# STREAMFLOW LOSSES AND CHANGES IN GROUND-WATER LEVELS ALONG THE SALT AND GILA RIVERS NEAR PHOENIX, ARIZONA—FEBRUARY 1978 TO JUNE 1980

By Larry J. Mann and Paul B. Rohne, Jr.

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## CONVERSION FACTORS

For readers who prefer to use metric units, the conversion factors for terms used in this report are listed below:

| Multiply | By | To obtain |
|---|---|---|
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| acre-foot (acre-ft) | 0.001233 | cubic hectometer ($hm^3$) |
| foot per day (ft/d) | 0.3048 | meter per day (m/d) |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/s$) |
| acre | 0.4047 | hectare (ha) |

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## ABSTRACT

From March 1978 to June 1980, high runoff from the Salt and Verde drainage basins combined with large carryover storage in the reservoir system led to the release of about 8.26 million acre-feet of water. About 2.89 million acre-feet of the water was diverted above Granite Reef Dam, and about 5.45 million acre-feet was released into the normally dry channel of the Salt River. The total streamflow losses in the 74-mile reach between Granite Reef and Gillespie Dams were at least 474,000 acre-feet. Most of the water infiltrated into the permeable alluvial deposits along the Salt and Gila Rivers and increased the amount of ground water in storage.

From February 1978 to May 1980, ground-water levels in 169 wells that tap the alluvial deposits in the Salt River Valley rose an average of 35.5 feet. The rise in ground-water levels was a direct result of the infiltrating floodwaters and a marked decrease in ground-water pumpage because of the availability of abundant surface water. For 1978-80, the average annual amount of ground-water pumpage was about 1.08 million acre-feet as compared to 1.71 million acre-feet annually for 1975-77, which is a reduction of about 35 percent. The reduction in ground-water pumpage in 1978-80 accounted for a total of about 1.9 million acre-feet of water.

## INTRODUCTION

Flow in the Salt River between Granite Reef Dam and the Gila River is a rare occurrence. In 1945 the last of a series of water-conservation reservoirs was completed on the Verde River, which is the major tributary of the Salt River. From 1942 to 1964, all runoff from the Salt and Verde drainages was stored in the reservoirs. Water is released from the reservoirs into the channels of the Salt and Verde Rivers and flows downstream to Granite Reef Dam—a low-head diversion dam—where it is diverted into two canals for irrigation and municipal use in and near Phoenix.

The first significant release of water into the Salt River below Granite Reef Dam occurred in 1965. This release was followed by others

in 1966, 1968, and 1973. The total volume of water released between 1965 and 1973 was less than 2 million acre-ft. From March 1978 to June 1980, high runoff from the Salt and Verde drainage basins combined with large carryover storage in the reservoirs from previous years led to the release of about 8.26 million acre-ft of water. About 2.89 million acre-ft of the water was diverted above Granite Reef Dam, and about 5.45 million acre-ft was released into the normally dry channel of the Salt River. Tributary inflow to the Salt River below Granite Reef Dam and to the Gila River below the Salt River increased the flow by about 800,000 acre-ft. The largest contribution was from the release of water from Waddell Dam on the Agua Fria River. Most of the water in the Salt River below Granite Reef Dam and the Gila River below the Salt River flowed downstream to Gillespie Dam—a low-head diversion dam. From Gillespie Dam, the water continued downstream and was stored in Painted Rock Reservoir near Gila Bend.

A cooperative program between the U.S. Geological Survey and the Salt River Project was initiated in February 1978. The program was designed to monitor the changes in ground-water levels owing to the large release of water to the otherwise dry channels of the Salt River, part of the Gila River below the Salt River, and the Agua Fria River. An observation-well network of about 180 sites was designed, and water-level measurements were made periodically beginning in February 1978. In December 1978 the network was modified to include five sites at which the ground-water levels were recorded on a continuous basis.

