

The vegetation in the Agua Fria drainage basin has been grouped into four classes—ponderosa pine and mixed conifer, chaparral, pinyon-juniper, and semidesert shrub (U.S. Forest Service, 1968). The chaparral-covered areas are of principal interest in the vegetation-modification scheme because, through the conversion of chaparral to grassland, these areas probably have the greatest potential for an increase in water yield.

Any increase in water yield that may be derived from vegetation modification may be decreased by use by riparian vegetation during the conveyance of the water between the point of entry into the stream and the storage site. Along the Agua Fria River and its major tributaries, the dominant riparian vegetation is mesquite; many other species of phreatophytes are interspersed among the mesquite, such as saltcedar, willow, arrow-weed, catclaw, cottonwood, and miscellaneous weeds and grasses. Dense stands of mesquite are common along the lower reach of the Agua Fria River above Lake Pleasant because abundant water is available at shallow depths. Increases in evapotranspiration losses may occur in these areas; however, the present (1970) losses may be nearly equal to the potential evapotranspiration losses.

METHOD OF ESTIMATING INCREASES IN STREAMFLOW LOSSES

The anticipated increase in water yield owing to vegetation modification may result in downstream increases in evaporation and plant transpiration because of a shallower ground-water supply in the flood plains of the Agua Fria River and Humbug Creek. The additional evapotranspiration losses were estimated on the basis of the differences between the natural conditions and an assumed environment of perennial flow in the study reaches and shallow ground-water levels in the flood-plain areas. The greatest increase in evapotranspiration losses will occur in places where, under present conditions, the stream is not perennial and where ground water is relatively deep during part of the year. The differences were estimated on the basis of the relations between water use by vegetation and the depth to ground water along the Agua Fria River. The increases in evapotranspiration losses were estimated for three classifications of areal vegetation density: (1) vegetation converted to 100 percent areal density, (2) bare soil, and (3) open water surfaces and saturated soil.

For purposes of discussion and analysis, Humbug Creek and the Agua Fria River were divided into six reaches (fig. 1). Humbug Creek was divided into two reaches; reach 1 extends from Lake Pleasant upstream to the mouth of Cow Creek, a distance of 4 miles, and reach 2 continues upstream from Cow Creek to a point near the Prescott National Forest boundary, a distance of 12.7 miles. The Agua Fria River was divided into four reaches. Reach 1 extends from Lake Pleasant to above the mouth of Boulder Creek, a distance of about 8 miles; reach 2 continues upstream from Boulder Creek to the bedrock outcrop at the old highway bridge at Black Canyon City, a distance of 9.5 miles; reach 3 includes all the alluvial area and extends from the highway bridge to above the mouth of Lousy Canyon, a distance of 8.7 miles; and reach 4 is the remaining 18.0 miles upstream to the gaging station at Sycamore damsite.

The flood plains were mapped using aerial photographs. Temporal variations in the flow regimen in Humbug Creek and the Agua Fria River were documented at frequent intervals, and changes in depth to ground water were measured or estimated in places where the streams did not flow during part of the year.

Flood-Plain Mapping

The area that may be affected by an increase in streamflow was mapped using aerial photographs at a scale of 1:16,000 or 1 inch equals about a quarter of a mile. Data for the land areas of the three classifications of areal vegetation density were determined from these photographs, which were taken in the summer of 1968.

The areal density of vegetation was estimated from the photographs as dense, medium, or light. The term "areal density" is used to define the percent of surface area covered or shaded by the plant canopy in relation to the total area; dense represents 100 percent coverage; medium, about two-thirds coverage; and light, about one-third coverage. The percent of vegetative cover multiplied by the area converts the total area into two corresponding partial areas—one of 100 percent areal vegetation density and one of bare soil. (See table 2 for results of vegetation mapping.)

Temporal Flow Characteristics

The primary factor that will limit the increase in water loss that may occur if streamflow is increased is the degree of change that may occur in the flow regimen in a particular segment of the stream channel. Little or no change will occur in the segments that have year-round flow. About 70 percent of the study reach of the Agua Fria River contains flow in late summer, and 100 percent contains flow in the winter. At times as little as 5 percent of the study reach of Humbug Creek contains flow; at other times, there is flow throughout the reach.

The 3-mile segment of alluvial channel in reach 3 of the Agua Fria River is the first place where streamflow will cease during the year. The dry segment extends upstream slowly with time as the flow into the reach diminishes. Figure 2 shows the percent of each reach of the Agua Fria River that contains streamflow during an average year. The data were averaged for the period March 1968 to April 1970 and indicated two recession periods. In 1968, a year of relatively high runoff, the first cessation of streamflow was in late June, but in 1969, a year of low runoff (table 1) the cessation of flow occurred in early May; little variation in flow occurred during the other parts of the period.

Variations in the flow regimen of Humbug Creek are greater than those in the Agua Fria River (fig. 3), and flow ceases in most of the study reach in May. In the two recession periods, flow ceased in late May 1968 and in early May 1969. Flow in the large alluvial area in reach 1 is dependent almost entirely on rainfall at the higher altitudes; flow ceased in early May, and this part of the reach remained dry until the following December or January. The upstream end of reach 1 contains flow the year round. Several springs are present in this area, and the flow is probably from local ground-water discharge.

