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ABSTRACT

Indians have occupied and irrigated the reservation lands along the Gila River for centuries. Knowledge of the hydrologic conditions that existed before development of the water resources by non-Indian settlers is needed to aid in evaluation of water-right claims.

Water resources of the Gila River Indian Reservation for the period before development by non-Indian settlers were characterized by perennial flow in the Gila River and ground water near the land surface. Depths to water ranged from 10 to 70 feet and the direction of ground-water movement was from the northeast, east, and southeast toward the northwest. The ground-water reservoir was essentially in equilibrium and was sustained mainly by the infiltration of water from the Gila River.

Mesquite thickets and groves of cottonwood trees covered large parts of the flood plain and other lowlands along the Gila River. Evapotranspiration averaged 200,000 acre-feet per year. On the basis of available streamflow data and long-term runoff estimates from tree-ring data, the mean annual flow of the Gila River upstream from the reservation was estimated to be 500,000 acre-feet and the median annual flow 380,000 acre-feet. Tree-ring data do not indicate a significant change in precipitation from 1602 to 1970. Ground water was discharged by evapotranspiration by phreatophytes where water levels were shallow and by return to surface flow mainly in the western third of the reservation where bogs and sloughs were common.

A numerical model was developed to simulate ground-water flow, stream-aquifer connection, and evapotranspiration for purposes of evaluating predevelopment hydrologic conditions. The model represents average conditions in the ground-water system before the system was affected significantly by diversions upstream from the reservation. Average values for components of ground-water flow determined from the model include recharge by infiltration from the Gila River, 94,000 acre-feet per year; evapotranspiration from ground water, 96,000 acre-feet per year; and discharge to surface flow in the western third of the reservation, 29,000 acre-feet per year.

INTRODUCTION

The Gila River Indian Reservation was established in 1859 in an area along the Gila River that had been occupied and irrigated by the

Indians for centuries (Bancroft, 1889; Haury, 1976, p. 357; Ezell, 1963). Non-Indian settlers arrived in Arizona in large numbers in the 1860's and 1870's and began diverting water from the Gila River and its tributaries upstream from the Gila River Indian Reservation. The development and activities that have occurred since that time have significantly changed the hydrology of the area. The flow of the Gila River and recharge to the ground-water system on the reservation have been greatly diminished as a result of upstream diversions and storage. Water levels in wells have declined and the direction of ground-water flow has changed as a result of pumping for irrigation in areas adjacent to the reservation. General adjudication to determine water rights of water users in the Gila River watershed is being conducted in the superior courts of Arizona under authority established by Arizona Revised Statutes Title 45, Chapter 1, Article 6. In order to develop data pertinent to the adjudication process, the U.S. Bureau of Indian Affairs entered into a cooperative agreement with the U.S. Geological Survey to evaluate the hydrologic conditions that existed prior to the arrival and development of the area by non-Indian settlers.

Location, Physiography, and Climate

The study area includes about 2,200 square miles in south-central Arizona, of which about 580 square miles is in the Gila River Indian Reservation (fig. 1). The reservation consists of a parcel of land about 50 miles long and 3 to 10 miles wide on both sides of the Gila River. The study area includes part of the Salt River Valley north of the reservation and the lower Santa Cruz basin south of the reservation. The Ak-Chin Indian Reservation, the north tip of the Papago Indian Reservation, and the south edge of the Salt River Indian Reservation are within the study area.

The study area is characterized by broad desert plains dissected by arroyos, and valleys separated by rugged low-lying mountains. The altitude of the desert plains ranges from 1,600 feet above sea level east of the reservation to less than 1,000 feet at the northwest corner. To the east and northeast of the reservation, the terrain slopes irregularly upward to an altitude of more than 5,000 feet in the Superstition mountains.

The dominant native vegetation types are mesquite and saltbush along the washes and palo verde and cacti on the hills. Creosotebush covers most of the desert floor except where it has been replaced by crops. Dense thickets of mesquite and groves of cottonwood and willow covered large areas along the rivers when the non-Indian settlers arrived (Lee, 1905) but most have been removed.