In May 1979 a second data-collection phase of the study was begun in cooperation with the U.S. Bureau of Reclamation. Four streamflow-gaging stations were installed on the Salt and Gila Rivers between Granite Reef and Gillespie Dams when additional releases of water into the Salt River below Granite Reef Dam were anticipated. The purpose of the gages was to monitor streamflow losses between the dams; controlled releases of less than 30,000 $ft^3/s$ were planned so that streamflow losses could be accurately measured. Streamflow data were obtained for May 1979. The flows in February 1980, however, were more than 150,000 $ft^3/s$ and destroyed two of the gaging stations and topped the third.

## Scope

This report summarizes part of the hydrologic data needed to determine the effects of streamflow on ground-water storage. The report includes (1) streamflow data at selected points between the water-conservation reservoirs on the Salt and Verde Rivers and the Gila River at Gillespie Dam, (2) changes in ground-water levels in 169 observation wells from February 1978 to May 1980, (3) an estimate of the streamflow losses along the Salt and Gila Rivers between Granite Reef and Gillespie Dams from March 1978 to June 1980, and (4) the infiltration rates on May 9, 1979, for the Salt River downstream from Granite Reef Dam.

Most of the hydrologic data in this report are available in computer-printout form and may be consulted at U.S. Geological Survey offices in: Federal Building, 301 West Congress Street, Tucson, and Valley Center, Suite 1880, Phoenix. Copies of the data can be obtained at private expense.