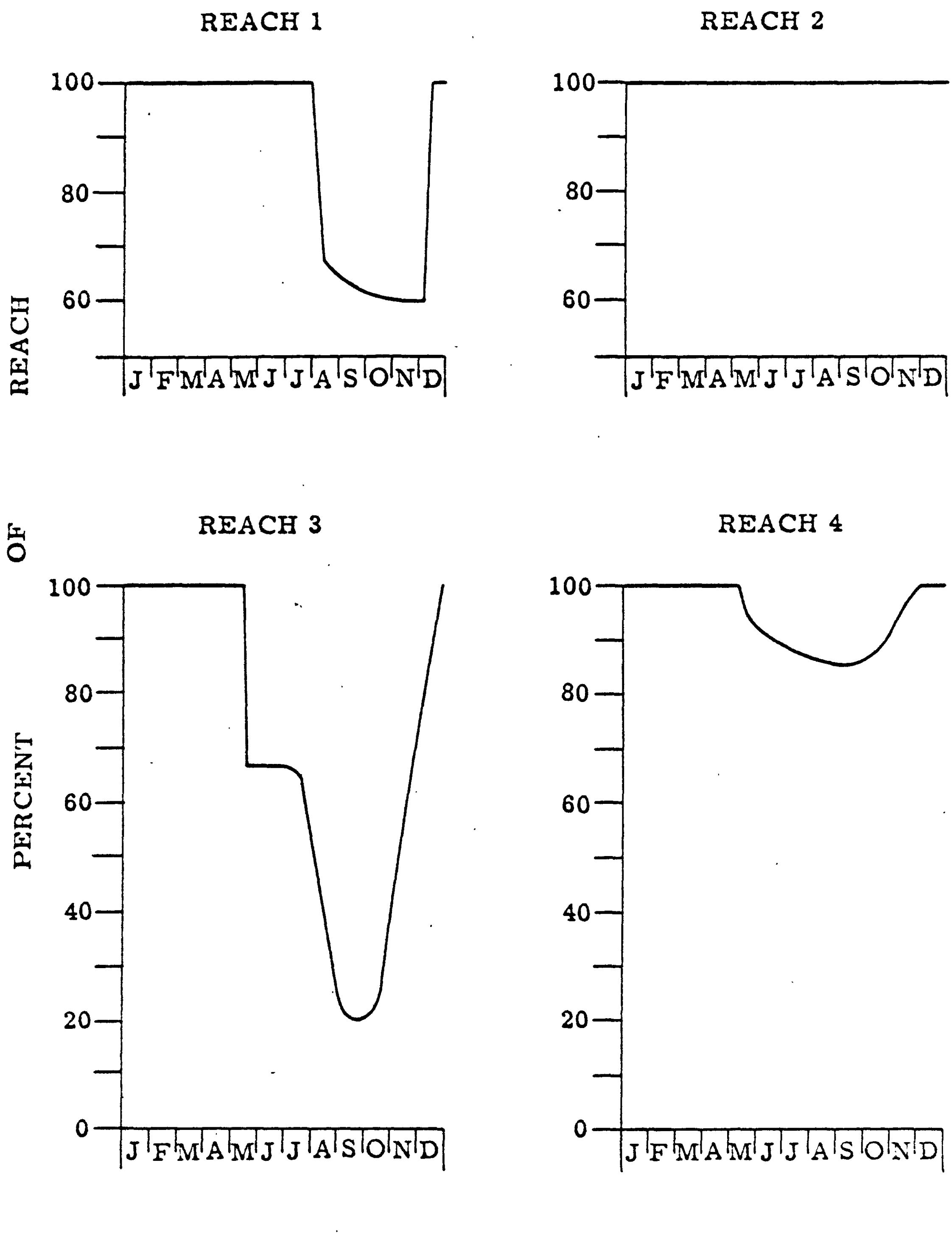


Figure 2.--Percent of the study reach of the Agua Fria River that contains flow during an average year.

Table 1.--Comparison of streamflow for 1968-69 water years with the average for the period of record, Agua Fria River

[Data from U.S. Geological Survey, issued annually]

Station name	Period of record	Streamflow (in acre-feet per year)		
		Average for period of record	1968 Water year	1969 Water year
Agua Fria River near Mayer, Ariz.	1940-69	11,950	28,730	5,190
Agua Fria River at Waddell Dam, Ariz.	1914-19, 1933-69	61,610	107,100	29,300

