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ANNUAL REPORT ON GROUND WATER IN ARIZONA SPRING 1965 TO SPRING 1966

BY

E. B. HODGES AND OTHERS

PREPARED BY THE GEOLOGICAL SURVEY

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ANNUAL REPORT ON GROUND WATER IN ARIZONA, SPRING 1965 TO SPRING 1966

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ABSTRACT

By

E. B. Hodges

The depletion of the ground-water resources in Arizona is continuing at a rapid rate. The economy of Arizona, especially that of agriculture, is dependent on the availability of adequate water supplies of suitable chemical quality. Nearly two-thirds of the water supply for the State is obtained from ground water. In order to manage the available supplies to provide for the growing demand for ground water, it is necessary to have a comprehensive knowledge of the hydrogeologic characteristics that control the storage and transmission of water through the saturated subsurface rocks.

The current program of ground-water studies conducted by the U.S. Geological Survey in cooperation with the Arizona State Land Department includes the collection of the geologic and hydrologic data necessary to the evaluation of the ground-water resources of the State. More important, however, it also includes a detailed analysis of the data and research into new and better methods of analysis that will provide solutions to the problems of availability, effects of withdrawal, and changes in the chemical quality of the water. This report presents discussions of the ground-water conditions in selected basins and areas in the State based on the hydrologic data collected from spring 1965 to spring 1966.

Declining water levels are common in nearly all the highly developed areas in the State, especially in the Basin and Range lowlands province of southern Arizona, where the use of water for irrigation is greatest. The largest agricultural areas in the State are the Salt River Valley and the lower Santa Cruz basin; it is in these areas that the greatest water-level declines have taken place. The average decline in water level in one area of the lower Santa Cruz basin was more than 8 feet from spring 1965 to spring 1966 and has been more than 170 feet since 1940. Other areas in the Basin and Range lowlands where large water-level declines have taken place include the Stewart and Kansas Settlement areas in the Willcox basin, the Bowie and San Simon areas in the San Simon basin, and the Avra Valley west of Tucson.

New development in other areas, such as the Sierra Bonita Ranch area in the Willcox basin and large parts of the Douglas basin, probably will increase the rate of decline of the water level in these areas.

The withdrawal of ground water for all purposes was about 4.0 million acre-feet in 1965 compared with about 4.5 million acre-feet for the last several years. The chief use of ground water in the State is for the irrigation of crops. For the most part, the 1,160,000 acres of land cropped in Arizona in 1965 was irrigated with ground water, although about 2.6 million acre-feet of surface water was diverted for use in the State in 1965. Most of the ground water is withdrawn and used in the Basin and Range lowlands province, and two areas--the Salt River Valley and the lower Santa Cruz basin--account for more than 60 percent of the total amount withdrawn in the State.

INTRODUCTION

By

E. B. Hodges

The economy of Arizona is dependent on the availability of adequate water supplies. In arid regions, the demand for water is greater and the supply is smaller than in humid areas. In Arizona, most of the rainfall evaporates before it reaches the streams. Although some streamflow is stored in reservoirs for irrigation use, the amount of surface water available is not sufficient to supply the demands of the large agricultural developments in southern Arizona. Agriculture, therefore, is being sustained by ground water, which furnishes nearly two-thirds of the water supply for the State. Depletion, or "mining," of ground-water reserves is recognized as a practical means of providing sufficient water supplies in arid lands. This "mining," however, must be controlled by proper management in order to conserve and, where possible, supplement the supplies.

Proper management of the ground-water resources to distribute the supplies adequately requires a comprehensive knowledge of the hydrogeologic characteristics that control the storage capacity and the transmission of water through the saturated subsurface rocks. Continued data collection specialized studies, and new methods of hydrologic analysis will provide this knowledge.

Since July 1939, a cooperative agreement that provides for equal financial participation in a planned program of ground-water studies has been in effect between the U.S. Geological Survey and the State of Arizona. From 1939 to 1942, the State was represented by the State Water Commissioner; since 1942, the State has been represented by the State Land Department. In the early years, the program consisted mostly of the collection of basic data concerning the development of ground-water resources. In recent years, there has been more emphasis on compilation and analysis of the hydrologic and geologic data and particularly on research into new and better methods of analysis that will provide quantitative solutions to the problems of availability, effects of withdrawal, and changes in chemical quality of the water. Analysis of hydrologic data by electrical-analog model is a method that has many advantages over some of the standard mathematical methods. The method is based on the fact that the flow of ground water in aquifers is analogous to the flow of electrical current; thus, it is possible to simulate conditions in a ground-water system with electronic equipment and instrumentation. A resistance-capacitance electrical curcuit serves as an exact analog for the flow of ground water in an aquifer. Analysis of the hydrologic data by electrical-analog methods for a basin may make it possible not only to appraise the water resources of an area and the current trend of development but also to predict what may happen in the future under different specified sets of circumstances.

Scope of the Federal-State Cooperative Ground-Water Program

By

E. B. Hodges

The current cooperative ground-water program in Arizona consists of three major closely related parts, which are described below. (1) The statewide ground-water survey provides the long-term basic records necessary to a comprehensive ground-water investigation. This phase of the cooperative program includes well inventories, periodic water-level measurements, collection of water samples for chemical analysis, and collection and cataloging of drill cuttings from new wells. These data are compiled and analyzed, and the results are summarized each year in the "Annual Report on Ground Water in Arizona." The report is published by the State Land Department, and copies are available to the public. An additional phase of the program is aimed at a systematic analysis of current ground-water conditions and, wherever feasible, predictions of future conditions in specified basins or areas. The purpose of this phase is to make better use of the data that are collected under the main part of the statewide ground-water survey. This objective is accomplished by a more comprehensive analysis of the data that can be achieved for the annual report on groundwater for the entire State and by the publication of this analysis in separate reports that will be more detailed and timely for use by the public. Several reports of this type are being prepared this year; these reports will present more comprehensive discussions of ground-water conditions in Douglas basin, the Waterman Wash area, Gila Bend basin, and McMullen Valley. (2) Comprehensive ground-water investigations are made in selected areas where ground-water conditions are becoming critical due to overdevelopment, where ground-water development is beginning, or where there is some special problem or interest. These more comprehensive investigations result in an overall evaluation of the water resources of an area. (3) Studies related to specific hydrologic problems, such as insufficient water supplies, equitable distribution and protection of the available supply, and deterioration in quality of water, may be needed wherever ground water is pumped in large quantities. For the most part, these studies are made in relation to the particular problem rather than to an area or basin. This phase of the program includes research into new and better methods of analysis.

Summary of Current Ground-Water Programs in Arizona

By

E. B. Hodges

In addition to the statewide ground-water survey and the resulting reports described above, field investigations were in progress for four projects, and reports were in various stages of completion for five projects under the Federal-State cooperative program in 1965.

Projects for which fieldwork is in progress are as follows: (1) Ground-water resources of the western part of the Salt River Valley (Beardsley area). The purpose of this project is to estimate the ground-water storage capacity of the water-bearing deposits to an economical pumping depth under present conditions. (2) Basin potential of Sycamore Creek. The objective of this project is to determine the potential surface inflow to Sycamore Creek and the total outflow from the basin. (3) Water resources of southern Coconino County. Most of the large water supplies in this area are obtained either from the deeply buried multiple aquifer system or from storage of surface water in open and leaky reservoirs. The purpose of the project is to determine the amount, availability, and movement of ground water in both the deep and the shallow aquifers. (4) Water resources of the Sacramento and Hualapai Valleys. This project is designed to determine the quality and quantity of the water resources in the area and to determine the average annual inflow and outflow.

Projects for which reports are in the final stages of preparation are: (1) Geology and ground-water resources of Big Sandy Valley, Mohave County; (2) Geohydrology and utilization of water in Willcox basin; (3) Change in water yield by defoliation and vegetation removal, Cottonwood Wash, Mohave County; (4) Basin potential of Sycamore Creek (fieldwork also still in progress); and (5) Anticipated changes in the flow regimen of the East Verde River caused by importation of water.

In addition to the projects described above, another special project will present the results of an electrical-analog analysis of geologic and hydrologic data for a part of central Arizona. This part of Arizona is the most highly developed agricultural area in the State, and large amounts of ground water are withdrawn each year. The water levels in the area are declining, and the aquifer is being dewatered. The analog model for the area has been constructed on the basis of geologic and hydrologic data collected over many years. The model will be used to predict future ground-water conditions in the area under a hypothesized set of conditions that relate to the withdrawal of ground water. The analog-model analysis may provide solutions to the problems that confront water management in areas where ground-water withdrawal far exceeds the replenishment, as in this part of central Arizona.

In addition to the Federal-State cooperative program, work also was in progress under agreements with several other cooperators in 1965. Two studies were being conducted in cooperation with the University of Arizona. Cooperation with other Federal agencies included projects for the U.S. Army and the Bureau of Indian Affairs. The results of the work done under these programs also benefit the State. Figure 1 is a pictoral summary of the status of current groundwater work in Arizona.

Current Publications of the Arizona District

By

C. L. Hicks

The following reports on the water resources and geology of Arizona were published or released to the open file from July 1, 1965, through June 30, 1966.

Surface-water records of Arizona, 1964, by U.S. Geological Survey: U.S. Geol. Survey open-file report, 1964. 206 p., 2 figs.

> The surface-water records for the 1964 water year for gaging stations and miscellaneous sites in the State of Arizona and a few pertinent gaging stations in bordering States are given in the report.

Water-quality records in Arizona, 1964, by U.S. Geological Survey: U. S. Geol. Survey open-file report, 1964. 80 p., 1 fig.

> The water-quality records for the 1964 water year for Arizona are given in this report.

Earth cracks--a cause of gullying, by Willaim Kam, in Geological Survey research 1965: U.S. Geol. Survey Prof. Paper 525-B, 1965. p. 122-125, 3 figs.

> The development of earth cracks accompanying land-surface subsidence that results from differential compaction of heterogeneous unconsolidated sediments favors gullying. Where newly formed earth cracks transect drainageways, lower base levels established at the points of transection favor more rapid erosion and the formation of gullies upstream from the cracks. At other places, new gullies form upslope from earth cracks where no drainageways had existed before. Where the material beneath the cracks does not absorb the water transmitted by these gullies, diversion of the gully streams along the cracks may lead to changes in drainage pattern.

Electrical-analog analysis of hydrologic data for San Simon basin, Cochise and Graham Counties, Arizona, by N. D. White and W. F. Hardt: U.S. Geol. Survey Water-Supply Paper 1809-R, 1965. 30 p., 2 pls., 5 figs., 1 table.

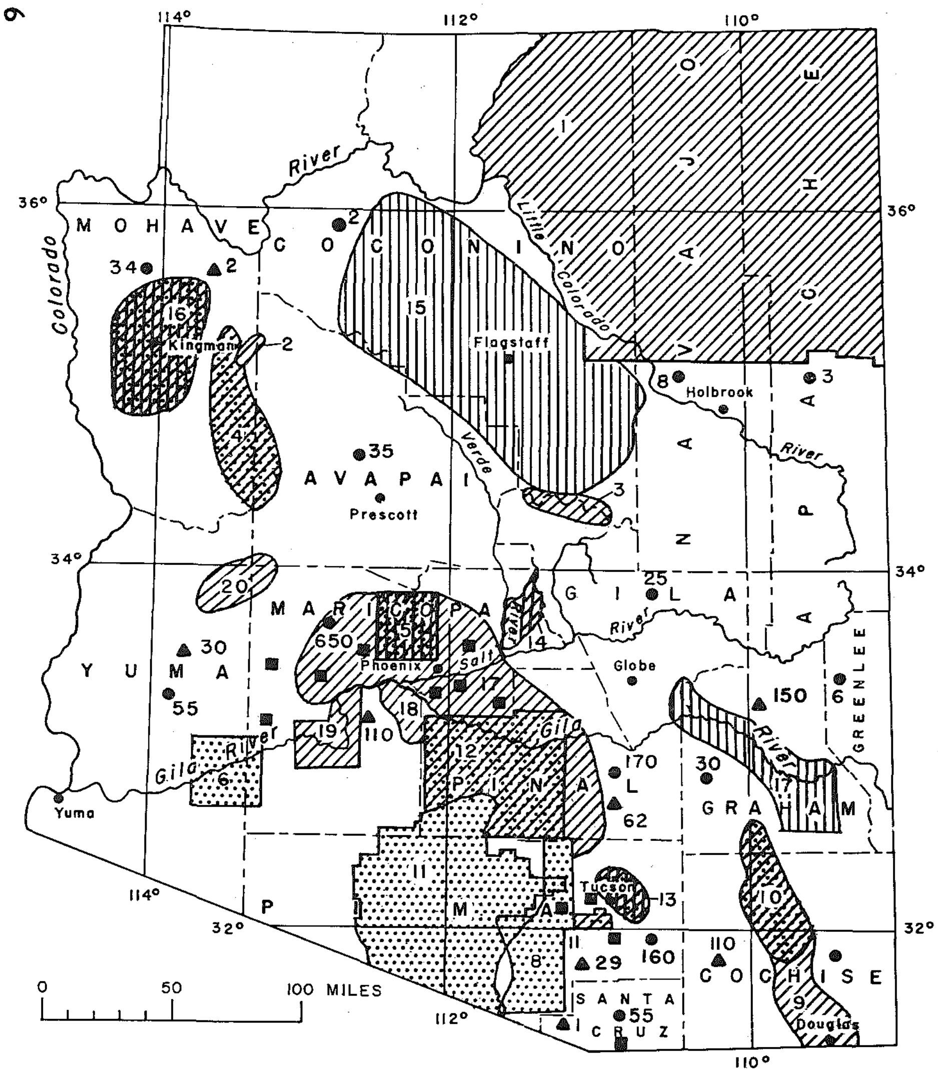


Figure 1.--Summary of ground-water programs and location of data-collection sites.