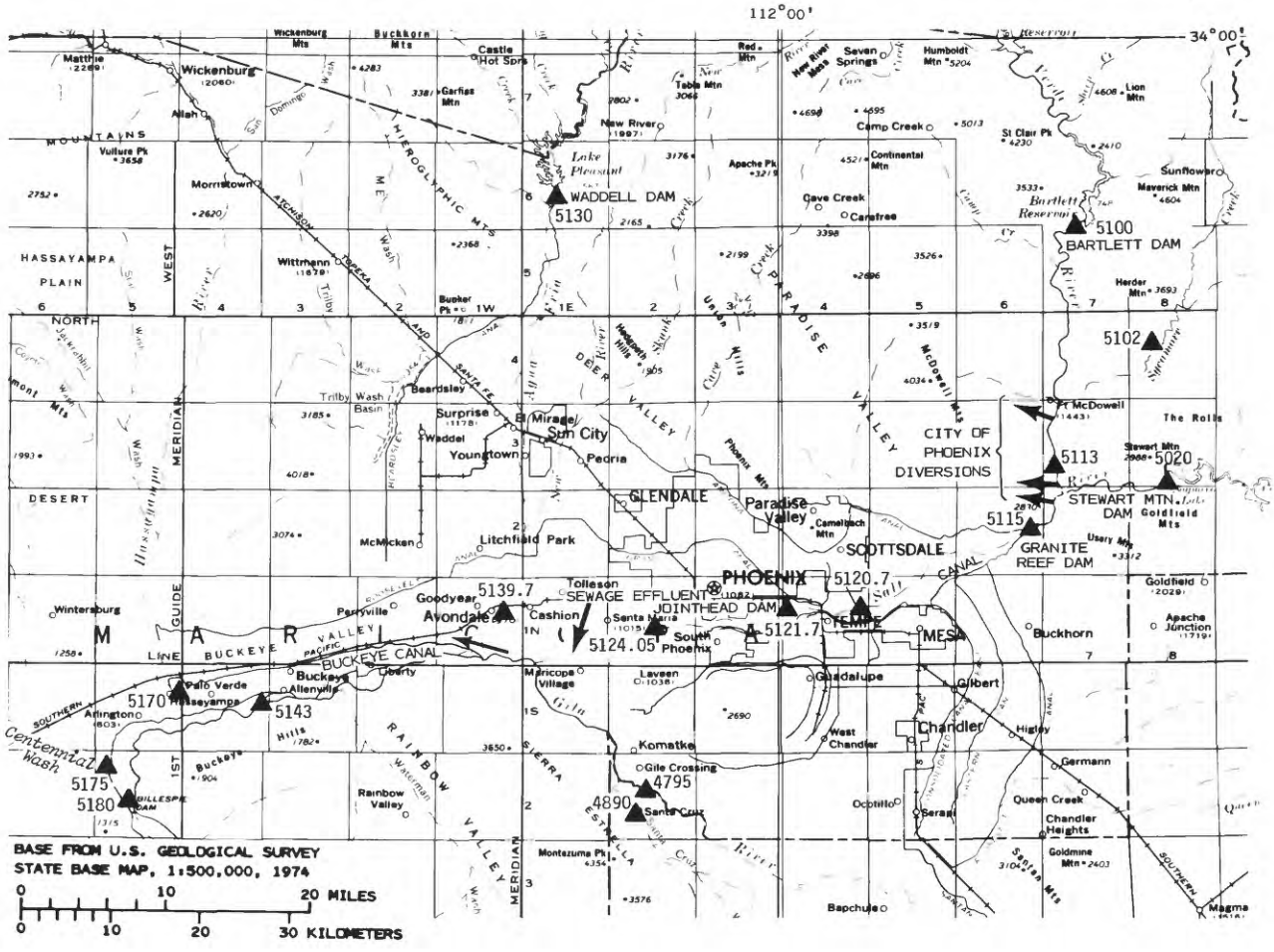
## Physical Setting

The Salt River flows westward from its headwaters in east-central Arizona and about 25 mi east of Phoenix is joined by the Verde River—its major tributary (fig. 1). The Verde River flows southward from its headwaters in central Arizona. Water-conservation reservoirs on each river provide storage for the Phoenix area. Below the confluence of the Salt and Verde Rivers, water is diverted at Granite Reef Dam. From Granite Reef Dam, the Salt River flows westward through Phoenix to its confluence with the Gila River (fig. 2). About 3 mi downstream from its confluence with the Salt River, the Gila River is joined by the southward-flowing Agua Fria River. Between the Agua Fria River and Gillespie Dam, the Gila is joined by three large tributaries—Waterman Wash from the southeast, Hassayampa River from the north, and Centennial Wash from the northwest. In and near Phoenix, streams tributary to the Gila are ephemeral and flow only in response to precipitation, controlled releases from reservoirs, or releases of wastewater.

In addition to water supplied by the reservoirs on the Salt, Verde, and Agua Fria Rivers, ground water is also a major source of water in the Phoenix area. From 1915 to 1980, more than 78 million acre-ft of ground water was withdrawn from permeable alluvial deposits that underlie the wide valley of the Salt and Gila Rivers (U.S. Geological Survey, 1982).

## STREAMFLOW

Streamflow data for 16 sites on the Salt and Gila Rivers and their major tributaries (fig. 2) were used to calculate flow volumes and changes from March 1978 to June 1980. Flow at Granite Reef Dam is derived mainly from releases of water from Bartlett Dam on the Verde River and Stewart Mountain Dam on the Salt River and inflow from Sycamore Creek—a tributary to the Verde River. In addition, several small ungaged tributaries to the Salt and Verde Rivers added an unknown volume of water to the rivers. The total amount of flow released from the reservoirs on the Salt and Verde Rivers and inflow from Sycamore Creek was about 8.26 million acre-ft (table 1). About 2.89 million acre-ft was diverted above Granite Reef Dam, and about 5.45 million acre-ft was released into the Salt River below Granite Reef Dam. The releases below and diversions above Granite Reef Dam are about 79,000 acre-ft more than the combined amount of water released from the reservoirs on the Salt




EXPLANATION

5124.05▲ GAGING STATION—Number, 5124.05, is abbreviated station number; complete number is 09512405