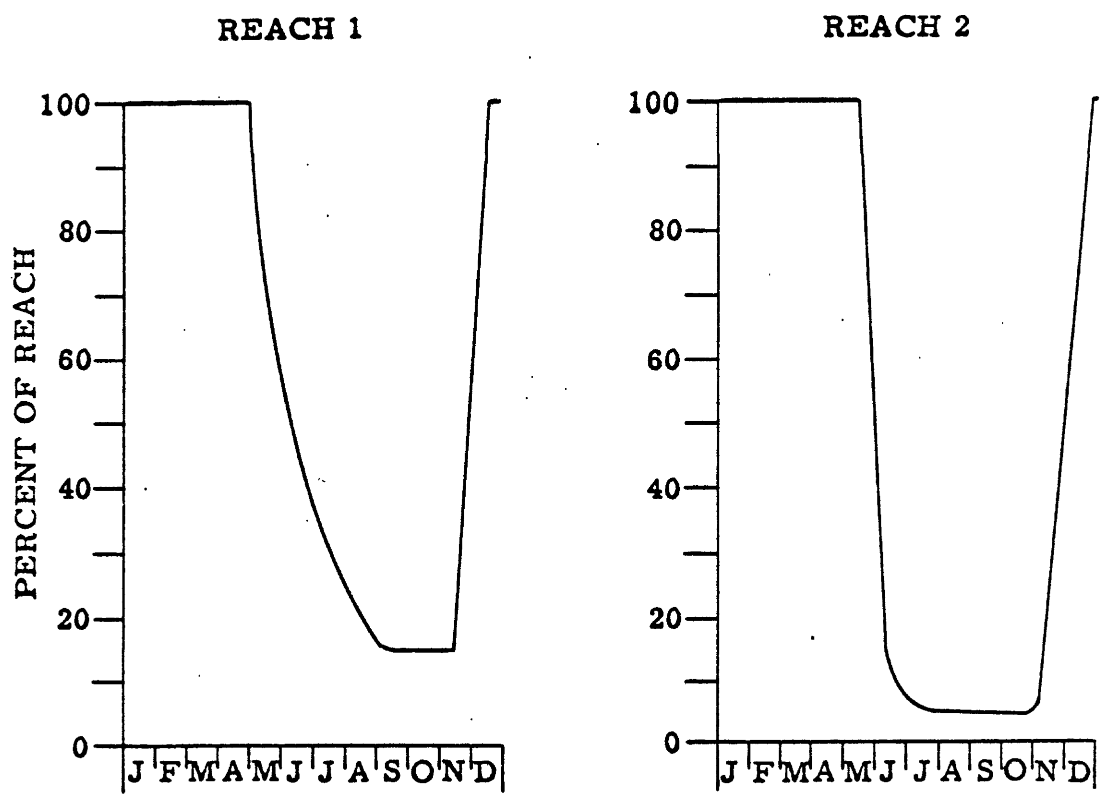


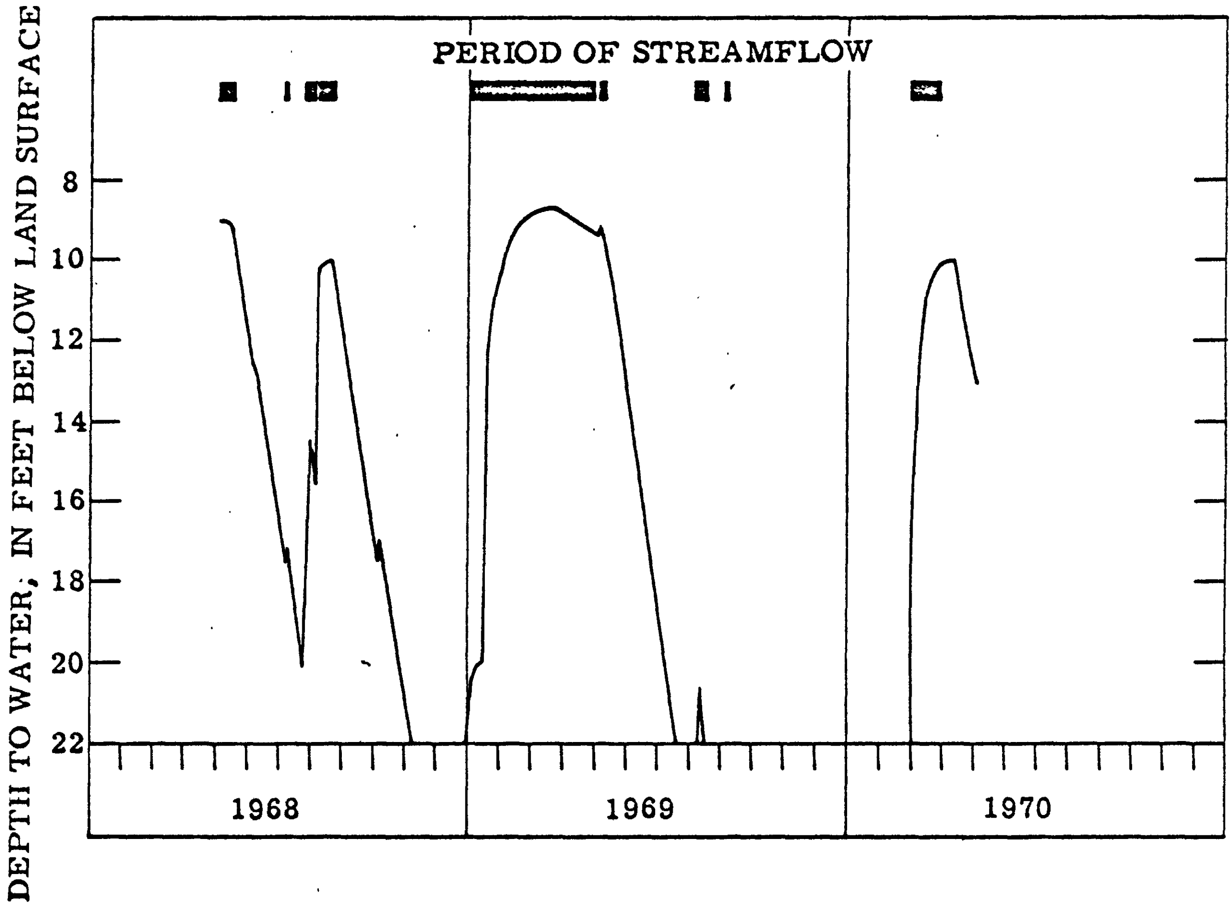
Figure 3. --Percent of the study reach of Humbug Creek that contains flow during an average year.

Depth to Water in Alluvial Areas

The possible increase in evapotranspiration is greatest in the areas where the channels do not contain streamflow during at least part of the year. In the alluvial area along the Agua Fria River at Black Canyon City the depth to water ranges from zero to more than 50 feet. A well was drilled recently in the alluvial deposits about 150 feet from the river; water-level measurements show that the depth to water decreased from 29 to 17 feet below the land surface in response to streamflow. Figure 4 shows the relation between depth to ground water in the alluvial area at Black Canyon City and streamflow in the Agua Fria River. The ground-water reservoir in the alluvial pocket fills and drains rapidly in response to runoff. The water levels in the alluvial area along Humbug Creek respond to streamflow in a similar manner; in this area water levels as much as 73 feet below the land surface have been measured in late summer.

Consumptive Use of Water by Riparian Vegetation

The use of ground water through evapotranspiration by a particular plant species is dependent on many factors, such as chemical quality of the ground water, chemical and physical characteristics of



NOTE: Depth to water measured in an abandoned domestic well 30 feet from the Agua Fria River in the SE-1/4SE-1/4NE-1/4 sec. 28, T. 9 N., R. 2 E. Well depth, 22 feet

Figure 4.--Relation between depth to ground water and streamflow, Agua Fria River study reach.

the soil, climatic factors, areal density of plants, and depth to ground water. The factors considered to be the most important in this study were areal density and depth to water; the other factors were assumed to be the same as when the empirical data were determined.

The vegetation along the Agua Fria River and Humbug Creek is primarily mesquite. Based on the meager amount of data available, the relation between water use by mesquite and depth to ground water has been estimated (fig. 5); use of water by plants through evapotranspiration is greatest where the ground water is at shallow depth and decreases as the depth to water increases.

In addition to the water used by mesquite, some water is used by grasses and weeds along the stream channels, and some water losses occur by direct evaporation from bare soil and open water surfaces. Relations between water use by grasses and bare soil and depth to water were developed to give estimates of present and future losses. The curves on figures 6 and 7 were drawn using lysimeter data from areas where conditions are similar to those in the Agua Fria River and Humbug Creek drainage basins.