AREAS OF INVESTIGATIONS

1. Navajo-Hopi Indian Reservations
2. Cottonwood Wash
3. East Verde River
4. Big Sandy Valley
5. Western part of the Salt River Valley (Beardsley area)
6. Dateland-Hyder area
7. Arid-lands study (Safford Valley)
8. Avra-Altar Valley
9. Douglas basin
10. Willcox basin
11. Papago Indian Reservation
12. Western Pinal County
13. Tucson basin
14. Sycamore Creek
15. Southern Coconino County
16. Sacramento and Hualapai Valleys (Kingman area)
17. Part of central Arizona
18. Waterman Wash area
19. Gila Bend area
20. McMullen Valley

Area where field investigation is in progress (As of June 1966)

Area for which a report is in preparation (As of June 1966)

Area for which a report was released July 1965-June 1966

A multiple pattern indicates that, although a report was released in the prescribed period, further work and (or) reports also are in progress

● 480 Active observation wells (figure indicates number of observation wells in county)

▲ 150 Well-discharge measurements made in 1965 (figure indicates number of measurements made in county)

■ Site where continuous water-stage recorder is in operation

Ground-water levels may be expected to decline as much as 120 feet near Bowie and 160 feet near San Simon from 1960 to 1980. By superimposition of these decline data on known data for 1960, the altitude of the water level for 1980 is predicted. The predictions were made on the basis of data from an electrical-analog-model analysis of the aquifers in the basin.

Mesozoic formations in the Comobabi and Roskruge Mountains, Papago Indian Reservation, Arizona, by L. A. Heindl and C. L. Fair: U.S. Geol. Survey Bull. 1194-H, 1965. 15 p., 2 figs.

The report defines and describes briefly a composite Mesozoic section in south-central Arizona. The section comprises six new formations, which consist of andesitic to rhyolitic volcanic rocks and of sedimentary deposits largely derive from them. The composite section is between 20,000 and 35,000 feet thick. The Mesozoic age of the deposit is made on the basis of contrast of the volcanic character of the lowest unit to the marine character of the Paleozoic rocks, nonspecific dinosaurian fossil fragments, and radiometric dating of the top unit.

Mesozoic(?) rocks in the Baboquivari Mountains, Papago Indian Reservation, Arizona, by L. A. Heindl and C. L. Fair: U.S. Geol. Survey Bull. 1194-I, 1965. 12 p., 1 fig.

The report defines and describes briefly a Mesozoic section and probable related metamorphic rocks in south-central Arizona. The section comprises three formations, which consist of sedimentary deposits and volcanic rocks of rhyolitic to andesitic composition. The section is about 20,000 feet thick. The Mesozoic(?) age is given largely on the basis of the similarity of some units to Mesozoic rocks nearby, their dissimilarity to Paleozoic rocks, and their angular unconformity with overlying Tertiary deposits.

Quaternary geology of the Southwest, by F. E. Kottlowski, M. E. Cooley, and R. V. Ruhe, _in_ The Quaternary of the United States, H. E. Wright, Jr., and D. G. Frey, eds.: New Jersey, Princeton University Press, 1965. p. 287-298, 3 figs.

The report describes the Quaternary geology of the Southwest, including Arizona. The Southwest is a key junction of the Quaternary deposits and geomorphic surfaces of the Great Plains from the east, the semiarid Basin and Range on the west and to the northwest, the Colorado Plateaus on the north, and the glaciated Rocky Mountains and their intermontane basins on the northeast.

Water-resources investigations in Arizona, 1965, by U.S. Geological Survey: U.S. Geol. Survey open-file report, 1965. 8 p., 6 figs.

The report gives the number of streamflow stations, quality-of-water collection sites, and investigations in progress in 1965. It also contains a list of publications by the U.S. Geological Survey regarding water-resources investigations in Arizona.

Bibliography of U.S. Geological Survey water-resources reports, Arizona, 1891 to 1965, by U.S. Geological Survey: Arizona State Land Dept. Water-Resources Rept. 22, July 1965. 59 p., 4 tables.

The bibliography includes all Arizona district water-resources reports through 1965.

Description and analysis of the geohydrologic system in western Pinal County, Arizona, by W. F. Hardt and R. E. Cattany: U.S. Geol. Survey open-file report, August 1965. 92 p., 24 figs., 7 tables.

The report includes a flow-net analysis, water-level data, and an evaluation of the geohydrologic system in western Pinal County. About 25 percent of the water pumped in Arizona comes from this 2,000-square-mile area, the second largest agricultural area in the State.

Ground water in fractured volcanic rocks in southern Arizona, by L. A. Heindl: Yugoslavia, Dubrovnik, Symposium hydrol. of fractured rocks, August 1965. 28 p., 3 figs.

Fractured volcanic rocks, mostly andesitic flows, provide only small to moderate amounts of water in southern Arizona. Their water-bearing potential is virtually untested, largely because adequate volumes of water are obtained from shallower and more easily drilled alluvial deposits. Nonetheless, andesitic flows underlie alluvium in many places and are untapped sources of ground water of usable quality. Wells in andesitic flows locally yield as much as 1,000 gallons per minute of water, but yields are highly variable and cannot now be predicted, even within short distances.

Geohydrology of the Dateland-Hyder area, Maricopa and Yuma Counties, Arizona, by W. G. Weist, Jr.: Arizona State Land Dept. Water-Resources Rept. 23, November 1965. 46 p., 8 figs., 6 tables.

The ground-water reservoir in the Dateland-Hyder area is recharged by precipitation, underflow, and excess irrigation water. Discharge occurs by underflow, pumping from wells, and evapotranspiration. In general, the water levels in the area slowly are declining. The average specific capacity of the irrigation wells is 42 gallons per minute per foot of drawdown. This indicates a coefficient of transmissibility of about 71,000 gallons per day per foot. It is estimated that the first 100 feet of saturated material contains about 5,000,000 acre-feet of available ground water. Additional development of ground water for irrigation is possible in most of the area.

Annual report on ground water in Arizona, spring 1964 to spring 1965, by N. D. White and others: Arizona State Land Dept. Water-Resources Rept. 24, December 1965. 62 p., 22 figs.

The Arizona water-level report is based on hydrologic data collected from spring 1964 to spring 1965. The report discusses ground-water conditions, pumpage, and surface-water diversions in selected basins and areas in Arizona.

A reconnaissance of lakes and proposed lake sites in the White Mountains, Fort Apache Indian Reservation, Arizona, by R. H. Musgrove and M. E. Cooley: U.S. Geol. Survey open-file report, December 1965. 15 p., 3 figs.

During the past several years, 12 lakes were built for recreational purposes on headwater streams of the Salt River on the Fort Apache Indian Reservation in the White Mountains. At least nine additional lakes are proposed. The purpose of this study was to determine the feasibility of measuring the amount of surface water that flows through the lakes as a means of calculating the effects of the lakes on the water resources of the area. The report concludes that the fracturing, large number of open channels, and water in the broad seepage areas that cannot be gaged preclude calculating the effects of the lakes on the water resources by means of streamflow measurements.

Activities of the Water Resources Division in Arizona, by U.S. Geological Survey: U.S. Geol. Survey open-file report, 1966. 14 p., 1 fig.

Investigations in Arizona by the Water Resources Division of the Geological Survey include collection of basic data, areal studies of water resources, and research to develop a broader understanding of the hydrology of arid lands. Each of these broad categories is directed toward obtaining the information needed by water management for the solution or alleviation of water problems of the State.

Arizona Water, by J. W. Harshbarger, D. D. Lewis, H. E. Skibitzke, W. L. Heckler, and L. R. Kister, revised by H. L. Baldwin: U.S. Geol. Survey Water-Supply Paper 1648, 1966. 85 p., 22 figs.

The report summarizes the occurrence and use of water in Arizona. It is designed to be read by the general public, as well as by the professional audience. Arizona's problems of high evaporation, scarcity of surface water, declining ground-water levels, and soil salinity are discussed in the report. It considers possible methods of water conservation, and contains suggestions for better water management.

Maps showing flouride content and salinity of ground water in the Willcox basin, Graham and Cochise Counties, Arizona, by L. R. Kister, S. G. Brown, H. H. Schumann, and P. W. Johnson: U.S. Geol. Survey Hydrol. Inv. Atlas HA-214, 1966. 6 p., 2 map sheets.

The available hydrologic and geologic data relating to the chemical quality of the ground water of the Willcox basin are summarized in this report.

Salinity of the ground water in western Pinal County, Arizona, by L. R. Kister and W. F. Hardt: U.S. Geol. Survey Water-Supply Paper 1819-E, 1966. 21 p., 2 pls., 5 figs., 2 tables.

The chemical quality of the ground water in western Pinal County is nonuniform areally and stratigraphically. The main areas of highly mineralized water are near Casa Grande and Coolidge. Striking differences have been noted in the quality of water from different depths in the same well.

Throughfall for summer thunderstorms in a juniper and pinyon woodland, Cibecue Ridge, Arizona, by M. R. Collings: U.S. Geol. Survey Prof. Paper 485-B, 1966. 13 p., 6 figs., 5 tables.

The report is concerned with a method of determining throughfall. The throughfall is influenced by (a) the gage direction, (b) the distance the gage is from the tree bole, (c) the tree size, and (d) the tree species. Comprehensive analyses are made of the factors involved, and their statistical significance is discussed. The relation between throughfall, precipitation, stemflow, and interception is investigated and analysed.

Water resources of Fort Huachuca Military Reservation, southeastern Arizona, by S. G. Brown, E. S. Davidson, L. R. Kister, and B. W. Thomsen: U.S. Geol. Survey Water-Supply Paper 1819-D, 1966. 57 p., 2 pls., 17 figs., 9 tables.

Spring flow in two mountain streams near the Fort is adequate to supplement the presently overdeveloped ground-water supply, either through direct use or through artificial recharge to the aquifer. A second well field can be developed by tapping ground water that now moves northeastward out of the reservation area.

An appraisal of the ground-water resources of Avra and Altar Valleys, Pima County, Arizona: Arizona State Land Dept. Water-Resources Rept. 25, February 1966. 66 p., 12 figs., 5 tables.

In Altar Valley ground-water development is minimal, and the effects of withdrawal are local. However, large amounts of ground water are withdrawn from the aquifer in Avra Valley, and the effect is a regional lowering of the water table. A map in the report shows the predicted depth to water for spring 1970 in Avra Valley. The predictions are based on past trends in ground-water conditions and a hypothesized regimen of ground-water withdrawal.

Basic hydrologic data of the Hualapai, Sacramento, and Big Sandy Valleys, Mohave County, Arizona, by J. B. Gillespie, C. B. Bentley, and William Kam: Arizona State Land Dept. Water-Resources Rept. 26, March 1966. 39 p., 6 figs., 10 tables.

The report is a summary of the basic hydrologic data for Hualapai, Sacramento, and Big Sandy Valleys. The purpose of the report is to make available selected well records, drillers' logs, and quality-of-water information, which will be useful in developing the water resources of the area.

Structure and stratigraphy of the central, northern, and eastern parts of the Tucson basin, Arizona, by E. F. Pashley, Jr.: U.S. Geol. Survey open-file report, May 1966. 273 p., 5 pls., 44 figs., 9 tables.

The report shows how such varied aspects of the geology as folds in the gneiss of the mountains and the character of the frontal fault affect the occurrence of ground water in the basin.

Basic ground-water data for western Salt River Valley, Maricopa County, Arizona, by William Kam, H. H. Schumann, L. R. Kister, and F. E. Arteaga: Arizona State Land Dept. Water-Resources Rept. 27, June 1966. 72 p., 11 figs., 4 tables.

The report is a summary of the basic ground-water data that are useful in planning and studing water-resources development in the area. The report contains selected well records, drillers' logs, and quality-of-water information.

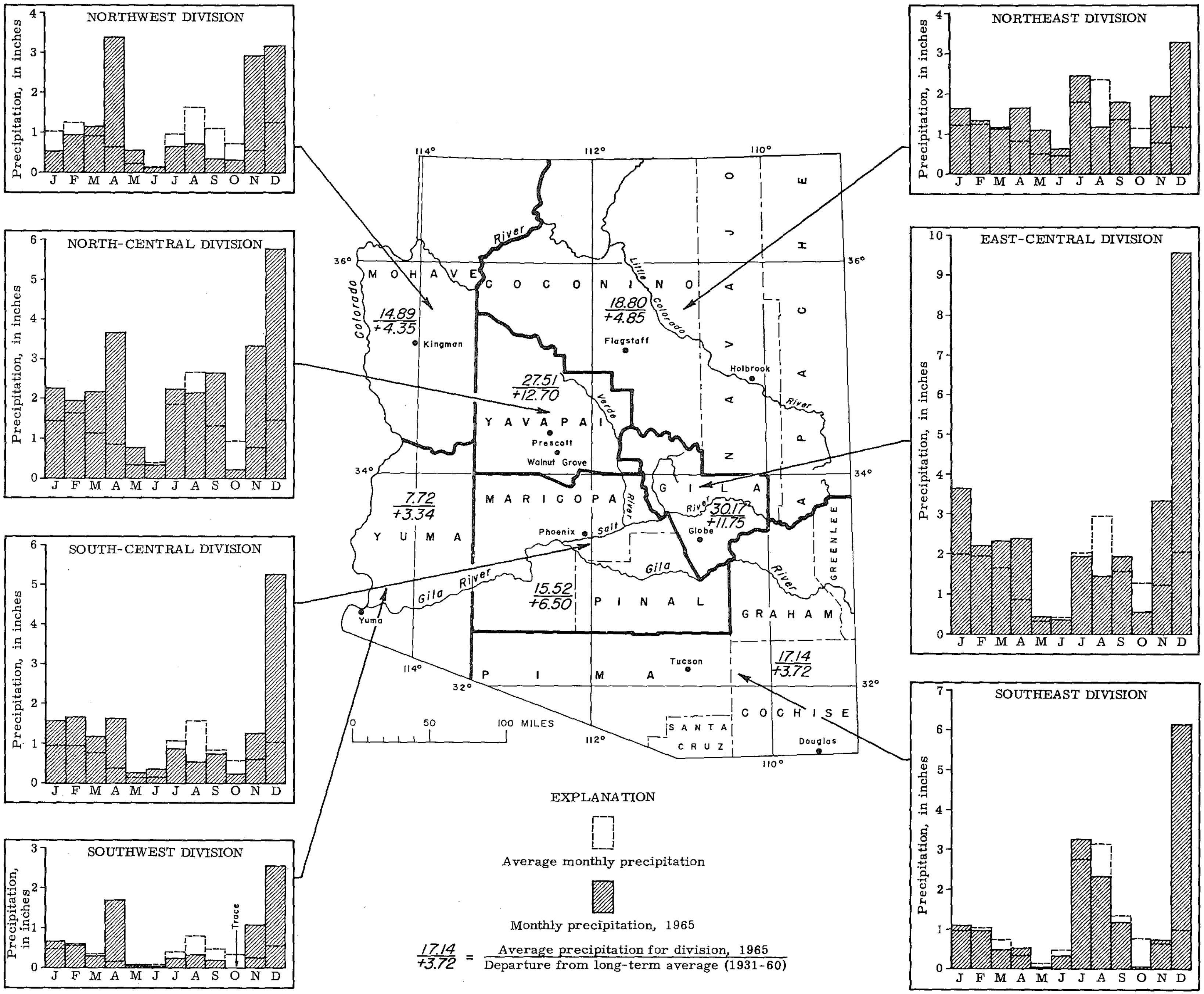
Climate

By

E. B. Hodges

The arid to semiarid climate of most of Arizona bears a direct relation to the need for irrigation of crops and, in particular, to the necessity of using ground water for irrigation. About half of Arizona receives less than 10 inches of precipitation annually. In general, the areas that have the highest temperatures and longest growing seasons are the most highly developed for agriculture; however, they also are the areas of lowest rainfall. Evaporation and transpiration rates are high, and only a small part of the total precipitation can be utilized beneficially, either directly by growing plants or as recharge to the ground-water reservoir. Only about 1 percent of the total annual precipitation is available for recharge; thus, it is impossible, in most areas, for natural ground-water recharge to equal ground-water withdrawal.