⟶ DIVERSION FROM OR RETURN TO RIVER

Index of gaging stations

| Abbreviated station number | Name |
|---|---|
| 4795 | Gila River near Laveen |
| 4890 | Santa Cruz River near Laveen |
| 5020 | Salt River below Stewart Mountain Dam |
| 5100 | Verde River below Bartlett Dam |
| 5102 | Sycamore Creek near Fort McDowell |
| 5113 | Verde River near Scottsdale |
| 5115 | Salt River below Granite Reef Dam |
| 5120.7 | Salt River at Hayden Road, at Tempe |
| 5121.7 | Salt River at Jointhead Dam |
| 5124.05 | Salt River at 35th Avenue, at Phoenix |
| 5130 | Agua Fria River at Waddell Dam |
| 5139.7 | Agua Fria River at Avondale |
| 5143 | Gila River at U.S. 80, near Buckeye |
| 5170 | Hassayampa River near Arlington |
| 5175 | Centennial Wash near Arlington |
| 5180 | Gila River above diversions, at Gillespie Dam |

Figure 2.--Location of selected streamflow-gaging stations on the Salt and Gila Rivers and their major tributaries.

Table 1.--Volumes of streamflow in selected reaches of the Salt, Verde, and Gila Rivers—March 1978 to June 1980

[Data compiled from U.S. Geological Survey, issued annually, and Salt River Project, written commun., 1978-80. The computed values for inflow and outflow are not meant to imply an accuracy to the number of significant figures shown. Symbol, >, indicates the actual value is greater than the value shown in the table. See figure 2 for location of sites]

| Site | Inflow, in acre-feet | Outflow, in acre-feet |
|---|---|---|
| **From Stewart Mountain and Bartlett Dams to Granite Reef Dam** | | |
| Salt River below Stewart Mountain Dam..... | 4,918,700 | -- |
| Verde River below Bartlett Dam..... | 3,126,400 | -- |
| Sycamore Creek near Fort McDowell..... | 214,270 | -- |
| TOTAL INFLOW..... | 8,259,370 | -- |
| City of Phoenix diversions..... | -- | 80,760 |
| Diversions above Granite Reef Dam..... | -- | 2,811,150 |
| Total diversions..... | -- | 2,891,910 |
| Salt River below Granite Reef Dam..... | -- | 5,446,320 |
| TOTAL OUTFLOW..... | -- | 8,338,230 |
| INFLOW MINUS OUTFLOW..... | -78,860 | |
| **Salt River from Granite Reef Dam to Jointhead Dam** | | |
| Salt River below Granite Reef Dam..... | 5,446,320 | -- |
| Salt River at Jointhead Dam..... | -- | 5,061,980 |
| INFLOW MINUS OUTFLOW..... | 384,340 | |
| **Salt River at Jointhead Dam to Gila River above diversions at Gillespie Dam** | | |
| Salt River at Jointhead Dam..... | 5,061,980 | -- |
| City of Phoenix sewage effluent..... | 228,000 | -- |
| Gila River near Laveen..... | 177,580 | -- |
| Santa Cruz River near Laveen..... | 54,840 | -- |
| Diversion to Buckeye Canal..... | -- | 165,590 |
| Agua Fria River at Avondale..... | 290,880 | -- |
| Hassayampa River near Arlington..... | >38,900 | -- |
| Centennial Wash near Arlington..... | >8,560 | -- |
| Base flow of Gila River above diversions at Gillespie Dam..... | 204,350 | -- |
| Gila River above diversions at Gillespie Dam..... | -- | 5,809,340 |
| TOTAL..... | >6,065,090 | 5,974,930 |
| INFLOW MINUS OUTFLOW..... | >90,160 | |