Surface drainage includes parts of three major rivers—the Gila, Salt, and Santa Cruz (fig. 1). The Salt and Santa Cruz Rivers are tributaries to the Gila River and both join the Gila near the northwest corner of the Gila River Indian Reservation. The Gila River drains more than 18,000 square miles east and southeast of the reservation. The Salt River and its major tributary, the Verde River, drain more than 12,000 square miles north and northeast of the reservation. The Santa Cruz

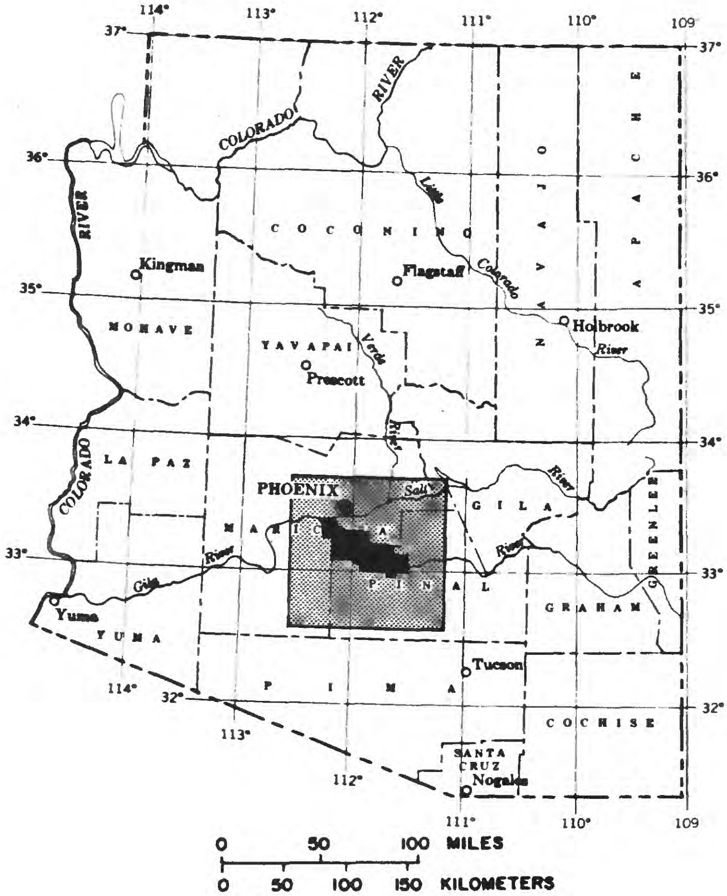

Figure 1.--Location of study area (shaded).

River drains more than 8,000 square miles south and southeast of the reservation (fig. 1). The Gila and Salt Rivers contributed perennial flow to the study area prior to the arrival of non-Indian settlers but now are only intermittent streams. The Santa Cruz River flows mainly in response to intense rainfall.

The climate is dry and incapable of supporting more than a minimum vegetation growth without irrigation. Summers are hot, and daily temperatures generally exceed 100 °F from mid-June through August. Mean daily temperatures range from about 64 °F to 105 °F. The relative humidity generally is low, ranging from about 20 to 50 percent (Sellers and Hill, 1974). Winters are mild, and average temperatures range from 60 °F to 80 °F in the afternoons and from 30 °F to 40 °F in early mornings. Subfreezing temperatures occur on only a few days during an average year (Sellers and Hill, 1974). Mean daily temperatures range from about 33 °F to 70 °F.

Annual precipitation averages about 8 inches and results mainly from two types of storms. Summer thunderstorms, which develop as a result of the flow of moist tropical air from the Gulf of Mexico, make July and August the wettest months. Regional storms from the Pacific Ocean produce gentle widespread showers during the fall and winter months. April, May, and June are the driest months. Occasional tropical storms produce large amounts of rain in the fall.

Wind movement in the area is relatively light. In 1895, the monthly average wind speed was about 5 miles per hour at Phoenix (Davis, 1897a, p. 31). U.S. Weather Bureau records for January 1948 through December 1955 at Phoenix show that average wind speeds did not exceed 8.3 miles per hour (Sellers and Hill, 1974, p. 30).