The U.S. Weather Bureau has subdivided the State into seven parts for the purpose of computing average precipitation values. The monthly and annual averages for each division for 1965 and the departures from the long-term average are shown in figure 2. Precipitation for 1965 was greatly above average in all divisions; in the north-central division it was 12.70 inches above average, and in the east-central division it was 11.75 inches above average. At individual stations within or immediately adjacent to these two divisions, the annual precipitation was generally the greatest since 1905. At Flagstaff and Walnut Grove the precipitation was more than for any year since the beginning of continuous records in 1898. Precipitation was more than 52



Data from U.S. Weather Bureau, 1966

FIGURE 2.--PRECIPITATION DATA FOR 1965 BY CLIMATIC SUBDIVISIONS.

inches at two stations, and six other stations reported more than 40 inches for the year. The lowest annual precipitation reported was 4.85 inches at Yuma, which, nevertheless, was 1.82 inches above average for this station. Only three stations, one in the northeast division and two in the southeast division, reported below-average precipitation; the departures from normal ranged from -0.12 to -0.58 inch.

Figure 2 shows some interesting precipitation patterns. Although the highest monthly average precipitation in Arizona occurs in August, the rainfall was below average in August 1965. Normally, April and November precipitation is the lowest of the year; however, rainfall was above normal in all divisions during these months in 1965. In December, precipitation ranged from 1.92 inches above average in the northwest division to 7.52 inches above average in the east-central division.

Several major storms occurred during 1965. In early January, about 4 inches of precipitation was measured along the Mogollon Rim in east-central Arizona. Large amounts of precipitation, mostly snowfall, occurred nearly every day during the first half of April; the largest storms were in the upper Verde River basin and Flagstaff areas, where snowfall was the greatest of record for that month. A series of storms beginning about November 22 and continuing through the end of December brought large amounts of precipitation to all parts of Arizona. At times the snow level reached low elevations; periods of warming temperatures and heavy rainfall caused frequent melting of the heavy snowpack. Flagstaff reported a record snowfall of 38.5 inches for December. Many stations in Arizona recorded the alltime maximum precipitation for December; many of these records have been continuous from 50 to 70 years.

Surface-Water Runoff, Storage, and Diversions

By

C. J. Cox

As is common in Arizona, stream runoff varied greatly in the 1965 water year (October 1, 1964, to September 30, 1965)--from month to month throughout the year and from place to place in the State. The variations are related to differences in precipitation, temperature, topography, and geology. The yearly mean discharge at six key gaging stations listed in the following tabulation ranged from 45 to 210 percent of the median of yearly mean discharge; the flow was above the median at three of the stations and below the median at three. The median of the yearly mean discharge is defined as the middle value of discharge when arranged in order of size. For the index stations, the median is computed from the yearly mean discharges for the 1931-60 period of record.

Discharge in the 1965 water year was excessive (in the upper 25 percentile of the reference period) at three of the key stations, deficient (in the lower 25 percentile of the reference period) at one station, and slightly below median at the other two stations. Monthly excessive flows and monthly deficient flows occurred sporadically during the year. Record-low monthly flows occurred in October and July in the Virgin River at Littlefield; no other record-high or record-low monthly flows occurred during the year.

Station	Discharge (acre-feet)	Percent of median
Colorado River near Grand Canyon 1/	10,980,000	----
Little Colorado River near Cameron . . .	225,900	132 (excessive)
Virgin River at Littlefield	120,400	83
Gila River at head of Safford Valley, near Solomon	183,800	90
San Pedro River at Charleston	16,140	45 (deficient)
Salt River near Roosevelt	734,400	188 (excessive)
Verde River below Tangle Creek, above Horseshoe Dam	603,500	210 (excessive)

1/ No longer used as a key station.

The discharge of the Colorado River near Grand Canyon no longer represents natural runoff, because of storage in Lake Powell (Glen Canyon Dam), which began in March 1963, and in other upstream reservoirs. The percent of median discharge has not been computed, and this gaging station is no longer used as a key station. Storage in Lake Powell increased 2,252,000 acre-feet in 1965; the maximum storage for the period of operation of the reservoir was on August 10, 1965, when the contents reached 8,715,000 acre-feet. The combined storage in Lakes Mead and Mohave increased 3,114,000 acre-feet during the 1965 water year; however, month-end storage was below average throughout the year.

There was no flow in the Little Colorado River near Cameron in November, December, and June. The lack of flow during November and December is a comparatively rare occurrence but is common in June.

The discharge of the Santa Cruz River at Tucson was 935 acre-feet for the 1965 water year, only 9 percent of the median flow for the period of record (1906-65). The Santa Cruz River is an intermittent stream subject to large variations in flow—from time to time and from place to place along the river. For example, a storm along the west boundary of the upper Santa Cruz basin in September resulted in a peak flow at Lochiel of 4,810 cfs (cubic feet per second)—a high for the period of record; however, the yearly flow in the Santa Cruz at this point for the 1965 water year was less than average.

In April, the flow of the Verde River below Tangle Creek, above Horseshoe Dam, was more than 14 times the median. The large flow resulted from a combination of sudden warm temperatures on heavy snowpack and large amounts of rainfall during the first 10 days of the month. The storage reservoirs on the Verde River were filled to capacity; the spillway gates on Bartlett Dam were opened on April 19 and spill continued until April 22. About 39,000 acre-feet of water was released during this period (Briggs and Werho, 1966). This was the first spill from the reservoir since 1941. The excess water flowed down the Salt River past Mesa, Tempe, and into Phoenix, causing some damage to stream-bed road crossings. The combined storage in the Salt and Verde Rivers systems of reservoirs increased 592,000 acre-feet during the water year, and the stored contents on September 30 amounted to 57 percent of capacity.

Storage in the principal reservoirs in Arizona as of March 31, 1966, compared with storage for the previous year, is shown below.

	Contents, in acre-feet	
Reservoir	March 31, 1966	March 31, 1965
Lake Pleasant	155,200	34,180
Verde River system	311,700	172,400
San Carlos Reservoir	495,400	76,700
Salt River system	1,684,000	950,000

The preceding tabulation shows substantial increases in reservoir storage from April 1, 1965, to March 31, 1966. Most of the increase was the result of the series of storms that occurred from late November through December. In flow to the Salt and Verde Rivers systems of reservoirs was more than 700,000 acre-feet during December, which completely filled the reservoirs. Water was spilled at Roosevelt Lake for the first time since 1941. Bartlett Reservoir on the Verde River spilled for the second time during 1965; the last previous spill, prior to April 1965, was in 1941. Flows in the Salt River past Phoenix caused extensive damage to bridges, pipelines, airport runways, and gravel pits in the river channel. Runoff from uncontrolled streams along the Gila River and some of its tributaries--the Salt, Verde, San Pedro, and Santa Cruz Rivers and Eagle Creek--generally produced the highest peak discharges since 1940; several were the highest since 1916. The runoff for December at several gaging stations was more than the normal runoff for an entire year.

The total diversion of streamflow in Arizona in the 1965 water year was about 2,640,000 acre-feet, slightly more than in 1964. About 1,630,000 acre-feet was diverted from the Colorado River for use by the Colorado River Indian Reservation, the Gila Project, and the Valley Division of the Yuma Project. These projects use only surface water for irrigation. About 658,000 acre-feet of the water diverted from the Colorado River was returned to the river or discharged across the Arizona-Sonora international boundary.

More than 1,000,000 acre-feet of surface water was diverted from the Gila River basin in the 1965 water year. Of this amount, 765,000 acre-feet, including 60,000 acre-feet for municipal use by the city of Phoenix, was diverted from the Salt River above and at Granite Reef Dam. The other significant surface-water diversions are in the Duncan-Safford and the San Carlos Project areas, where surface water is used in combination with ground water. Figure 3 shows a comparison of diversions and reservoir storage.

Acknowledgments

By

E. B. Hodges

Many irrigation districts, cities, well drillers, water and power companies, government agencies, and individuals provided exceptional cooperation in furnishing information. The following organizations were particularly helpful: Arizona Corporation Commission, Arizona Public Service, Arizona Water Company, Buckeye Irrigation District, city of Phoenix, city of Tucson, Cortaro Farms, Gila Water Commissioner, Goodyear Farms, Maricopa County Municipal Water Conservation District, Roosevelt Irrigation District, Roosevelt Water Conservation District, Salt River Valley Water Users' Association, Salt River Power District, San Carlos Irrigation District, Southwest Gas Corporation, Sulphur Springs Valley Electrical Cooperative, Tucson Gas and Electric Company, U.S. Bureau of Indian Affairs, U.S. Bureau of Reclamation, and U.S. Weather Bureau.

GROUND-WATER CONDITIONS BY AREAS

By

E. B. Hodges

Arizona may be divided into three water provinces that are synonymous with the physiographic provinces. The occurrence of ground water in the State is controlled by the physiography and geology of the provinces. These provinces are (1) the Plateau uplands or Colorado Plateaus province in the northern part of the State, (2) the Basin and Range lowlands province in the southern part of the State, and (3) the Central highlands province, which is transitional between the other two provinces. Each province has certain distinctive ground-water characteristics, and the current ground-water conditions in each will be discussed separately. All wells in the State are located by the numbering system explained in figure 4. Figure 5 outlines the various basins and areas for which ground-water conditions are discussed in this report.