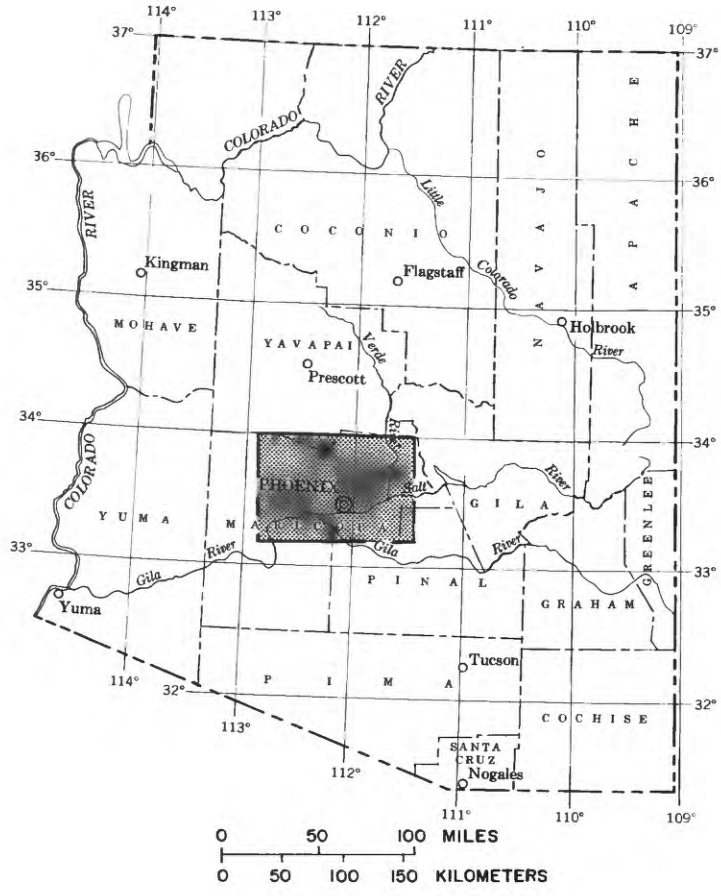



Figure 1.--Area of report (shaded).

and Verde Rivers and contributed by Sycamore Creek. This increase can be attributed to two factors: (1) the ungaged tributary inflow and (2) small inaccuracies in the streamflow data—the increase of 79,000 acre-ft is less than 1 percent of the inflow.

Of the 5.45 million acre-ft of water released into the Salt River below Granite Reef Dam, about 384,000 acre-ft was lost in the 19.5-mi reach between Granite Reef and Jointhead Dams (table 1). This 384,000 acre-ft represents the minimum loss, because several points of inflow between Granite Reef Dam and Jointhead Dam are ungaged; the ungaged inflow is negligible when compared to the volume of water released into the Salt River.

Between Jointhead Dam on the Salt River and the diversions above Gillespie Dam on the Gila River, the streamflow losses were at least 90,000 acre-ft (table 1). Most of the larger tributaries to the Salt and Gila Rivers in this reach are gaged, but several tributaries are ungaged or are gaged by partial-record stations. For example, Waterman Wash is ungaged, and a complete record is not available for the Hassayampa River or Centennial Wash. Streamflow data for the Hassayampa River are available only for days when the discharge exceeded 500 $ft^3/s$; flow in Centennial Wash was not gaged from October 1, 1979, to May 14, 1980. The total losses therefore could have been significantly larger owing to ungaged inflow.

Another significant inflow component that must be considered is the base flow of the Gila River above diversions at Gillespie Dam. The base flow is maintained by a combination of (1) ground-water discharge to the river, (2) ground-water pumpage near Buckeye to reduce water logging, (3) spills from irrigation canals, and (4) surface- and subsurface-irrigation returns. The combined inflow from these four sources from March 1978 to June 1980 was estimated to be about 204,000 acre-ft (table 1). This estimate was made using the base-flow record from October 1974 to September 1981 for the Gila River above diversions at Gillespie Dam (fig. 3).