The use of water by riparian vegetation varies greatly with time and is dependent mainly on depth to ground water. The growing season for mesquite is from May through October, and the greatest

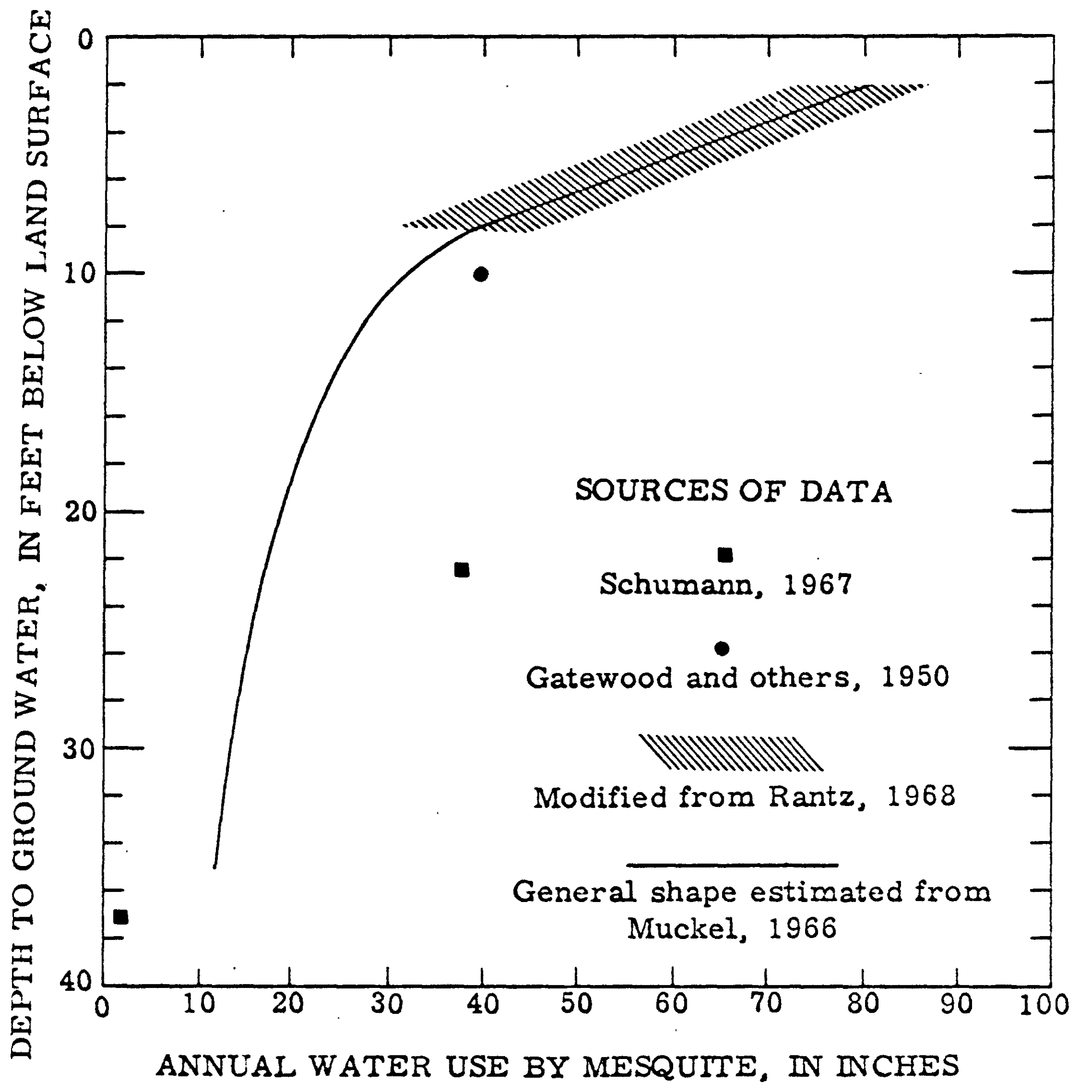


Figure 5.--Estimated relation between depth to ground water and annual water use by typical mesquite.