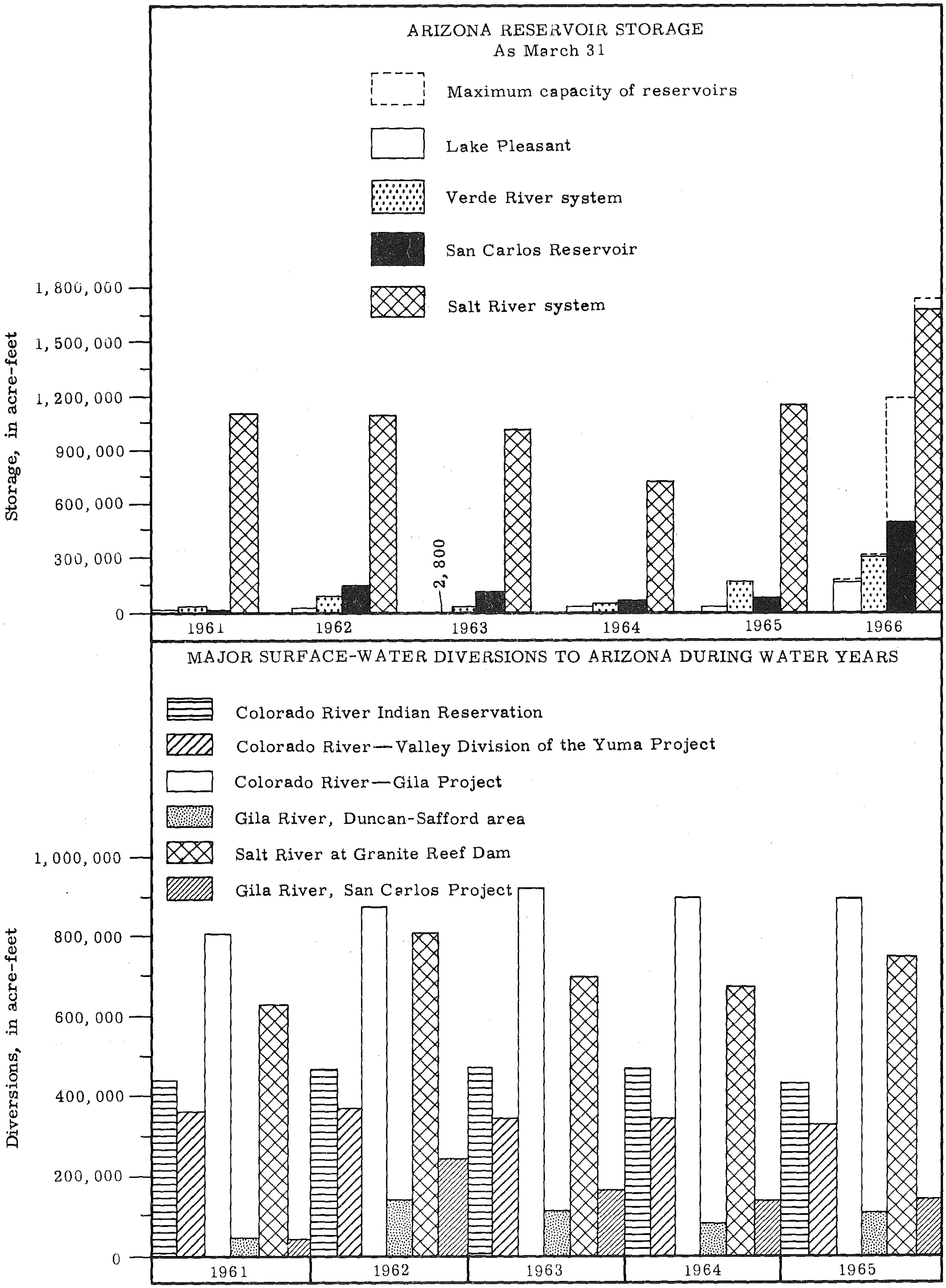
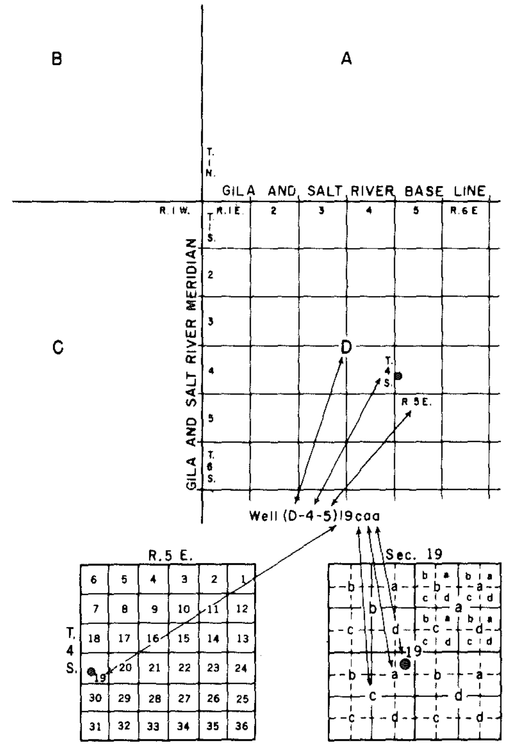
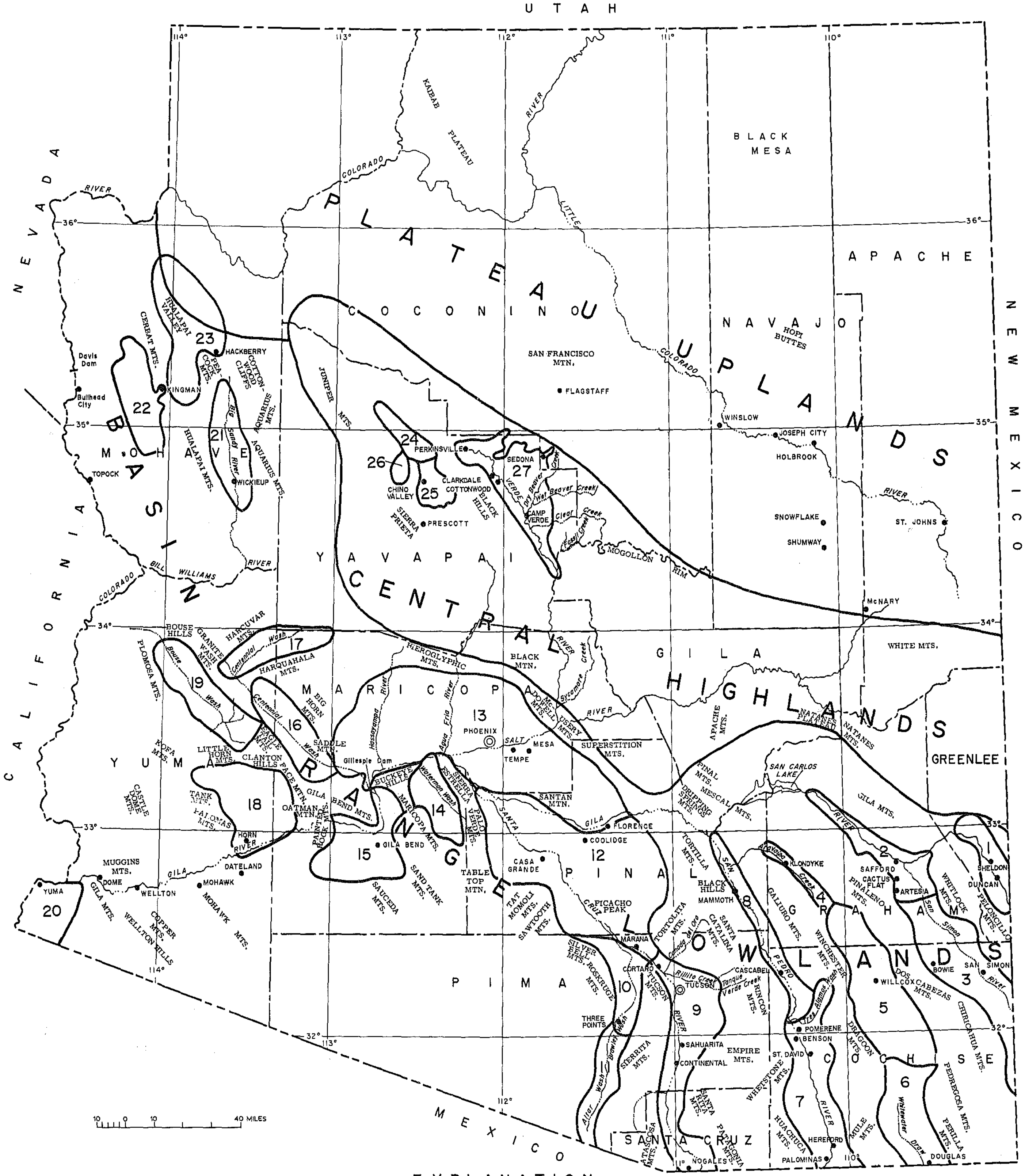


Figure 3. --Surface-water reservoir storage and diversions.



The well numbers used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base line, which divide the State into four quadrants. These quadrants are designated counterclockwise by the capital letters A, B, C, and D. All land north and east of the point of origin is in A quadrant, that north and west in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters also are assigned in a counterclockwise direction, beginning in the northeast quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the well number. In the example shown, well number (D-4-5)19caa designates the well as being in the NE$\frac{1}{4}$NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 19, T. 4 S., R. 5 E. Where there is more than one well within a 10-acre tract, consecutive numbers beginning with 1 are added as suffixes.

Figure 4. --Well-numbering system.



EXPLANATION

BASINS AND AREAS

1. DUNCAN BASIN
2. SAFFORD BASIN
3. SAN SIMON BASIN
4. ARAVAIPA VALLEY
5. WILLCOX BASIN
6. DOUGLAS BASIN
7. UPPER SAN PEDRO BASIN
8. LOWER SAN PEDRO BASIN
9. UPPER SANTA CRUZ BASIN
10. AVRA VALLEY
11. ALTAR VALLEY
12. LOWER SANTA CRUZ BASIN
13. SALT RIVER VALLEY
14. WATERMAN WASH AREA
15. GILA BEND AREA
16. HARQUAHALA PLAINS AREA
17. McMULLEN VALLEY
18. PALOMAS PLAIN AREA
19. RANEGRAS PLAIN AREA
20. SOUTH GILA VALLEY, YUMA MESA, AND YUMA VALLEY AREA
21. BIG SANDY VALLEY
22. SACRAMENTO VALLEY
23. HUALAPAI VALLEY
24. BIG CHINO VALLEY
25. LITTLE CHINO VALLEY
26. WILLIAMSON VALLEY
27. VERDE VALLEY

Figure 5.--Basins and areas for which ground-water conditions are discussed.

Basin and Range Lowlands Province

By

E. B. Hodges

The Basin and Range lowlands province consists of broad gently sloping valleys and basins and high isolated mountain ranges that rise sharply above them. For the most part, the basins are filled with alluvial materials, which, in places, are as much as several thousand feet thick. The unconsolidated or weakly consolidated sediments within this alluvium store large amounts of ground water and yield it readily to wells. The climate in the province is arid to semiarid, growing seasons are long, and the environment generally is favorable for crops and light industry.

During the last few decades there has been extensive development of the water supply in the Basin and Range lowlands province, and it is by far the most extensively developed of the three provinces from the standpoint of ground-water use. More than 1 million acres of land is irrigated using more than 6 million acre-feet of water annually. The ground-water reservoirs are the main source of water used for irrigation. The vast reserves of ground water are being depleted, and the result is a downward trend of the water levels in nearly all the highly developed areas in the Basin and Range lowlands province. The following paragraphs give discussions of the ground-water conditions in all the developed areas in the province by basins and areas, beginning at the eastern edge of the State.

Duncan Basin

By

E. B. Hodges

In the Duncan basin (fig. 5, No. 1), water for irrigation is obtained by diversion from the Gila River when the flow is sufficient to supply the decreed acreage (8,061 acres). When adequate surface water is not available, ground water is pumped from wells; the combined surface-water and ground-water withdrawals remain fairly constant from year to year. In 1965 no diversion of surface water was made in the Duncan basin, and the entire water supply was obtained from wells.

Most irrigation wells in the basin obtain water from the alluvium underlying the flood plain of the Gila River. The water level in the alluvium ranges from a few feet to about 40 feet below land surface. Water levels in a few selected wells are measured regularly to show the long-term effects of pumping ground water for irrigation.

Water levels measured in spring 1966 were from 1 to 3 feet higher than in spring 1965 and from 2 to 7 feet higher than in spring 1961. The hydrographs of the water level in wells (D-8-32)32 and (D-7-31)4 (fig. 6) show changes typical for the area.

Safford Basin

By

V. E. Watson

The majority of irrigation wells in the Safford basin (fig. 5, No. 2) tap the alluvium that underlies the flood plain of the Gila River under conditions similar to those in the Duncan basin. The water levels are from about 10 to 60 feet below land surface and fluctuate in response to the flow of the Gila River and the amount of Gila River water applied to irrigated fields in the area.

From spring 1965 to spring 1966 water levels in wells at the head of Safford Valley rose from about 7 to 8 feet, as illustrated by the hydrographs of the water level in wells (D-7-27)2 and (D-6-28)31 (fig. 6). Well (D-7-27)2 is in the artesian aquifer, and well (D-6-28)31 is in the shallow water-table aquifer. In the area between the head of the valley and Safford, water-level changes ranged from a decline of 0.8 foot to a rise of nearly 12 feet. From Safford to Geronimo, water levels rose from about 1.5 feet to slightly more than 5 feet; the changes in water level in wells (D-6-24)5 and (D-4-22)13 (fig. 6) probably are typical for this area. Water levels were measured in two wells in the Cactus Flat-Artesia area; the water level in one well was slightly lower than in spring 1965, whereas the water level in the other well rose nearly 4 feet.

San Simon Basin

By

D. E. Click

The San Simon basin (fig. 5, No. 3), in southeastern Arizona, is part of a northwest-trending structural trough that extends from south of the international boundary to Globe, Ariz. The hydrology of the basin has been discussed in two recent reports (White, 1963; White and Hardt, 1965), and the basic hydrologic data on which the reports are based also have been published (White and Smith, 1965).

In the San Simon basin there are two major areas and one minor area of ground-water development. The two major areas are (1) the Bowie area, centered around the town of Bowie in the northwest part of the basin; and (2) the San Simon area, located southeast of Bowie in the center of the basin. The minor area of development is near Rodeo, N. Mex., along the Arizona-New Mexico State line.

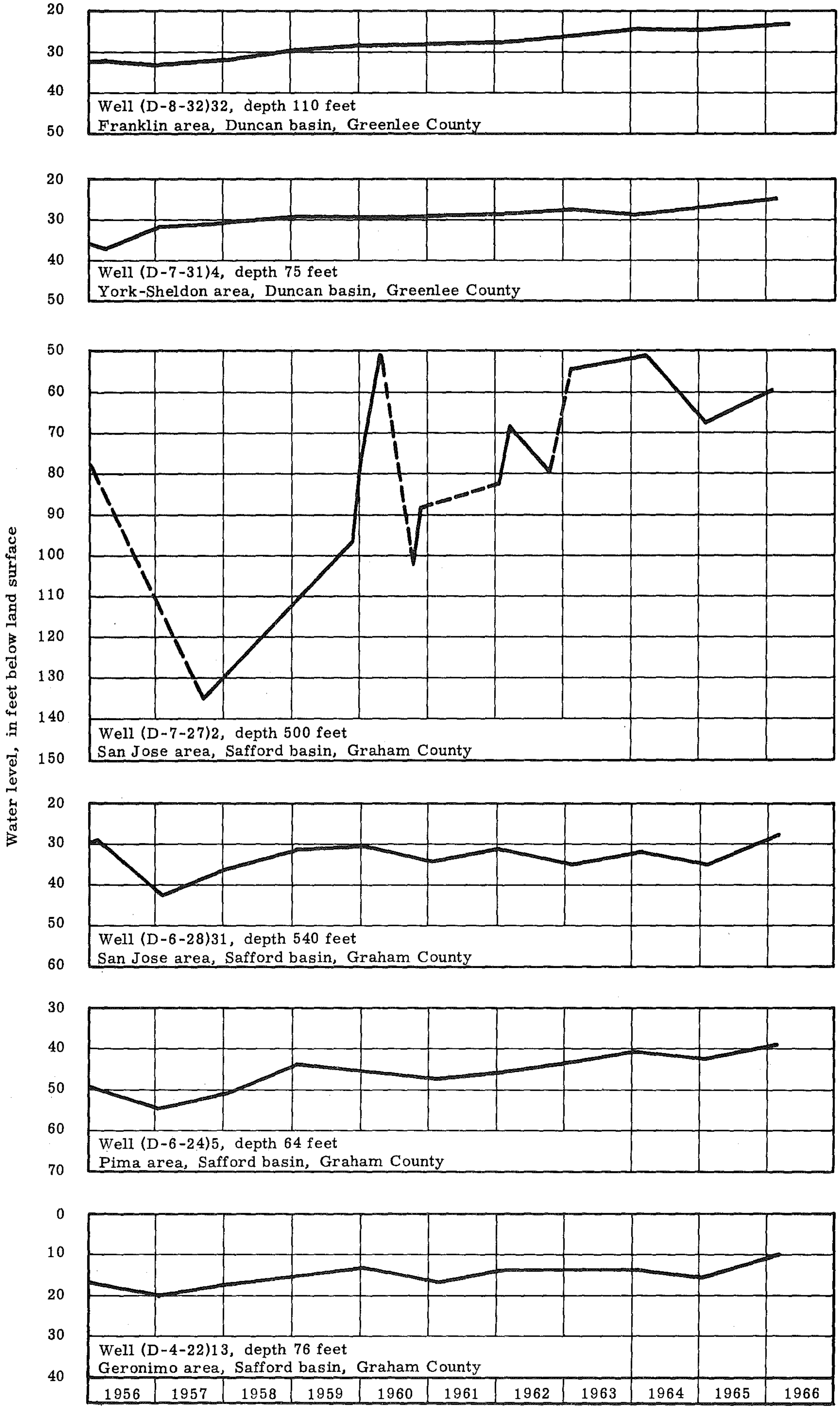


Figure 6. --Water levels in selected wells, Duncan and Safford basins.