Purpose and Scope

The purpose of this report is to describe the hydrologic conditions that existed in the area of the Gila River Indian Reservation prior to development by non-Indian settlers. Non-Indian settlers were diverting significant quantities of water from the Gila River and its tributaries upstream from the reservation in the 1870's (Olberg, 1919). No pre-1870 hydrologic data are available; therefore, data collected since 1870 were used to evaluate predevelopment conditions. The results of the evaluation represent average hydrologic conditions during the 100-year period prior to 1870. The 100-year average was used in order to dampen the effect of short-term variations in hydrologic conditions.

The evaluation of hydrologic conditions prior to 1870 required estimating the flow of the Gila River upstream from the Gila River Indian Reservation and defining the ground-water system in and adjacent to the reservation. Estimates of average flow of the Gila River were made from recorded data with adjustments to represent predevelopment conditions. The adjustments were based on the effects of development on river flows and the mathematical evaluations of climatic trends. Studies of relations between streamflow and tree rings were used to help substantiate estimates of the predevelopment flow of the Gila River. The ground-water system was evaluated by the use of a numerical model. The model parameters were estimated initially from published values and recorded field data; each parameter was estimated independently. Evapotranspiration was calculated by using old maps and photographs to determine types and areas of vegetation and applying evapotranspiration rates determined in recent studies. The model covers an area slightly larger than the reservation (fig. 1) in order to encompass parts of the mountain ranges that form physical boundaries to much of the ground-water system.

Previous Investigations

A reconnaissance of the water supply for the Gila River Indian Reservation was made by the U.S. Geological Survey in 1886-87 (Davis, 1897b, p. 8). A streamflow-gaging station was established on the Gila River at the Buttes 12 miles upstream from Florence in 1889, and records were obtained for 1 year. The station was discontinued in 1890, reestablished in 1895, and operated through September 1899 (Lippincott, 1900).

An investigation of the water supplies available for irrigation in the Salt and Gila Valleys near Phoenix, Arizona, was made in 1896 by Arthur P. Davis. This investigation dealt mainly with surface-water supplies and the results, as they pertained to irrigation waters for the Gila River Indian Reservation, were reported to the U.S. Senate (Davis, 1897b). In a more general report, Davis (1897a) described the topographic and climatic conditions, irrigation works in use and under construction, facts relating to water supply, underground waters, evaporation, silting of reservoirs, and legal problems related to storing and diverting water. Davis (1897a) recommended a more detailed investigation of potential reservoir sites on the Gila River, which was conducted by Lippincott (1900).

W.T. Lee investigated the "underground waters" of the Gila Valley (1904) and the Salt River Valley (1905). The reports present tabulations of well records, water levels, and chemical quality of ground water. Also included are descriptions of the geology, physiography, and economics of pumping ground water. Ground waters of the Arizona territory were examined as to their suitability for sanitary, irrigation, and technical uses (Skinner, 1903).

A study of the geology and water resources of the Gila River Indian Reservation was made by the U.S. Department of Agriculture (Rott, 1936). A quantitative study of the ground-water resources of the Eloy district in Pinal County, Arizona, was conducted by the Agricultural Experiment Station of the University of Arizona (Smith, 1940). The U.S. Geological Survey investigated the ground-water resources of the Queen Creek area (Babcock and Halpenny, 1942), the Santa Cruz basin (Turner and others, 1943), and western Pinal County (Hardt and others, 1964; Hardt and Cattany, 1965; Kister and Hardt, 1966).

An electrical-analog model of the ground-water system in central Arizona was constructed to determine the probable future effects of continued ground-water withdrawal (Anderson, 1968). The model was

Table 3.--Comparison of basin characteristics

Stream	Drainage area, in square miles	Annual precipitation, in inches	Annual snowfall, in inches	Mean altitude, in feet	Forest area, in percent	Channel slope, in feet per mile	Irrigated area, 1982, in acres per square mile
Gila River at Kelvin..........	18,011	15.7	23	5,150	13	18	4.6
Salt River near Roosevelt..........	4,306	22.0	44	6,190	71	23	0.9
Verde River below Tangle Creek........	5,499	18.4	32	5,470	67	16	2.3
San Francisco River near Glenwood, New Mexico.........	1,653	17.6	52	7,780	85	55	1.2

for 1929-34 and 45 cubic feet per second for 1934-40 (P.V. Hodges, U.S. Indian Irrigation Service, written commun., 1941).