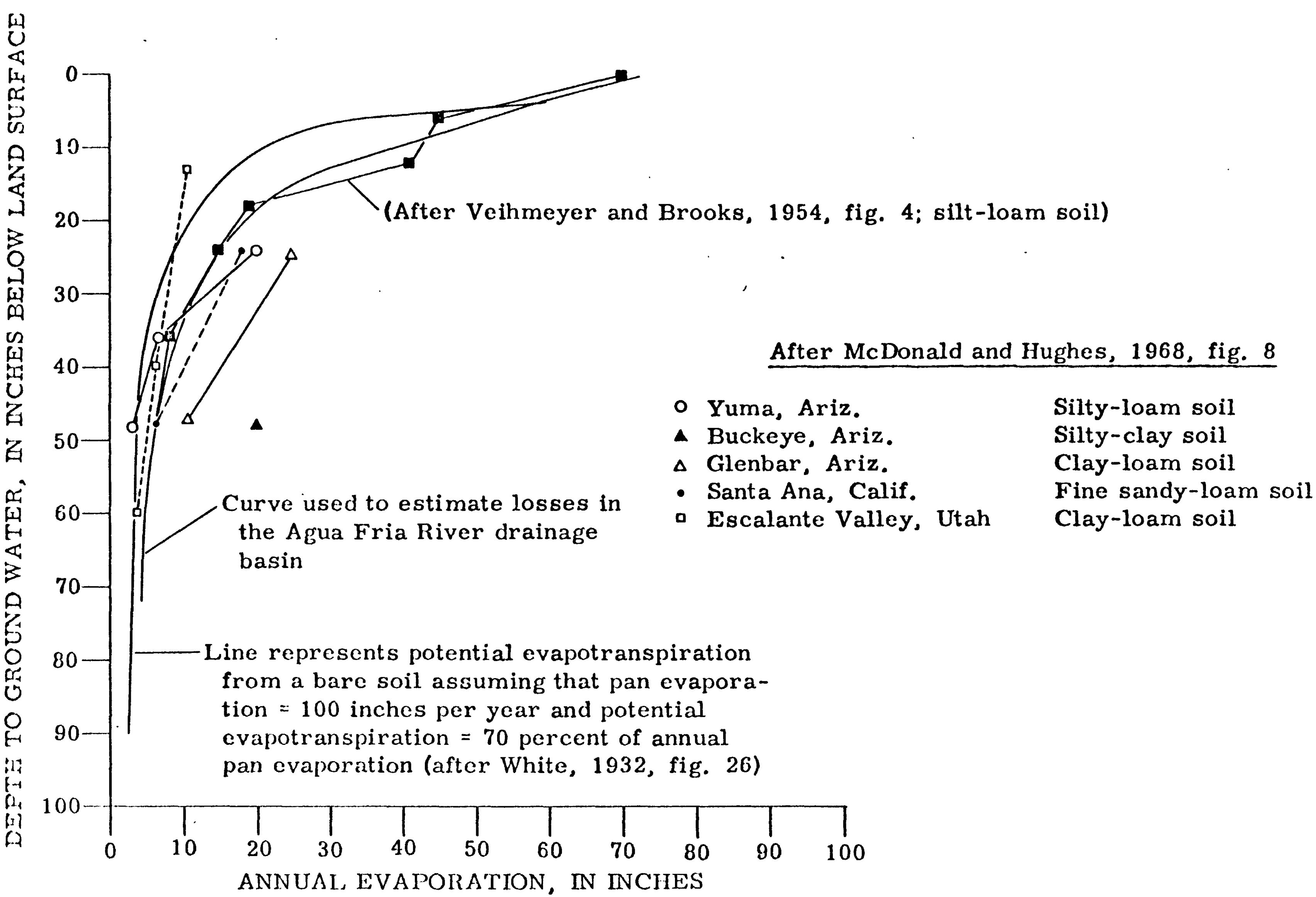
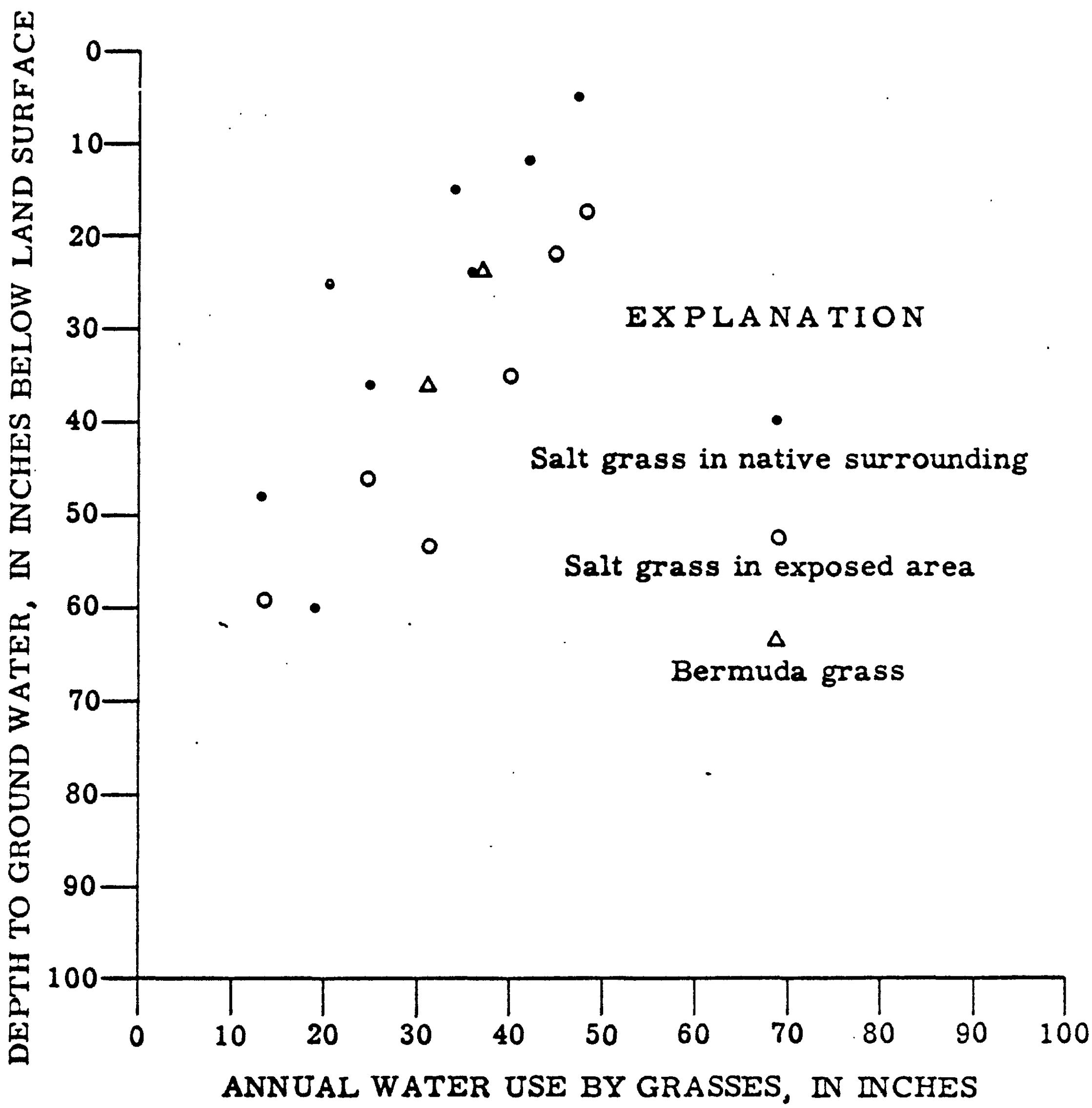