Water levels were measured in eight wells that tap the artesian aquifer in the Bowie area in spring 1966. Water-level declines from spring 1965 to spring 1966 ranged from 3.5 to 10.8 feet; the water level in one well rose 1.6 feet. The water level in well (D-12-28)35 (fig. 7) declined nearly 10 feet, slightly more than the average yearly decline for the past 10 years. The depth to water in the artesian wells measured ranged from 118 feet in a well near the northeast edge of the area to 238 feet in the center of the irrigated area. The water level in one well at the southwest edge of the artesian area was 298 feet below land surface. The well was originally artesian; however, the water level has dropped below the bottom of the confining layer, and the well is operating under water-table conditions. The water level in an artesian well in the undeveloped area about 9 miles southeast of Bowie was about 37 feet below land surface in spring 1966; the water level declined about 9 feet from spring 1965 to spring 1966. The water levels in this area are being affected by the cones of depression extending from the heavily pumped Bowie and San Simon areas. The water level was measured in only two water-table wells in the marginal zone in spring 1966. The water levels were 381 and 375 feet below land surface and indicated declines of 7 and 8 feet, respectively, since spring 1965. The hydrograph (fig. 7) for well (D-13-28)16 illustrates the decline in the marginal zone south of Bowie.

Water levels were measured in 14 artesian and 3 water-table wells in the San Simon area in spring 1966. Water-level declines since spring 1965 in 10 artesian wells ranged from 1.3 to 12.9 feet; whereas rises in four wells ranged from 0.4 foot to 8.0 feet. Water levels in the three water-table wells declined from 0.6 foot to 17 feet. The hydrograph (fig. 7) of the water level in well (D-14-31)24 shows conditions in the artesian aquifer. The water level in well (D-13-30)24, in the upper aquifer, remained essentially stable (fig. 7), as it has for several years. The depth to water in spring 1966 ranged from 43 to 161 feet in the artesian aquifer and from 39 to 65 feet in the water-table aquifer.

The development of ground water for irrigation in the Rodeo area is comparatively small; however, near Rodeo, some water is withdrawn for irrigation. In spring 1966 water levels in this area ranged from about 90 to nearly 160 feet below land surface. Changes in water levels from spring 1965 to spring 1966 were small, except for a decline of 7.8 feet in a well in T. 19S., R. 32E., and a rise of 4.5 feet in a well just east of Rodeo. The water levels in wells (D-18-32)11 and (D-18-32)26 (fig. 8) declined 1.6 and 2.6 feet, respectively, from spring 1965 to spring 1966.

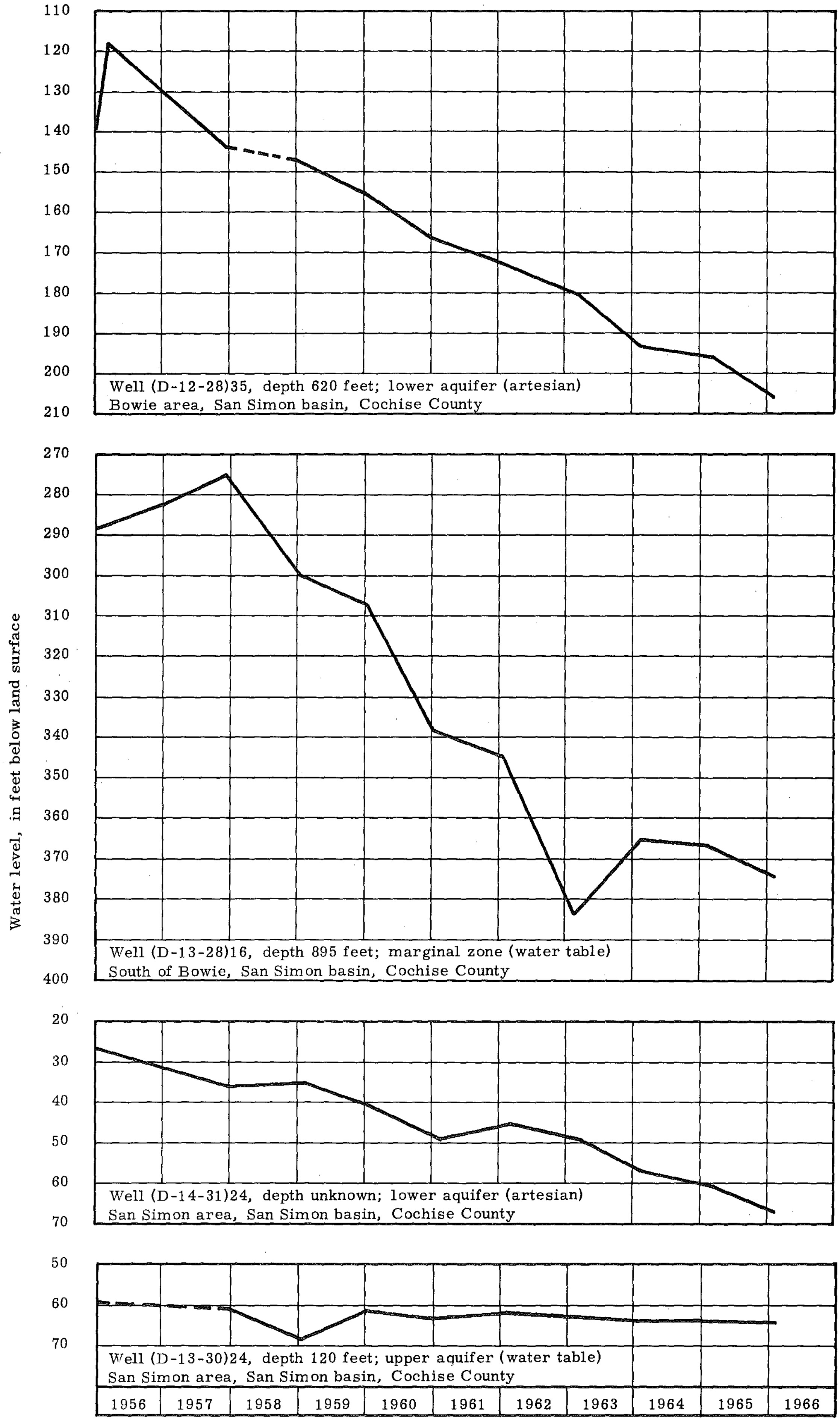


Figure 7. --Water levels in selected wells in the San Simon basin.

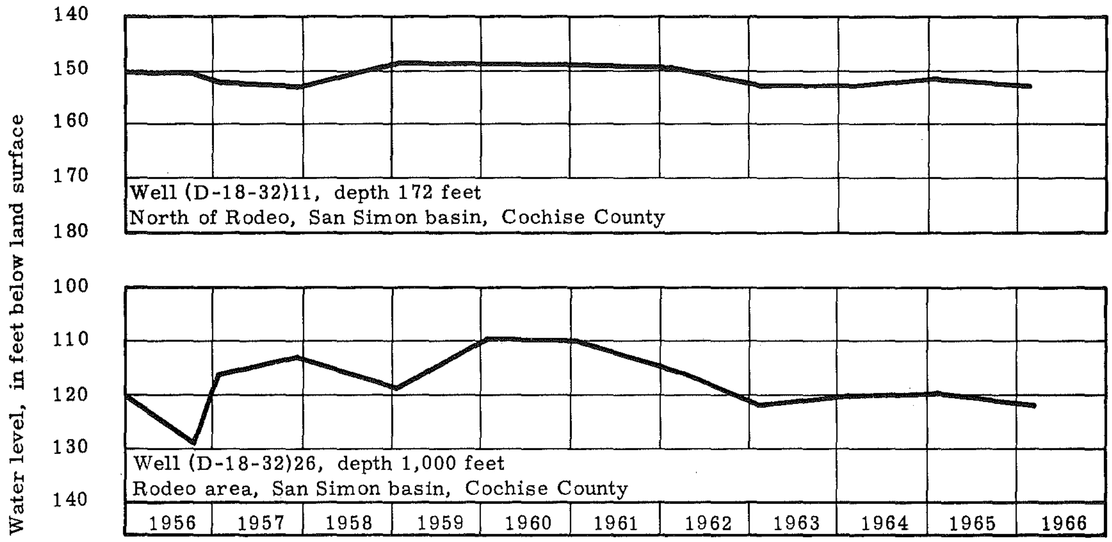


Figure 8. --Water levels in selected wells in the southern part of the San Simon basin.

Aravaipa Valley

By

T. K. Childers

Aravaipa Valley (fig. 5, No. 4) is just north of the Willcox basin. It extends northwestward from the drainage divide at the headwaters of Aravaipa Creek for a distance of about 44 miles and drains into the San Pedro River at a point about 15 miles upstream from the mouth of the San Pedro River. For the most part, the valley does not support extensive agricultural development.

Water levels were measured in five wells in spring 1966; all the wells are in the shallow alluvium along Aravaipa Creek. The depth to water ranged from 31 to 85 feet below land surface. From spring 1965 to spring 1966 water-level rises in three wells ranged from 5.6 to 23 feet, and water-level declines in two wells ranged from 3.5 to 5.1 feet. The greatest rise in water level was in a well near Klondyke, and the greatest decline was in a well near the head of the valley. The trend in water levels for 1961-66 is similar to that for 1965-66. The rises in water levels may be attributed to recharge from runoff; large amounts of precipitation resulted in the steady flow of Aravaipa Creek during the winter of 1965-66. The amount of water pumped for irrigation is small in this area, and ground-water withdrawal probably does not exceed natural recharge.

Water levels were measured in a few wells in lower Aravaipa Valley northeast of Mammoth in 1966. This part of the area is discussed in the section on the lower San Pedro basin.

Willcox Basin

By

T. K. Childers, S. G. Brown, and E. F. Pashley, Jr.

The Willcox basin (fig. 5, No. 5) occupies the northern three-fifths of the Sulphur Spring Valley (fig. 5, Nos. 5 and 6); the basin has no external drainage, and water moves toward the large barren flat known as the Willcox Playa. The northern boundary of the basin is the drainage divide at the headwaters of Aravaipa Creek; the southern boundary is the drainage divide in the buttes and ridges south of Pearce.

In spring 1966 the depth to water was measured in about 90 wells in the Willcox basin. The basin has been divided into five areas (fig. 9)--Sierra Bonita Ranch area, Stewart area, north playa area, Pearce-Cochise area, and Kansas Settlement area--on the basis of the time that development of ground water began, the amount of ground-water withdrawal, and geographic location. The areas are discussed separately below.

Sierra Bonita Ranch area.--Prior to 1965 development of ground water in the Sierra Bonita Ranch area was minor, and water-level declines were slight (fig. 10). In 1965 many wells were drilled and put into production in the area. The large increase in pumpage resulted in increased water-level declines; declines averaged 8 feet from spring 1965 to spring 1966 (fig. 10). The average change in water levels since 1952 has been a decline of slightly more than 24 feet. The depth to water was measured in eight new wells in T. 11S., R. 23E. in spring 1966; the depth to water in these wells ranged from 135 to 237 feet below land surface. Five new wells also were measured in T. 11S., R. 24E. in spring 1966; the depth to water in these wells ranged from 152 to 275 feet below land surface.

Stewart area.--The Stewart area (fig. 9) is one of the largest irrigated areas in the basin. Water levels were measured in 19 wells in this area in spring 1966. From spring 1965 to spring 1966 water-level declines averaged nearly 4½ feet. The average change in water levels since 1952 has been a decline of 34 feet. From spring 1961 to spring 1966, water-level declines averaged more than 12 feet.

North playa area.--In the north playa area (fig. 9) the average water-level decline from spring 1965 to spring 1966 was nearly 4 feet; the average decline from spring 1961 to spring 1966 was nearly 17 feet. The average change in water levels since 1952 in the north playa area has been a decline of more than 28 feet. Water-level declines in the area bordering the extensively developed Kansas Settlement area indicate that the cone of depression in the Kansas Settlement area has continued to spread northward.

Pearce-Cochise area.--The Pearce-Cochise area (fig. 9) is west of the Willcox Playa and the Kansas Settlement area. Water levels have continued to decline in the Pearce-Cochise area, except near the Willcox Playa, where the water levels in three wells showed rises of from 1 foot to nearly 5 feet

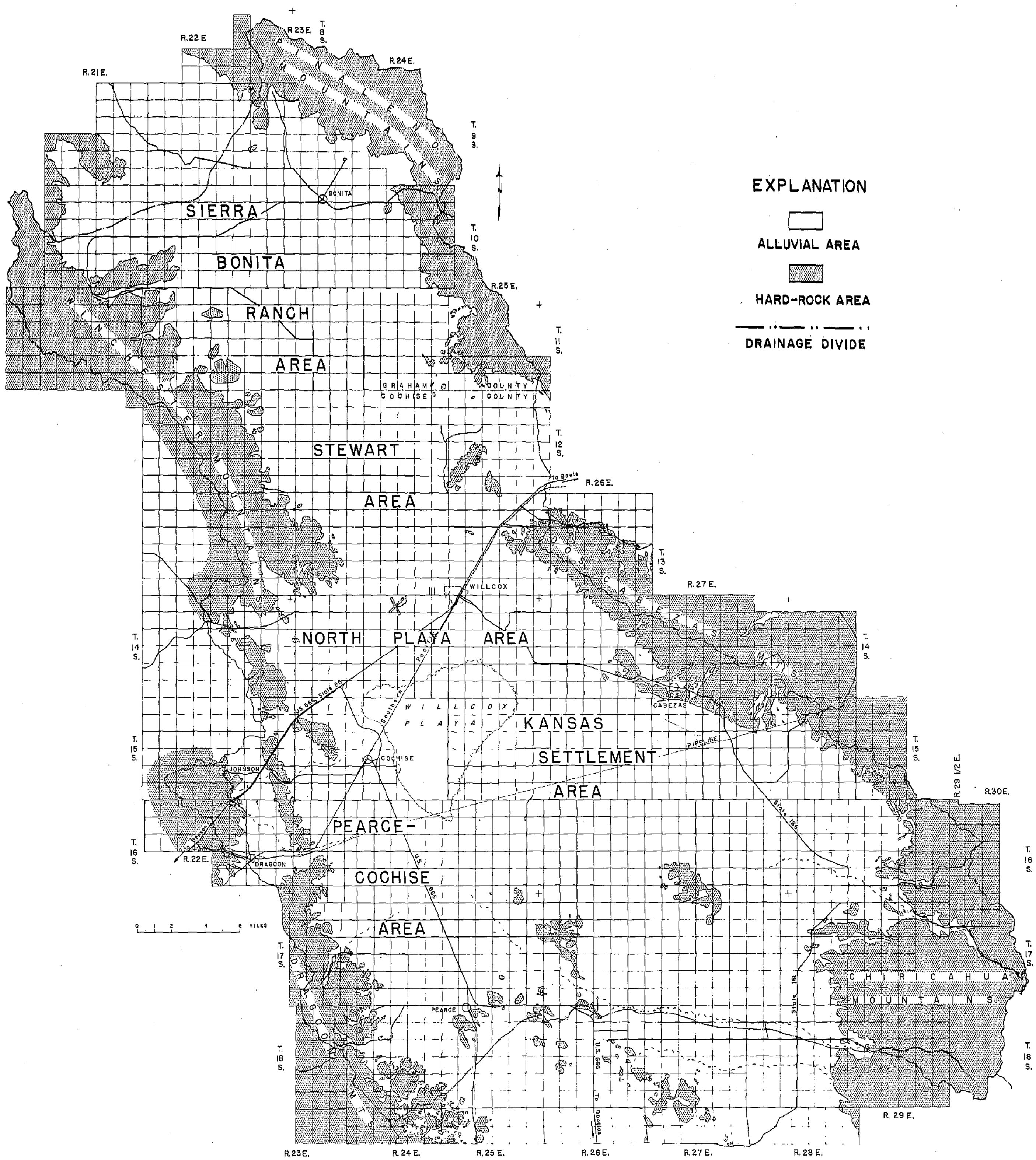


Figure 9. -- Subareas in Willcox basin.