Other streams that affect the reservation's water resources are the Salt and Santa Cruz Rivers; Queen Creek; Santa Rosa, Greene, and Vekol Washes; and many small streams along mountain fronts. The Salt River was perennial when non-Indian settlers arrived. The Santa Cruz River was ephemeral except near the confluence with the Gila River (Brown and others, 1981). Queen Creek was perennial in the upper reaches but most of the flow infiltrated into the alluvium near the contact with the bedrock. Santa Rosa, Greene, and Vekol Washes and other ephemeral channels that drain the mountains in and around the study area carry water only in response to heavy rainfall. Flow in the ephemeral channels generally travels only a short distance onto the valley floor before all the water infiltrates into the underlying material.

Ground-Water Flow

Recharge to the ground-water system occurs mainly from infiltration of streamflow. Prior to major diversion of water for irrigation, the Gila River was the main source of recharge. Queen Creek; the Santa Cruz River; Santa Rosa, Greene, and Vekol Washes; and other ephemeral channels that drain the mountains in and around the study area probably contributed minor amounts of recharge periodically. The Salt River was a source of recharge from the head of the valley—near the site of Granite Reef Dam—to a point about 10 miles downstream (Lee, 1905). A map of predevelopment water levels (Thomsen and Baldys, 1985) indicates that recharge from the Salt River may have reached the Gila River in the western third of the reservation.

Water is discharged from the ground-water system by surface flow, underflow, and evapotranspiration. Discharge of ground water into the Gila and Salt Rivers occurred regularly prior to development but seldom occurs now. In the western third of the reservation, water was discharged from