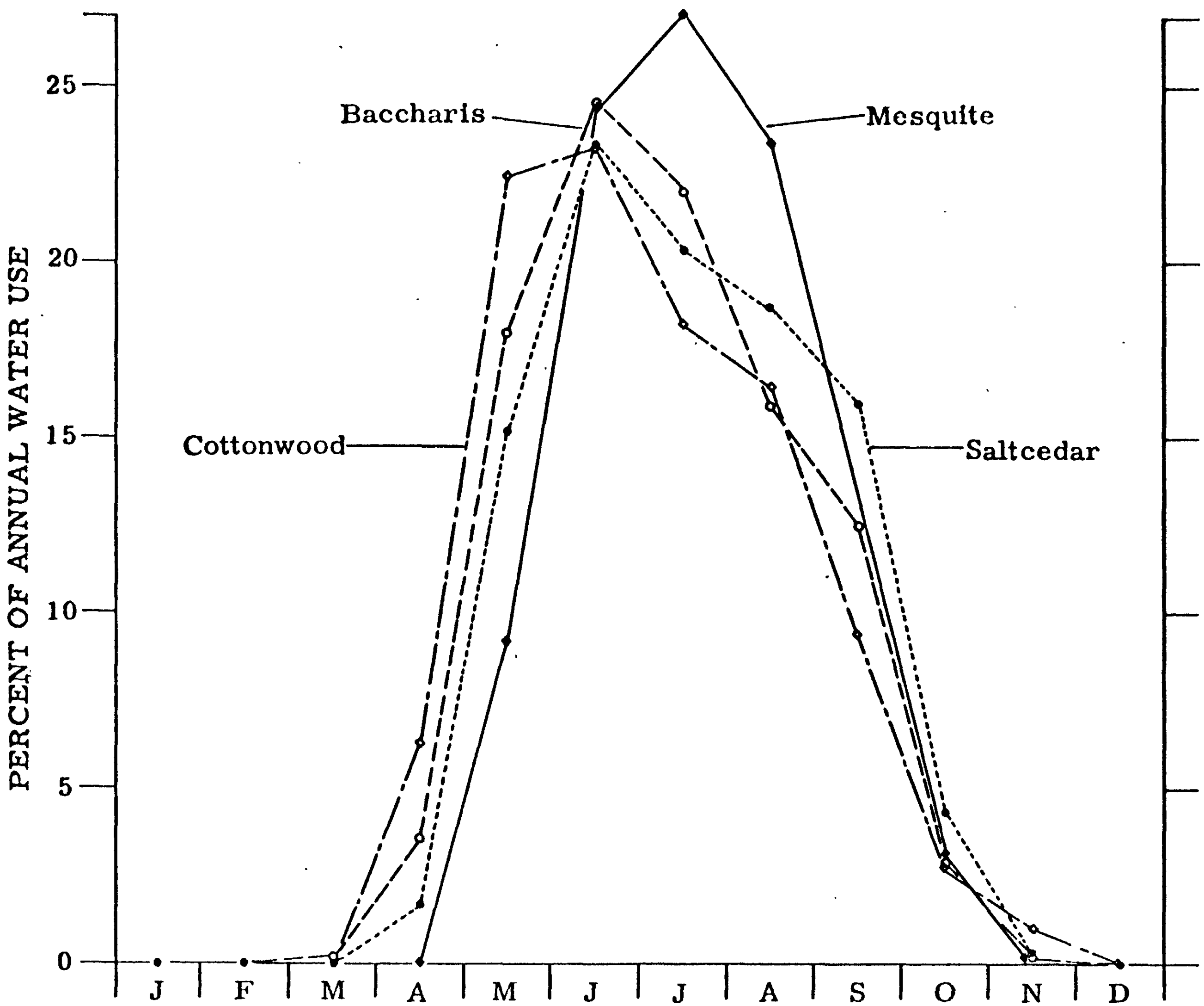
Figure 6.--Estimated relation between depth to ground water and annual evaporation from bare soil.



Data from Meinzer, 1942,
table 6

Figure 7. --Estimated relation between depth to ground water and annual water use by grasses.

water use by mesquite is in June, July, and August. The monthly water use by mesquite, cottonwood, baccharis, and saltcedar is given in figure 8. A comparison of figures 2, 3, and 8 shows that the beginning of the growing season coincides with the time when segments of the channels are dry.



Data from Gatewood and others, 1950, table 3

Figure 8. --Monthly use of water by different types of riparian vegetation.

PRESENT AND FUTURE EVAPOTRANSPIRATION LOSSES

Estimates of present (1970) and future possible evapotranspiration losses were made for each reach of the Agua Fria River and Humbug Creek. The estimates were made for an average depth to water in each reach for the entire growing season. The data were insufficient to determine changes in depth to water during the growing season.

The areal density of vegetation and the average depth to water for the parts of the Agua Fria River and Humbug Creek drainage basins in which large evapotranspiration losses may occur if streamflow is increased are given in table 2. The channel reaches that contain medium flow remain essentially clear of vegetation as a result of the frequent flow that either washes out or drowns the young plants. If the reaches contained perennial flow, the depth to water would be nearly zero.

The present (1970) water losses that result from evapotranspiration by riparian vegetation in the flood plains of the Agua Fria River and Humbug Creek are not large, and, based on an assumed environment of perennial flow in the study reaches, the future losses—after modification—probably will not be large (table 3). Figures 9 and 10 show the cumulative evapotranspiration losses as a function of distance above Waddell Dam and the areas where the greatest increases in losses may occur.

Table 2.--Areal density of vegetation and average depth to water in the Agua Fria River and Humbug Creek drainage basins under present (1970) conditions and in the future, after upstream vegetation modification

Reach	Dense vegetative cover in the flood plain			Medium vegetative cover in the flood plain			Light vegetative cover in the flood plain			Bare soil in the flood plain			Bare soil in the medium- or low-flow channel			Total area (acres)
	Area (acres)	Estimated average depth to water, 1970 (feet)	Estimated future average depth to water (feet)	Area (acres)	Estimated average depth to water, 1970 (feet)	Estimated future average depth to water (feet)	Area (acres)	Estimated average depth to water, 1970 (feet)	Estimated future average depth to water (feet)	Area (acres)	Estimated average depth to water, 1970 (feet)	Estimated future average depth to water (feet)	Area (acres)	Estimated average depth to water, 1970 (feet)	Estimated future average depth to water (feet)	
AGUA FRIA RIVER																
Reach 1	50	12	6	70	12	6	60	12	6	80	12	6	260	1	0	520
Reach 2	50	6	6	120	6	6	90	6	6	50	6	6	260	0	0	570
Reach 3	40	6	4	480	20	10	180	20	10	50	20	10	250	10	0	1,000
Reach 4	20	5	4	160	5	4	50	5	4	50	5	4	520	2	2	800
																2,890
HUMBUG CREEK																
Reach 1	--	35	10	40	35	10	120	35	10	20	35	10	50	35	2	230
Reach 2	--	3	2	30	3	2	20	3	2	20	3	2	40	1/	1/	110
																340
Total......	160			900			520			270			1,380			3,230

1/ The low-flow channel of reach 2 is mainly hard rock with small pockets of sand and gravel.