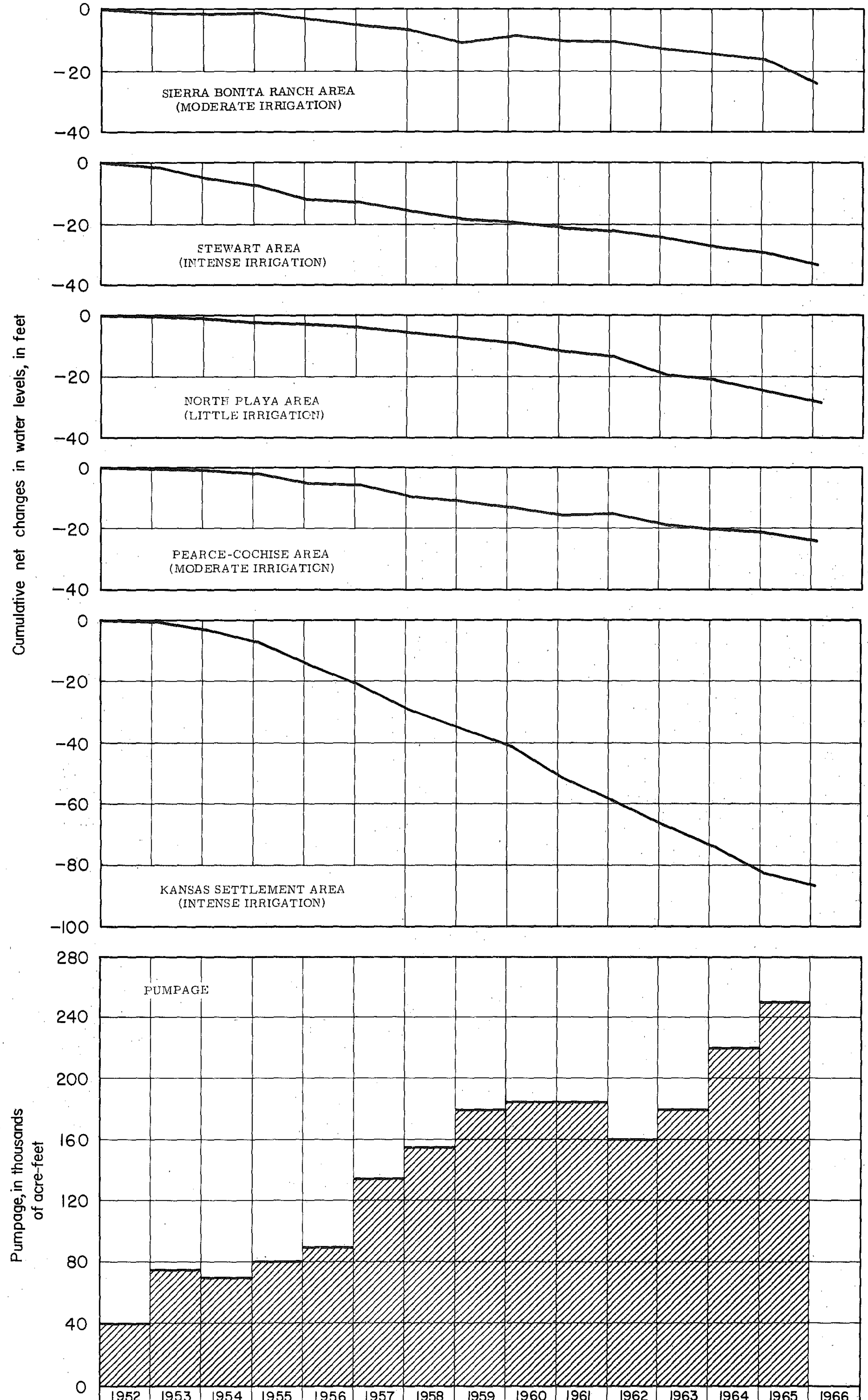


Figure 10.--Cumulative changes in water levels and pumpage, Willcox basin.

from spring 1961 to spring 1966. Water levels in three wells in the southern part of the area showed declines of 11 to 19 feet from spring 1961 to spring 1966; about a third of this decline took place from spring 1965 to spring 1966. The average change in water levels since 1952 has been a decline of about 24 feet (fig. 10).

Kansas Settlement area. --The Kansas Settlement area (fig. 9) is one of the largest irrigated areas in the Willcox basin. Water levels were measured in 35 wells in spring 1966; 26 wells showed water-level declines since spring 1965, and 9 showed rises. The average net change for the area was a decline of 3.8 feet, which is less than half the decline that took place from spring 1964 to spring 1965. The water-level rises were in wells west of the Kansas Settlement Road near the Willcox Playa and in a few wells near the edge of the area. From spring 1961 to spring 1966, the average water-level decline was more than 35 feet. The average change in water level since 1952 has been a decline of 86½ feet (fig. 10).

Douglas Basin

By

Dallas Childers

In spring 1966, water levels were measured in about 300 wells in the Douglas basin (fig. 5, No. 6). The depth to water ranged from 11 to 249 feet below land surface and was less than 100 feet in a large part of the basin.

From spring 1965 to spring 1966, the average change in water level in 111 wells was a decline of about 4 feet. In general, declines were greatest north of Elfrida and east of U.S. Highway 666. From spring 1961 to spring 1966, the average change in water level in 40 wells was a decline of nearly 10 feet. In general, declines for this period were greatest in the eastern half of the basin.

Many new wells have been drilled and much land has been cleared for farming in recent years in the Douglas basin. Much of the new land was irrigated in the summer of 1965, and it is expected that more land will go into production within the next few years. It is probable that the rate of decline of the water table will continue to increase. A detailed report on the present ground-water conditions in the Douglas basin is in preparation and will be available this year.

San Pedro River Valley

By

R. L. Thompson and E. K. Morse

The San Pedro River heads in Sonora, Mexico, flows northward, and crosses into Arizona just south of Palominas. In this report, the valley is described as extending from the international boundary to the Gila River near Winkelman. The valley is divided into the upper and lower San Pedro basins (fig. 5, Nos. 7 and 8).

Upper San Pedro basin. --The upper San Pedro basin (fig. 5, No. 7) extends from the international boundary on the south to the Narrows, about 8 miles north of Pomerene. The upper San Pedro basin is about 58 miles long and is from 15 to 35 miles wide. The direction of ground-water movement is similar to that of the surface drainage. The ground-water divide is in Mexico, and the movement of water is toward the San Pedro River from the bordering mountains and northward along the valley of the river.

The upper San Pedro basin has not been developed extensively, and pumping of ground water is minimal; however, ground-water withdrawal is slowly increasing. Some ground water is withdrawn from both the water-table and artesian aquifers for irrigation, chiefly in the St. David-Pomerene area. Several flowing wells are used for irrigation in the St. David-Pomerene area. A few new irrigation wells were put into production north and west of Palominas in 1966.

The depth to water in wells along the flood plain of the San Pedro River ranged from less than 17 to nearly 78 feet below land surface in spring 1966. Water-level fluctuations in these wells are erratic due to recharge from flow in the San Pedro River and irregular pumping of the wells. Water levels in the deeper wells on the flanks of the valley ranged from less than 38 to more than 200 feet below land surface. Water-level changes in the upper San Pedro basin ranged from a rise of 5 feet to a decline of 3 feet from spring 1965 to spring 1966.

The water level in well (D-16-20)34 rose nearly 5 feet from spring 1965 to spring 1966 (fig. 11). The well is not used, but the water levels are affected by recharge from the San Pedro River and pumping from nearby wells. The water level in well (D-17-21)32, a windmill stock well near St. David, declined about 20 feet from spring 1965 to spring 1966 (fig. 11). The decline probably was caused by the well having been pumped for several days prior to measurement. The water level in well (D-21-21)29 declined about 3 feet from spring 1965 to spring 1966 (fig. 11).

Lower San Pedro basin. --The lower San Pedro basin (fig. 5, No. 8) extends from the Narrows at Tres Alamos Wash, about 8 miles north of Pomerene, northward to the Gila River near Winkelman. The basin is about 65 miles long and 15 to 30 miles wide and has an area of about 1,420 square miles.

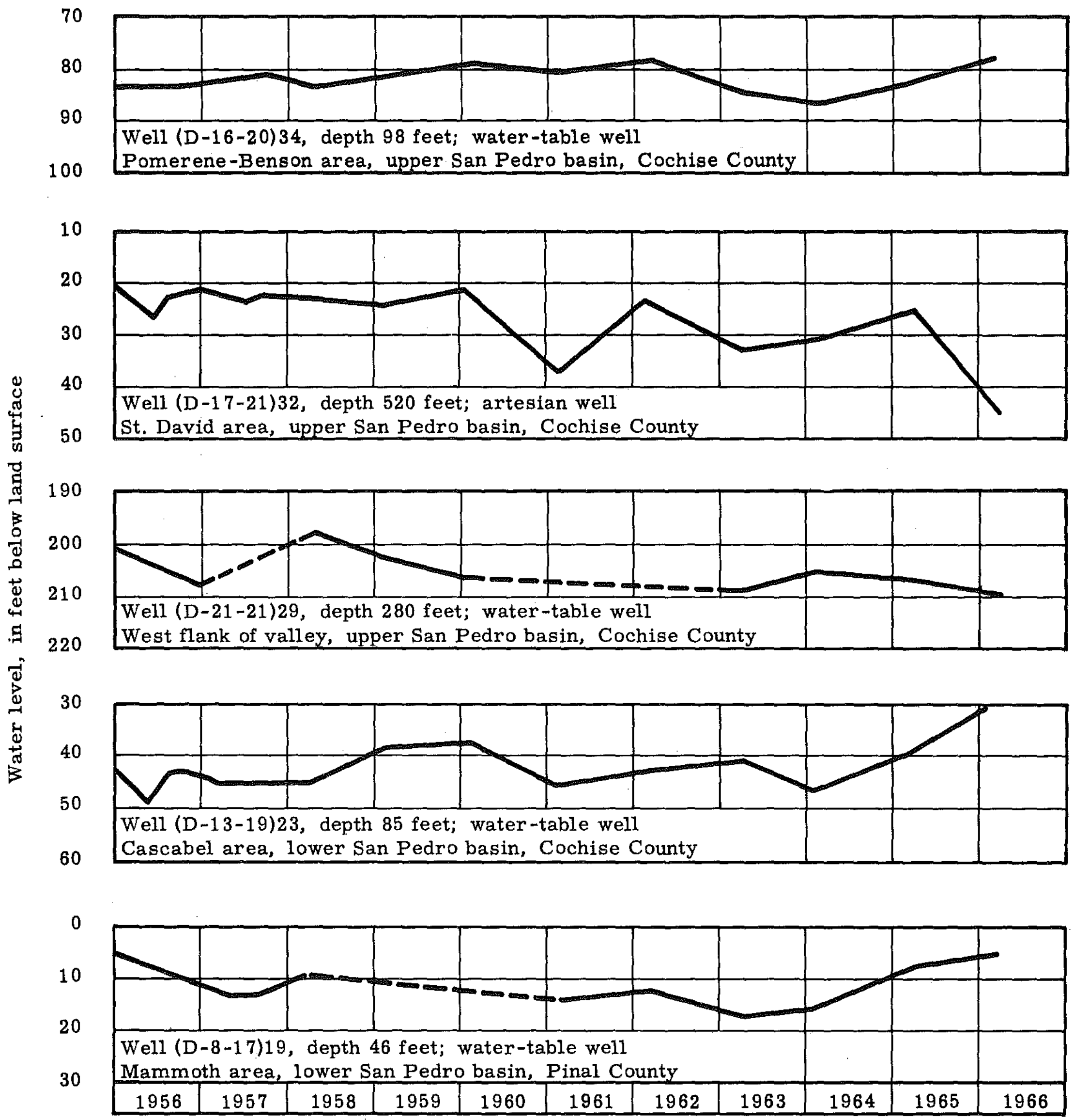


Figure 11. --Water levels in selected wells in the San Pedro River valley.

In the lower San Pedro basin most shallow wells along the flood plain are in the alluvium, which is from about 60 to 150 feet thick. Water levels in these wells generally are less than 40 feet below land surface, and the water-level fluctuations are due to recharge from the river and the pattern of pumping.

Water levels were measured in 18 wells in the flood plain of the lower San Pedro basin in 1966. From spring 1965 to spring 1966 water-level changes in the basin ranged from a rise of about 11 feet to a decline of more than 1 foot. From 1961 to 1966 water-level changes ranged from a rise of about 20 feet to a decline of about 1 foot.

The water level in well (D-13-19)23 about a mile south of Cascabel rose nearly 9 feet from spring 1965 to spring 1966 and more than 15 feet from spring 1961 to spring 1966 (fig. 11). The water level in well (D-8-17)19 near Mammoth rose about 2.5 feet from spring 1965 to spring 1966 and almost 9 feet from spring 1961 to spring 1966 (fig. 11). One well below Aravaipa Creek rose 2.7 feet, and the water level in another well in the same area declined 1.3 feet from spring 1965 to spring 1966.