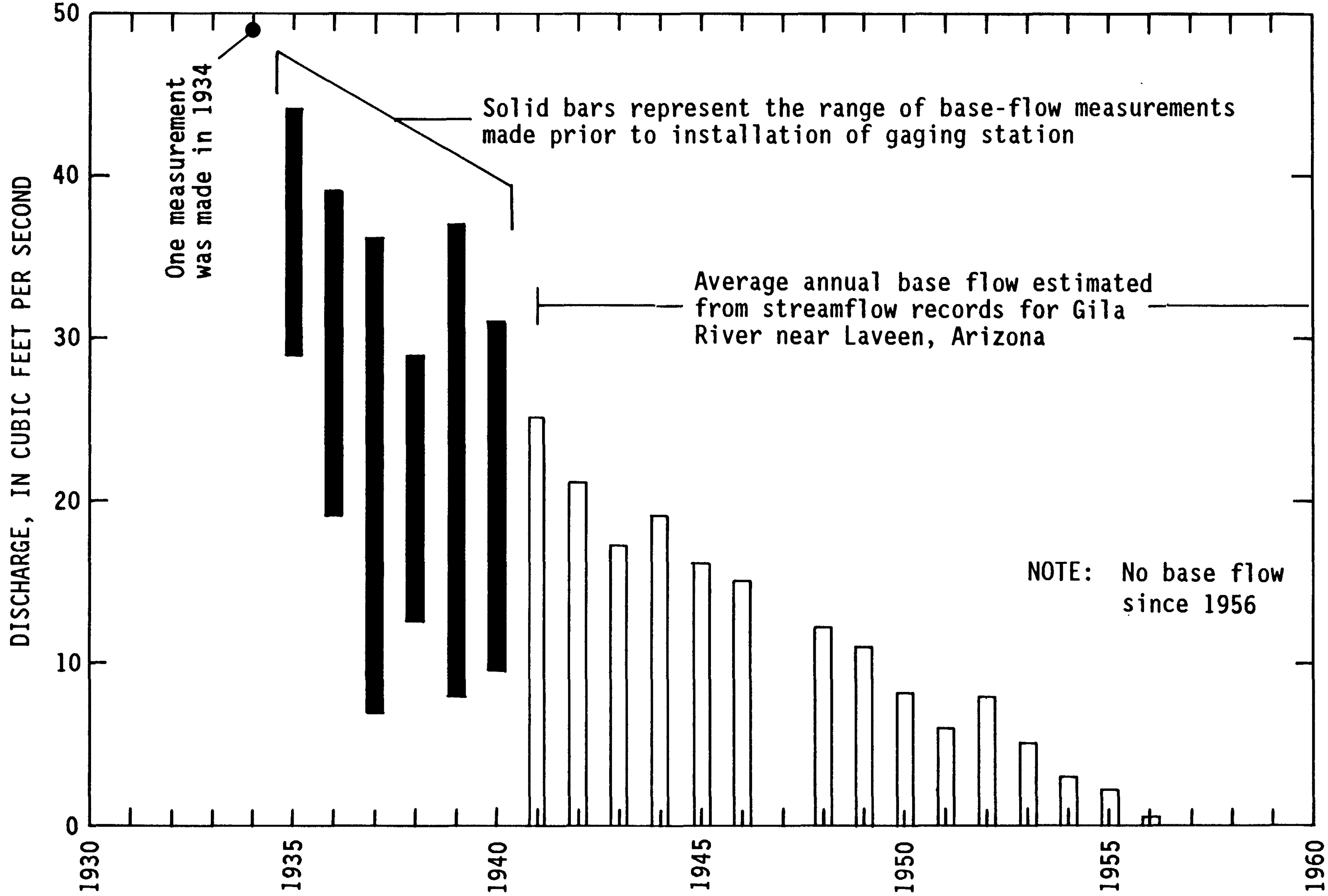

Figure 5.--Average annual base flow of the Gila River near Gila Crossing.

the aquifer to the Gila River channel and adjacent bogs and sloughs (Lee, 1904). As water in the aquifer moved northwestward between Sierra Estrella and South Mountain, the reduced cross-sectional area of the aquifer forced part of the water to the surface. The predevelopment ground-water discharge to the Gila and Santa Cruz Rivers in the western third of the reservation is estimated on the basis of streamflow measurements to have averaged 33,000 acre-feet per year. Ground-water discharge near Coolidge probably averaged about 3,000 acre-feet per year.

Ground water occurs mainly under water-table or unconfined conditions in the sedimentary material that underlies much of the Gila River Indian Reservation and the surrounding area. The water table is that surface in an unconfined water body at which the pressure is atmospheric. The water table is defined by the levels at which water stands in wells that penetrate the water body. Prior to development of the area by non-Indian settlers, water levels were 10 to 70 feet below the land surface and the water table was a surface of low relief, sloping in general with the grade of the river (Lee, 1904). The water level at Sacaton was 15 feet below the land surface. The direction of ground-water movement in 1900 was from the northeast, east, and southeast toward the northwest, and ground-water discharge occurred through the gap between South Mountain and Sierra Estrella (Thomsen and Baldys, 1985). The ground-water reservoir was in equilibrium and was sustained mainly by the infiltration of water from the Gila River. Ground water was discharged to the Gila River in the western part of the reservation. The movement of water from the Salt River to the ground-water reservoir and back to the Salt River affected a small part of the study area but had little effect on the overall ground-water system.

Mountain ranges that lie within the study area impede the movement of ground water. The rocks that form the mountains are generally not water bearing but may, where fractured, yield as much as a few tens of gallons per minute of water to wells. The stream alluvium and the upper basin fill yield as much as 4,000 gallons per minute of water to wells (Laney and Hahn, 1986). In places, the upper basin fill contains layers of fine-grained material that restrict the downward migration of water. The lower basin fill generally yields less than 50 gallons per minute of water to wells. The pre-Basin and Range unit is more permeable than the lower basin fill. Water in the pre-Basin and Range unit is under confined conditions in areas where the unit is overlain by the lower basin fill. Elsewhere, water in the upper basin fill and the pre-Basin and Range unit is in a common and generally unconfined water body.

Underflow

Underflow through permeable materials underlying the surface drainages recharges the ground-water system in the study area. Underflow is the subsurface movement of water from one basin to another. The Gila and Salt Rivers and Queen Creek enter from areas underlain by crystalline rocks; hence, the underflow from these drainages probably was negligible. The Santa Cruz River and Santa Rosa, Greene, and Vekol Wash drainages are underlain by thick alluvium, so the potential exists for a moderate amount of underflow through the alluvium. Underflow along the Santa Cruz, Santa