Table 3.--Estimated present and future possible annual losses through evapotranspiration, Agua Fria River and Humbug Creek drainage basins

Reach	Present annual water loss, 1970 (acre-feet)	Possible annual increase in water loss (acre-feet)	Total possible annual water loss (acre-feet)
AGUA FRIA RIVER			
Reach 1	800	1,300	2,100
Reach 2	2,300	0	2,300
Reach 3	900	2,000	2,900
Reach 4	1,500	100	1,600
Total............	5,500	3,400	8,900
HUMBUG CREEK			
Reach 1	70	230	300
Reach 2	180	200	380
Total............	250	430	680
Grand total	5,750	3,830	9,580

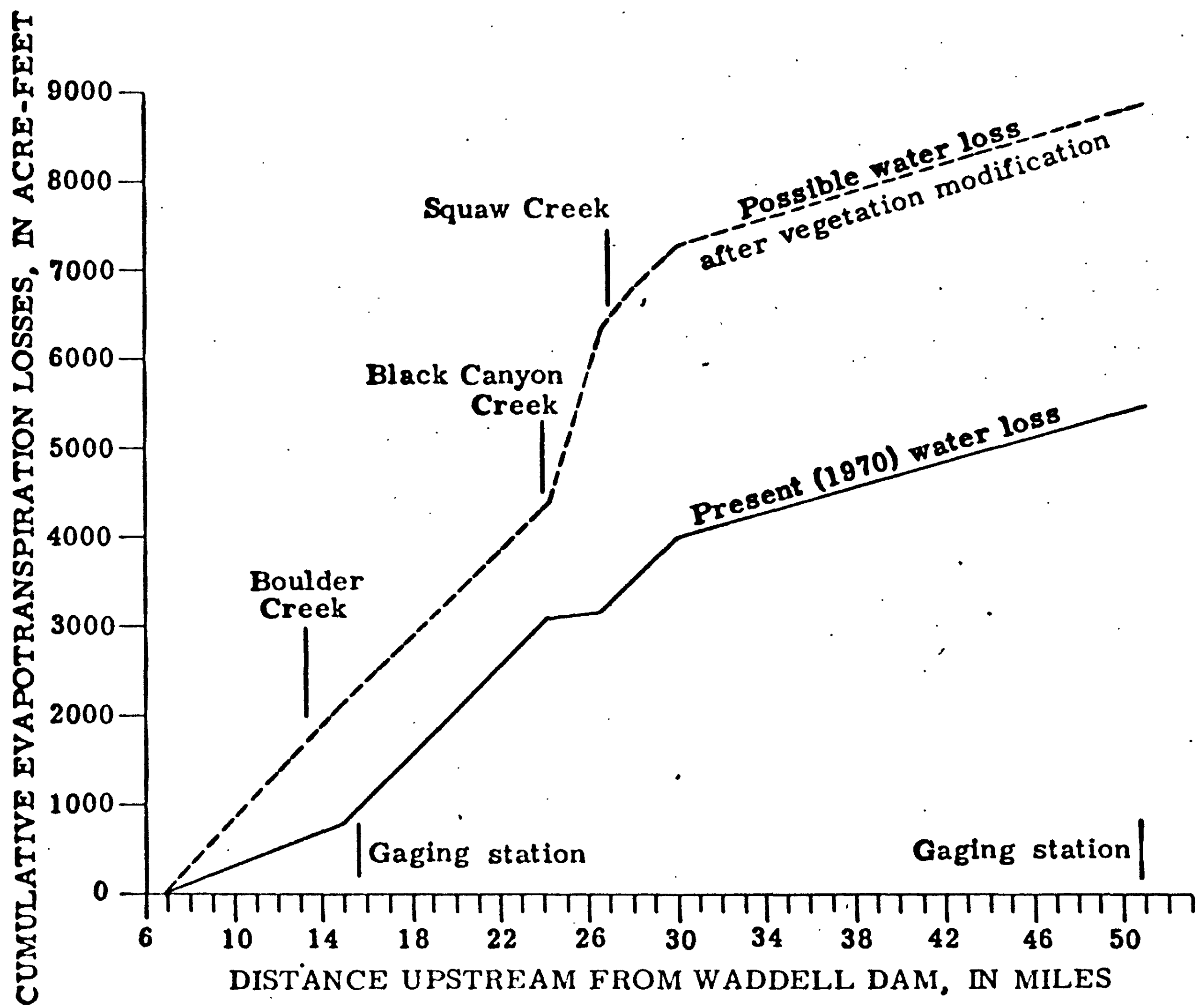


Figure 9. --Cumulative annual evapotranspiration losses in the Agua Fria River flood plain as a function of distance upstream from Waddell Dam.