Upper Santa Cruz Basin

By

T. M. Davey

The Santa Cruz River heads in the San Rafael Valley, Santa Cruz County, Ariz., flows southward into Mexico, turns west and then north, and reenters Arizona about 6 miles east of Nogales. From this point, it flows northward and then northwestward and joins the Gila River near the Pinal-Maricopa County line. The upper Santa Cruz basin (fig. 5, No. 9) is that part of the river valley that extends from the westerly crossing of the international boundary north to the Rillito Narrows between the Tucson and Tortolita Mountains, where there is a partial barrier to the movement of ground water.

Water levels in the upper reaches of the basin were affected by recharge from the floodflows in 1964 and the exceedingly high runoff of the Santa Cruz River near the international boundary in December 1965. Water levels in wells along the stream channels in the southern one-third of Santa Cruz County generally were less than 20 feet below land surface in spring 1966. In several wells the water levels were from 5 to 10 feet below the land surface. In the central part of the county, water levels ranged from about 6 to nearly 30 feet below land surface; record-high water levels were measured in six wells, indicating recharge from the high streamflow during the winter. In the northern one-third of the county, water levels ranged from 25 to 50 feet below land surface. In two wells along Sopori Wash near the Pima-Santa Cruz County line, the depth to water in spring 1966 was 132 and 172 feet below land surface. From spring 1965 to spring 1966 water-level changes in wells in Santa Cruz County ranged from a rise of 9.0 feet to a decline of 3.6 feet. Along the upper reaches of the basin, water levels generally rose in response to the high streamflow of December 1965 to February 1966. The water level in well (D-24-15)18 (fig. 12) changed very little from spring 1965 to spring 1966. The well is equipped with a continuous water-stage recorder, which showed the rise in water level resulting from the flow in the Santa Cruz River during the winter.

From the Pima-Santa Cruz County line to Continental, water levels along the river ranged from about 30 to 50 feet below land surface in spring 1966. Along the river in the Continental-Sahuarita area, water levels ranged from about 80 to 130 feet below land surface. A few miles from the flood plain of the river the water levels were more than 220 feet below land surface in spring 1966. From the county line to Continental, water-level rises ranged from about 3 to nearly 16 feet from spring 1965 to spring 1966. A water-level decline of 2.3 feet was measured in a well half a mile west of the river. In the Continental-Sahuarita area water-level changes from spring 1965 to spring 1966 ranged from a rise of 21 feet to a decline of nearly 15 feet. The water level in well (D-17-14)18 (fig. 12) declined about 4 feet from spring 1965 to spring 1966; however, water levels in this well rose continually during the 1965 pumping season. A general decline in water levels began after the summer storms at the end of the pumping season and continued through the December storm period.

In the central part of the Santa Cruz basin, as in other parts of the basin, water levels are shallowest along the stream channels. In spring 1966 water levels generally were 70 to 100 feet below land surface along the Santa Cruz River. The water level in well (D-15-13)2 (fig. 12), however, was about 40 feet below land surface in spring 1966 compared to 65 feet in spring 1965; the water level in this well responds rapidly to floodflows in the river.

Along Rillito and Tanque Verde Creeks the water levels generally were less than 70 feet and many were less than 30 feet below land surface in spring 1966. A short distance from the stream channels, water levels ranged from about 100 to 120 feet below land surface, and in the center of the area between the main drainages water levels were as much as 200 to 300 feet below land surface. From spring 1965 to spring 1966 water levels in wells near the creeks rose several feet; the rises were the result of the floods of December 1965. The December floods created a contamination problem in wells because of breaks in sewerlines along the stream channels. Water levels declined in wells beyond the flood plain of the streams.

From the mouth of Rillito Creek north to the Rillito Narrows there has been large-scale development of ground water for agriculture, mostly along the flood plain of the Santa Cruz River. Some ground water is pumped from aquifers along the stream channel of Canada del Oro for irrigation and domestic use. In the triangular area bounded by the Santa Cruz River, Canada del Oro, and the base of the Tortolita Mountains, water is withdrawn mostly for domestic use and irrigation of small gardens and golf courses. The rises in water levels measured in areas adjacent to Canada del Oro apparently were the result of recharge from heavy runoff in December.

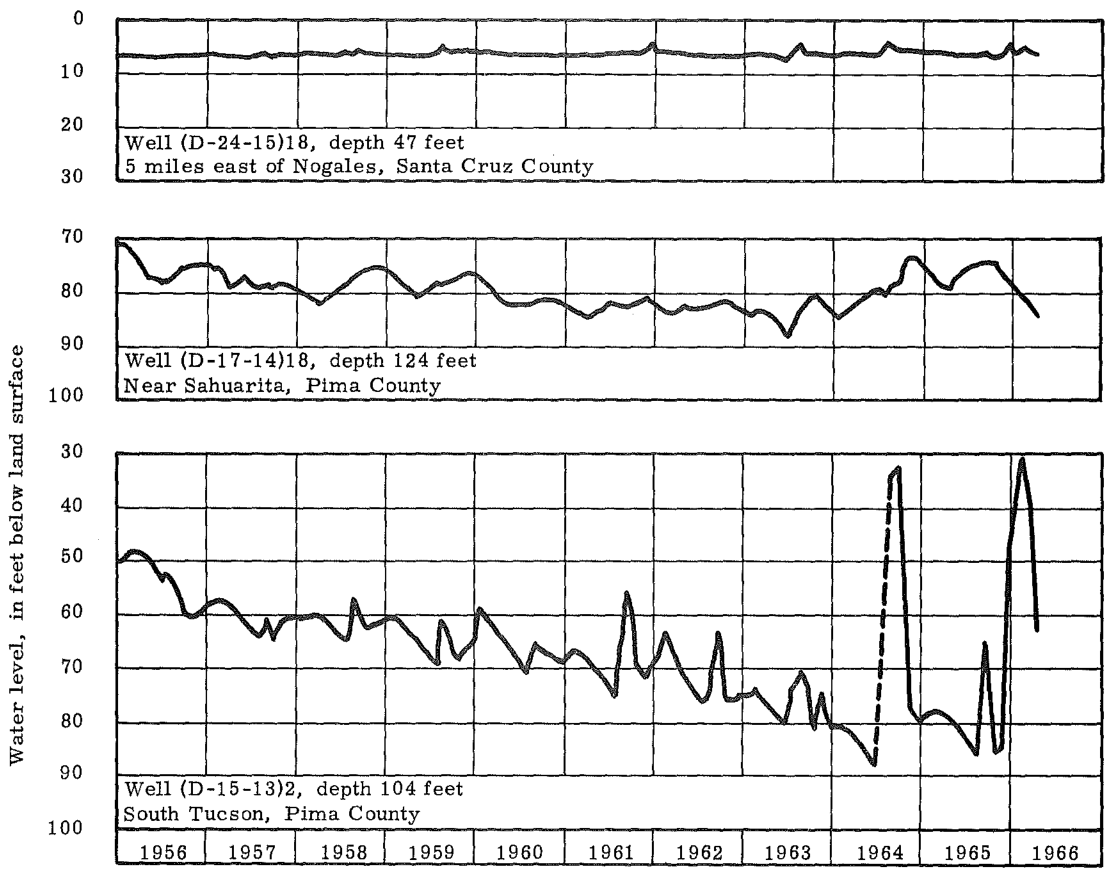


Figure 12. --Water levels in selected wells in the upper Santa Cruz basin.

Avra and Altar Valleys

By

W. B. Garrett

Avra and Altar Valleys (fig. 5, Nos. 10 and 11) comprise a north-trending basin that extends from a drainage divide about 3 miles north of the international boundary to a junction with the Santa Cruz basin about 5 miles north of the Pima-Pinal County line. The upper or southern part of the basin is known as Altar Valley, and the lower or northern part is known as Avra Valley. The arbitrary dividing line between the two valleys crosses Brawley Wash just south of Three Points. Altar Valley is narrow, and only a small amount of ground water is pumped; Avra Valley is a broad flat-lying area that is highly developed for agriculture. About 30,000 acres of land was under cultivation in Avra Valley in 1965; ground water is the source of supply for irrigation. The ground-water resources of Avra and Altar Valleys have been discussed in a report by White and others (1966).

The depth to water in Avra Valley ranges from about 200 feet along the southwest edge and at the north end of the valley to more than 400 feet along the southeast edge. From spring 1965 to spring 1966 water-level changes ranged from rises of 6 to 8 feet to declines of 3 to 25 feet. The greatest declines were in the central part of the valley.

In Altar Valley the depth to water varies greatly. In spring 1966 the depth to water at the north end of the valley ranged from 150 to 160 feet below land surface. At the extreme south end of the valley the depth to water ranged from less than 100 to nearly 200 feet below land surface, but a few miles north the depth to water ranged from 300 to 400 feet. In a few wells at the west edge of the valley the depth to water was less than 30 feet. From spring 1965 to spring 1966 water-level changes ranged from a rise of nearly 5 feet to a decline of more than 4 feet. Figure 13 shows the depth to water in selected wells in Avra and Altar Valleys.

Lower Santa Cruz Basin

By

S. G. Brown

The lower Santa Cruz basin has a common boundary with the upper Santa Cruz basin at the Rillito Narrows and extends downstream to the confluence of the Santa Cruz and Gila Rivers. Hydrologically, and adjacent area along the Gila River is part of the lower Santa Cruz basin, and this discussion contains information pertinent to the entire area (fig. 5, No. 12). The lower Santa Cruz basin is the second largest agricultural area in the State and is the second largest user of ground water.

In spring 1966, the depth to water was measured in about 150 wells in the lower Santa Cruz basin. In addition, about 90 water-level measurements were available from the San Carlos Irrigation Project. Of the 141 wells for which there were comparable water-level measurements made in spring 1965, water levels rose in 71 and declined in 70.

In spring 1966 the depth to water in wells in the Stanfield-Maricopa area ranged from about 100 to more than 500 feet below land surface. Water levels declined an average of 8.2 feet from spring 1965 to spring 1966 (fig. 14), and the average decline since spring 1940 has been 172 feet. The depth to water in wells in the Eloy area in spring 1966 ranged from about 130 to more than 350 feet below land surface. Water levels rose an average of 6.6 feet from spring 1965 to spring 1966 but have declined an average of 144 feet since 1940 (fig. 14). In the Casa Grande-Florence area, the depth to water ranged from about 50 to nearly 250 feet below land surface. Water levels rose an average of 2.6 feet from spring 1965 to spring 1966 but have declined an average of 97 feet since 1940 (fig. 14).

The rises in water levels in the lower Santa Cruz basin from spring 1965 to spring 1966 probably were the result of a reduction in the irrigated acreage and the occurrence of large amounts of runoff in December 1965 to January

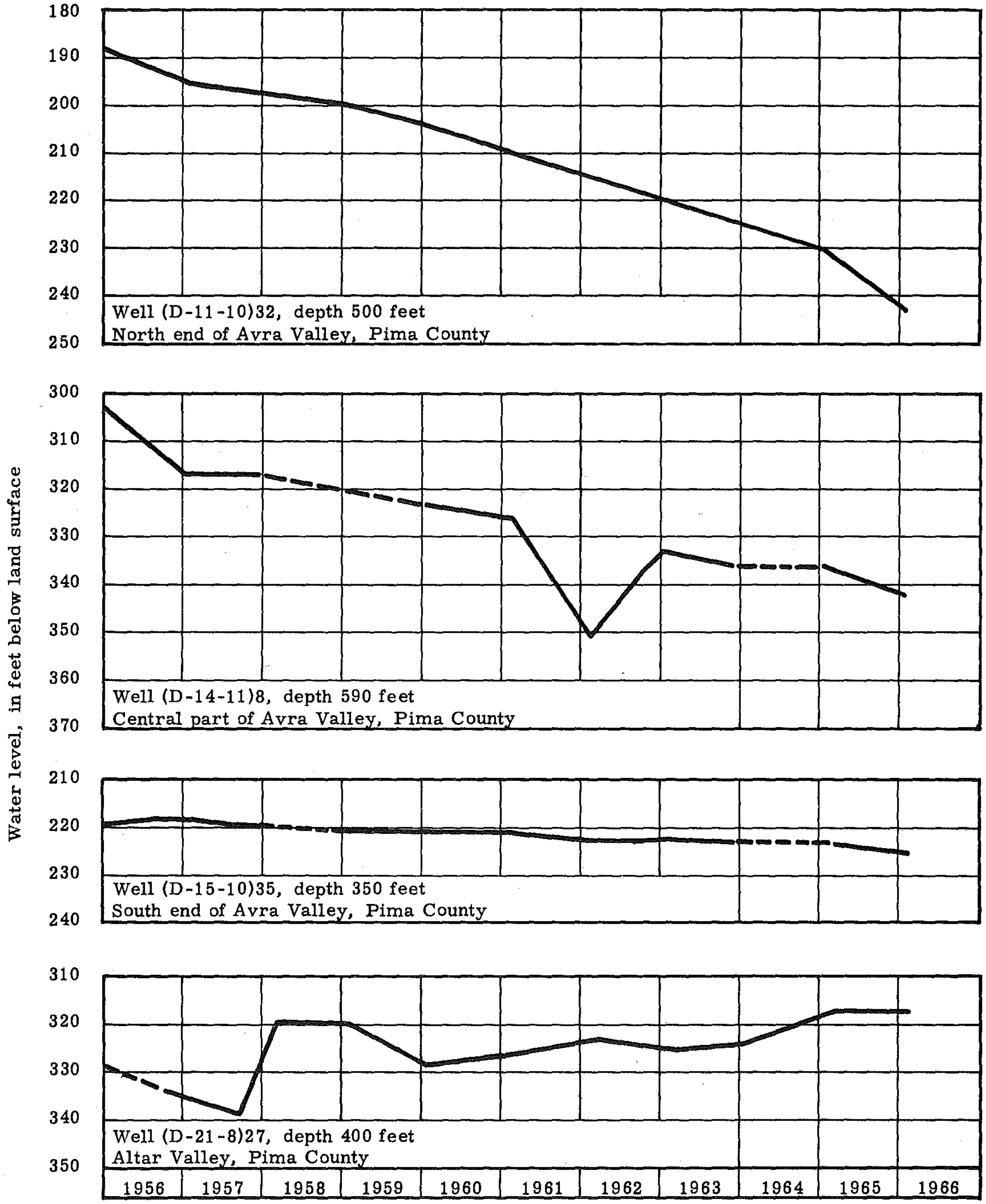


Figure 13.--Water levels in selected wells in Avra and Altar Valleys.