The total streamflow losses in the 74-mile reach between Granite Reef and Gillespie Dams were at least 474,000 acre-ft. Most of the water infiltrated into the permeable alluvial deposits along the Salt and Gila Rivers and increased the amount of ground water in storage; an unknown small percentage of the water, however, was evaporated or transpired.

Infiltration rates along the channel of the Salt River below Granite Reef Dam were computed for May 9, 1979. The computations were made using the streamflow losses between selected sites along the Salt River and the area inundated by the flow as defined by aerial photographs taken on May 9, 1979. The photographs did not show evidence of tributary inflow, and the volume of water lost to evapotranspiration was a few tens of acre-feet and was assumed to be negligible. Infiltration rates for the selected reaches were from 0.44 to 1.3 ft/d and averaged about 0.9 ft/d for the 29.8-mile reach of the river below Granite Reef Dam (table 2).

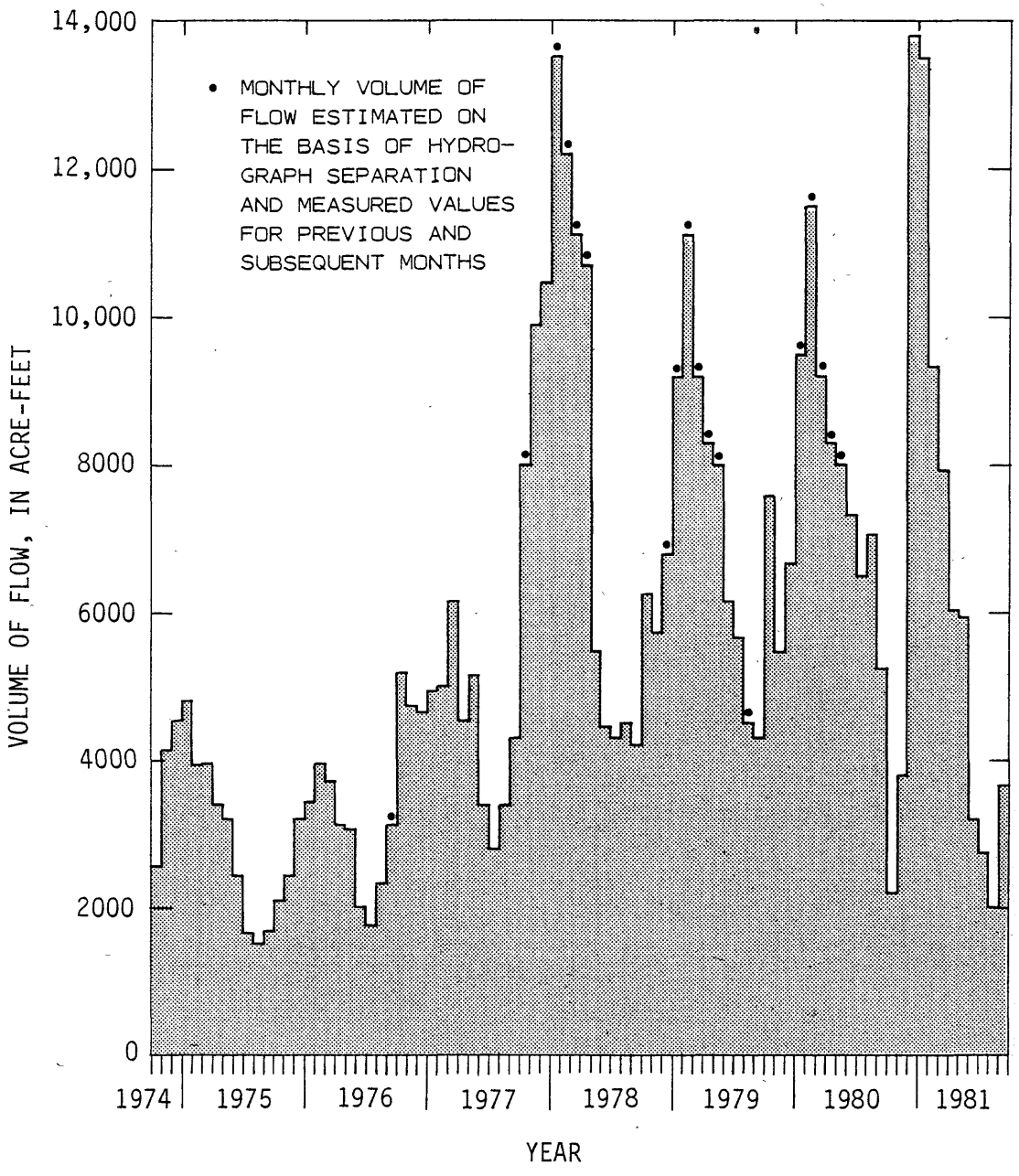



Figure 3.--Base flow for Gila River above diversions at Gillespie Dam.

Table 2.--Infiltration rates for selected reaches of the Salt River—May 9, 1979

| Site | Distance below Granite Reef Dam, in miles | Volume of flow, in acre-feet per day | Loss, in acre-feet per day | Inundated area, in acres | Cumulative total, in acres | Average infiltration rate, in feet per day |
|---|---|---|---|---|---|---|
| Salt River below Granite Reef Dam..... | 0 | 912 | --- | --- | --- | ---- |
| Salt River at Hayden Road..... | 15.4 | 274 | 638 | 486 | 486 | 1.3 |
| Salt River at Jointhead Dam... | 19.5 | 218 | 56 | 128 | 614 | 0.44 |
| Salt River at 35th Avenue..... | 29.8 | 87 | 131 | 288 | 902 | 0.45 |
| Total..... | ---- | --- | 825 | --- | 902 | 0.91 |