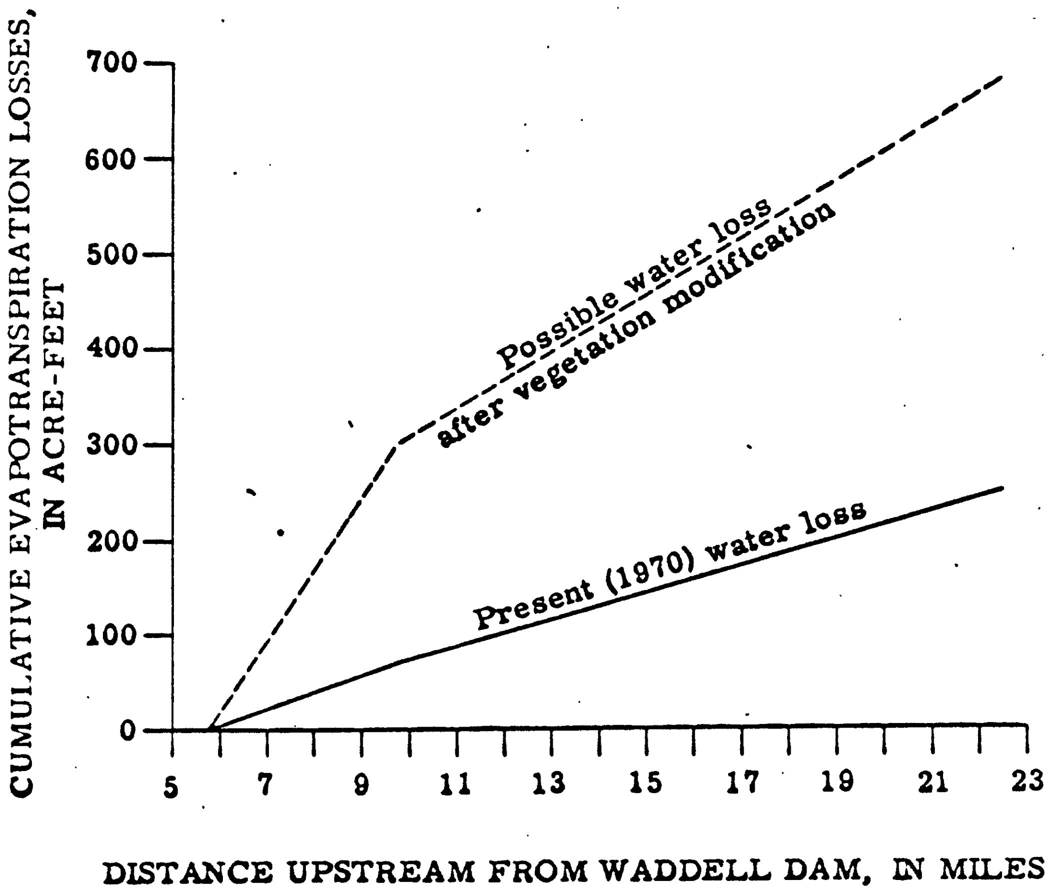


Figure 10.--Cumulative annual evapotranspiration losses in the Humbug Creek flood plain as a function of distance upstream from Waddell Dam.

Potential evapotranspiration has been defined as the "water loss that will occur if at no time there is a deficiency of water in the soil for use of vegetation" (Langbein and Iseri, 1960, p. 15). In the study area potential evapotranspiration is estimated to be about 70 inches per year. The estimate is based on the assumption that lake evaporation may be used as a good average estimate of potential evapotranspiration (Cruff and Thompson, 1967). In the study area lake evaporation is equal to the average annual class A pan evaporation of 100 inches (U.S. Geological Survey, 1967) times 0.70, which is the ratio of lake evaporation to class A pan evaporation (Linsley and others, 1958).

The greatest possible increase in evapotranspiration rate occurs in reaches 1 and 2 of the Agua Fria River (fig. 1). The estimated possible annual water use is about 48.5 inches. This rate is for a medium to dense flood-plain vegetative cover, a depth to water of zero and perennial flow in the medium-flow channel, and an average depth to water of about 6 feet elsewhere through a cross section of the flood plain at a right angle to the flow direction. The water-use figure compares favorably with the potential evapotranspiration value of 56 inches per year determined using the Blaney-Criddle method (Cruff and Thompson, 1967, p. 16).

Extrapolation of Data

Figures 9 and 10 may be used to estimate the evapotranspiration losses in other flood plains in the study area. The flood plains of Turkey, Poland, and Boulder Creeks are similar to that of reach 2 of Humbug Creek, and the water-loss rate for these streams may be assumed to be equal to the loss rate for reach 2 of Humbug Creek. Moreover, the water-loss rate for Black Canyon Creek probably is similar to that for reach 4 of the Agua Fria River. Superimposing the appropriate loss rate (as a slope) at the point representing the mouth of the tributary on the possible-loss line on figure 9 gives a new line that can be extended the required distance upstream to estimate graphically the possible losses through any drainage route below the gaging station at the upstream end of the study reach. The part of the drainage basin above the gaging station, with the exception of the Sycamore Creek area, is affected greatly by the ground-water system. Large increases in water losses may occur in this part of the drainage basin as a result of evapotranspiration and increasing ground-water withdrawals to meet domestic needs.

Factors That May Affect the Future Possible Increases in Water Loss

Several factors may affect the possible increases in evapotranspiration losses, assuming that perennial flow conditions are satisfied. The most important factor is an increase in the density of the riparian vegetation that may result from a more abundant water supply. Another factor is the possible invasion and spreading of a plant species, such as saltcedar, that consumes more water than the present (1970) vegetation. A significant increase in the withdrawal of ground water for domestic and agricultural uses along the Agua Fria River would deplete base flow, and any increase in streamflow would be used to satisfy the existing riparian vegetation water requirements.

Throughout the study, the assumption was that the proposed vegetation-modification program will result in perennial flow in the stream that drains the modified part of the drainage area. The assumption provided a means for estimating the maximum increase in evapotranspiration losses. The most probable result of the vegetation modification would be a slightly longer period of base flow and higher peak flows. The subsurface materials in the upper end of the Humbug Creek drainage area cannot store sufficient ground water to provide perennial flow throughout the entire length of Humbug Creek; therefore, the actual increase in evapotranspiration losses would be smaller than those shown in table 3.

SUMMARY

The purpose of this investigation was to estimate the possible increase in transitory water losses that may occur in a part of the Agua Fria River drainage as a result of an increase in runoff. The present and future evapotranspiration losses were estimated for the main stem of the drainage—the Agua Fria River—and for Humbug Creek, which drains an area that is typical of those being considered for vegetation modification. Evapotranspiration losses will increase owing to shallower ground-water levels in the areas where streamflow is increased as a result of vegetation modification. In order to evaluate the maximum possible loss situation, the Agua Fria River and Humbug Creek were assumed to be perennial throughout their lengths.

The method used to estimate the increase in evapotranspiration losses was based on the relation between water use by vegetation and the depth to ground water. The greatest possible increase in evapotranspiration rate occurs in reaches 1 and 2 of the Agua Fria River. The estimated possible annual water use is about 48.5 inches in the two reaches. At the present time (1970), evapotranspiration losses in the 44.2-mile-long study reach of the Agua Fria River are estimated to be about 5,500 acre-feet per year, and the future possible losses are

estimated to be about 8,900 acre-feet per year. In the 16.7-mile-long study reach of Humbug Creek, the present (1970) evapotranspiration losses are estimated to be about 250 acre-feet per year, and the future possible losses are estimated to be about 680 acre-feet per year.

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