The computed infiltration rates for May 9, 1979, are significantly less than those computed for April 1965 by Briggs and Werho (1966). For example, in the reach between Granite Reef Dam and 48th Street—referred to as Salt River at Jointhead Dam in this report—Briggs and Werho (1966) calculated an average infiltration rate of 2.5+ ft/d; in contrast, the computed rate for May 9, 1979, is 1.1 ft/d. The difference is the result of one or both of the following: (1) The channel of the Salt River had been virtually dry for more than 20 years prior to the release of April 1965, whereas the channel had been wet for most of a 6-month period prior to May 1979, or (2) the inundated area was 40 percent greater in April 1965, and the infiltration rates may be larger in areas not inundated in May 1979.

## CHANGES IN GROUND-WATER LEVELS

From February 1978 to May 1980, ground-water levels in 169 wells that tap the alluvial deposits in the Salt River Valley rose an average of 35.5 ft (table 3). The rise in ground-water levels was a direct result of the infiltrating floodwaters and the marked decrease in ground-water pumpage. Although an unknown percentage of the 474,000 acre-ft of streamflow losses was evaporated or transpired, most of the water recharged the ground-water system. In addition, ground-water pumpage was reduced by about 630,000 acre-ft/yr for 1978-80 owing to the abundance of surface water. For 1978-80, the average annual amount of ground-water pumpage was about 1.08 million acre-ft (U.S. Geological Survey, 1982) as compared to 1.71 million acre-ft annually for 1975-77, which is a reduction of about 35 percent. The reduction in ground-water pumpage in 1978-80 accounted for a total of about 1.9 million acre-ft of water.

Table 3.--Changes in ground-water levels in wells

| Period | Number of wells | Average water-level rise, in feet | Maximum water-level rise, in feet | Maximum water-level decline, in feet |
|---|---|---|---|---|
| February 1978 to April 1979..... | 183 | 22.0 | 124 | 76 |
| April 1979 to May 1980..... | 190 | 11.3 | 43 | 34 |
| February 1978 to May 1980..... | 169 | 35.5 | 145 | 43 |