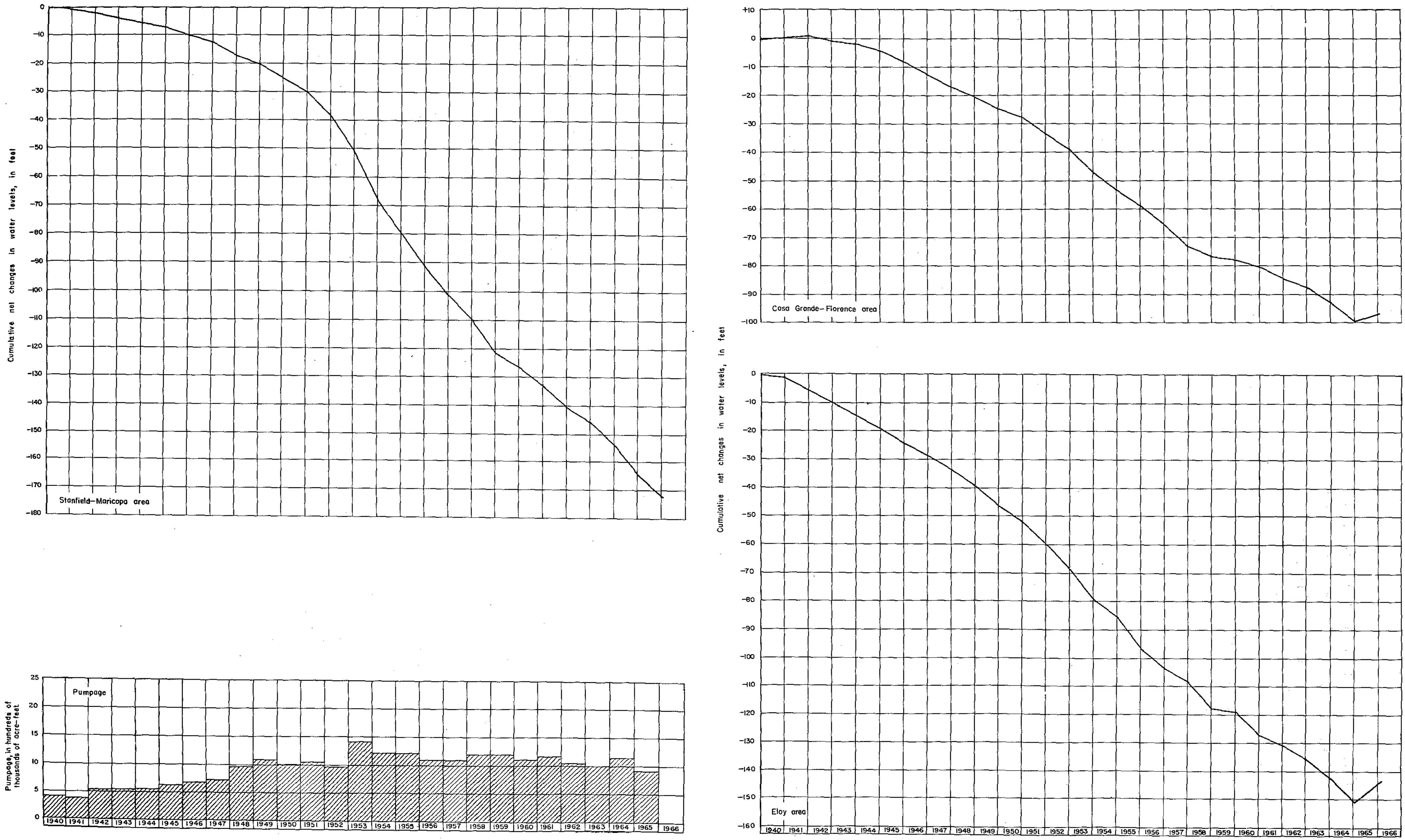


Figure 14.--Cumulative net changes in water levels by areas and total annual pumpage in the lower Santa Cruz basin within Pinal County.

1966. The cotton-acreage allotment was cut almost one-third, and the released acreage was planted in sorghum and alfalfa or left fallow; the need for irrigation prior to planting is less for these crops than for cotton. In addition, rains and consequent heavy runoff during December 1965 and January 1966 reduced the need for normal pre-planting irrigation during these months. The amount of water pumped for irrigation in this area in 1965 was less than that for any year since 1947.

Salt River Valley

By

R. A. Rukkila

The Salt River Valley (fig. 5, No. 13) comprises the valley lands near Phoenix, the tributary Paradise and Deer Valleys, lands west of the Hassayampa River, and the lower reaches of Centennial Wash. The area is drained by the Salt, Agua Fria, and Hassayampa Rivers, except for a small part on the east and south drained by the Gila River. A report by White, Stulik, and Rauh (1964) describes the ground-water conditions in the area and predicts the depth to water to 1969.

The Salt River Valley is the largest area of agricultural development in the State and, consequently, is first in the total amount of ground water pumped each year. In many parts of the Salt River Valley the water levels in wells rose from spring 1965 to spring 1966. Figures 15, 16, and 17 show the average changes in water level from spring 1965 to spring 1966 in the five subareas of the Salt River Valley; in the Litchfield Park-Beardsley-Marinette area the average change was a decline of 2.2 feet, but in the other subareas water levels rose from spring 1965 to spring 1966. In the Phoenix-Glendale-Tolleson-Deer Valley area the average change in water levels was a rise of 5.6 feet. Water-level rises were greatest in wells adjacent to the Salt River, where rises of as much as 37 feet were measured. Water-level rises of 5 to 20 feet were measured in the New River-Skunk Creek basins; rises of as much as 25 feet were measured near Higley. Large flows in the Salt River, which were diverted into all the canals of the system, were a big factor in reducing ground-water withdrawal. An unusual flow in the Salt River below Granite Reef Dam occurred in April 1965. Water-level rises of as much as 25 feet in wells near the river indicate that recharge occurred to the alluvium underlying the river (Briggs and Werho, 1966). A maximum water-level decline of 25 feet occurred in one well in the lower Centennial area. Substantial declines occurred in the heavily pumped Litchfield Park-Beardsley-Marinette area, in the northern part of the Liberty-Buckeye-Hassayampa area, and in the outlying Santan Mountain area south of Magma. Depths to water in the Salt River Valley in spring 1966 ranged from 15 feet below land surface near Queen Creek northeast of Florence Junction to 493 feet near Cave Creek in Deer Valley.

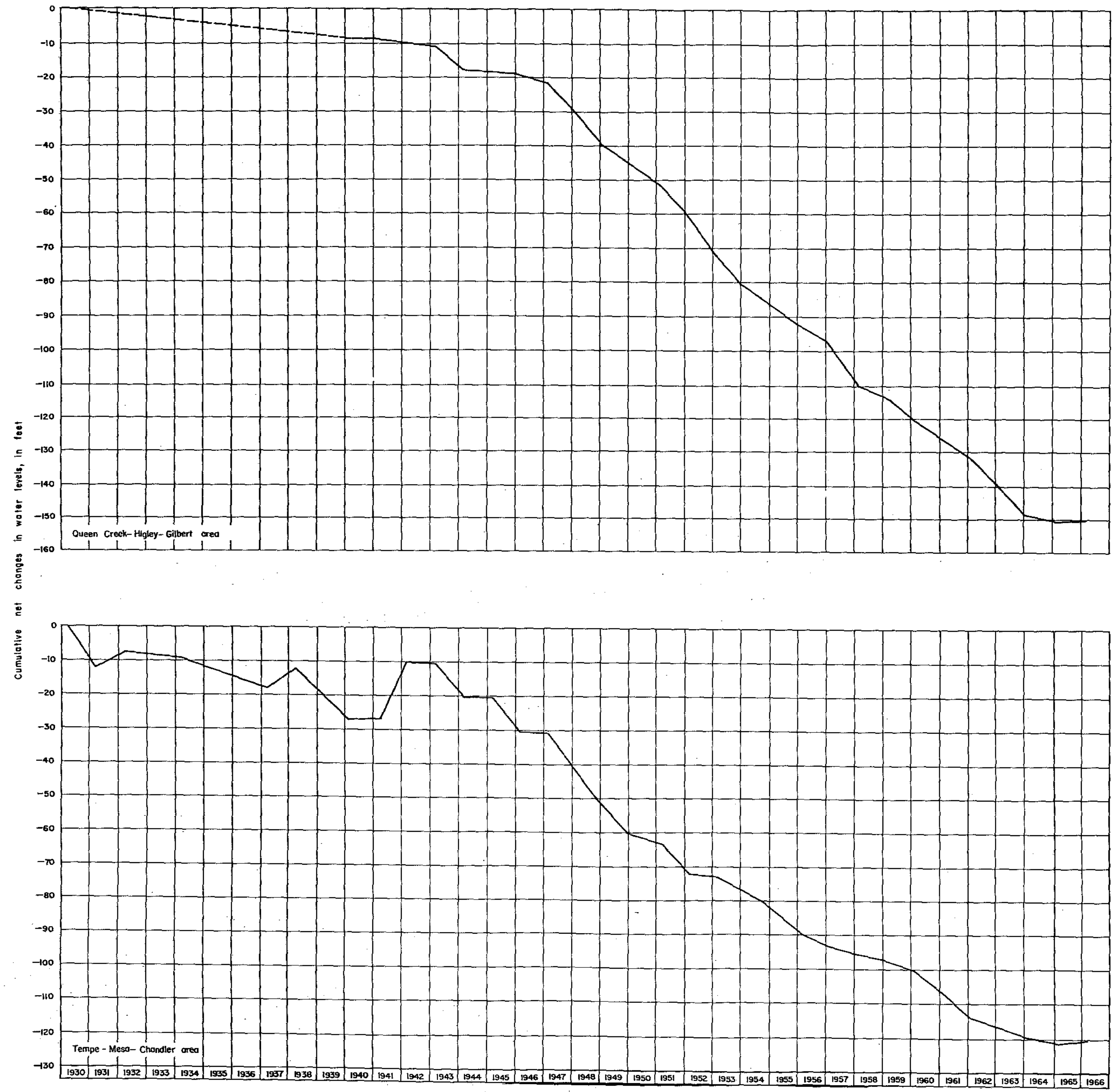


Figure 15.—Cumulative net changes in water levels in the Queen Creek–Higley–Gilbert and Tempe–Mesa–Chandler areas of the Salt River Valley.

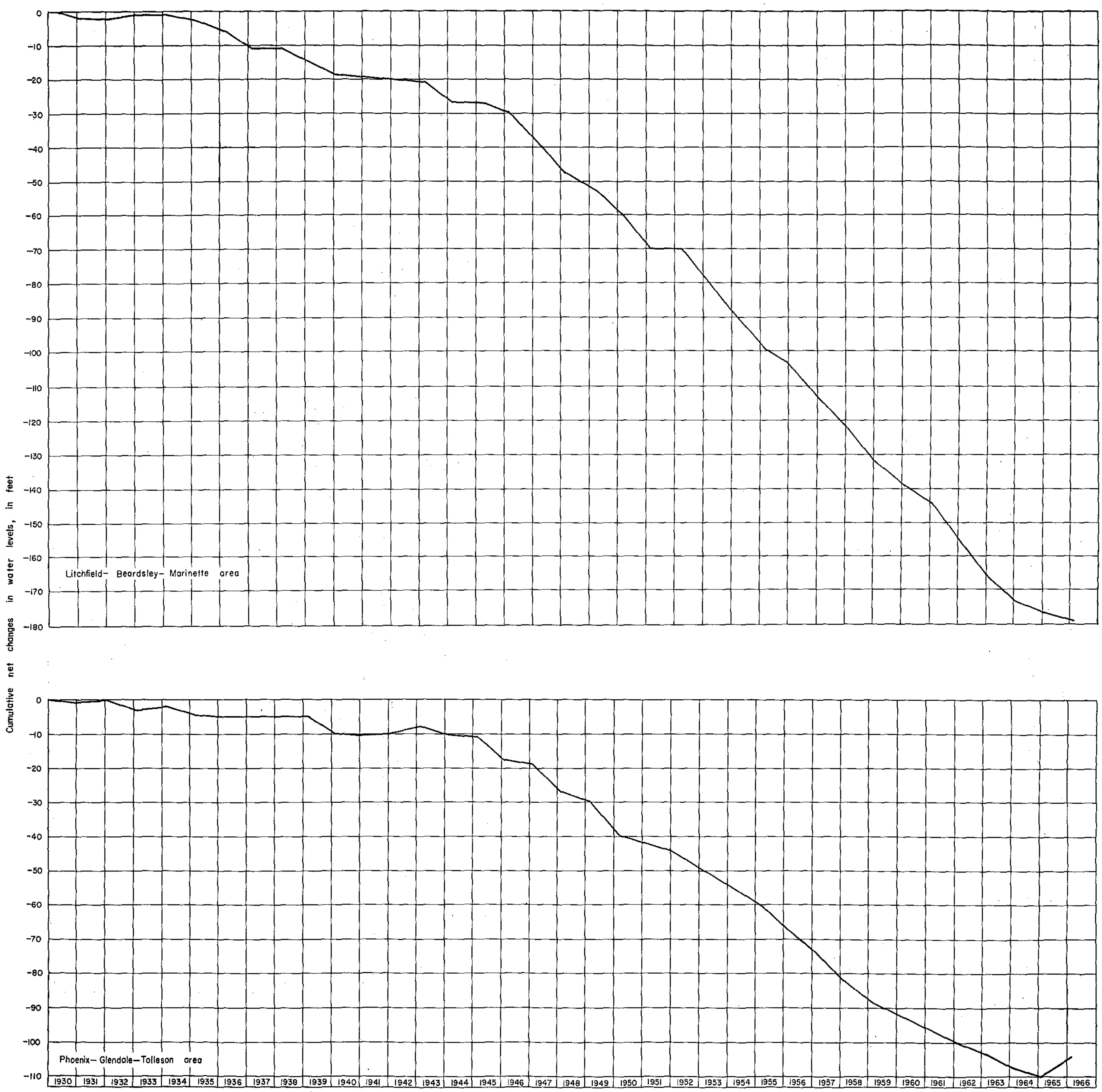


Figure 16.--Cumulative net changes in water levels in the Litchfield Park—Beardsley—Marinette and Phoenix—Glendale—Tolleson areas of the Salt River Valley.

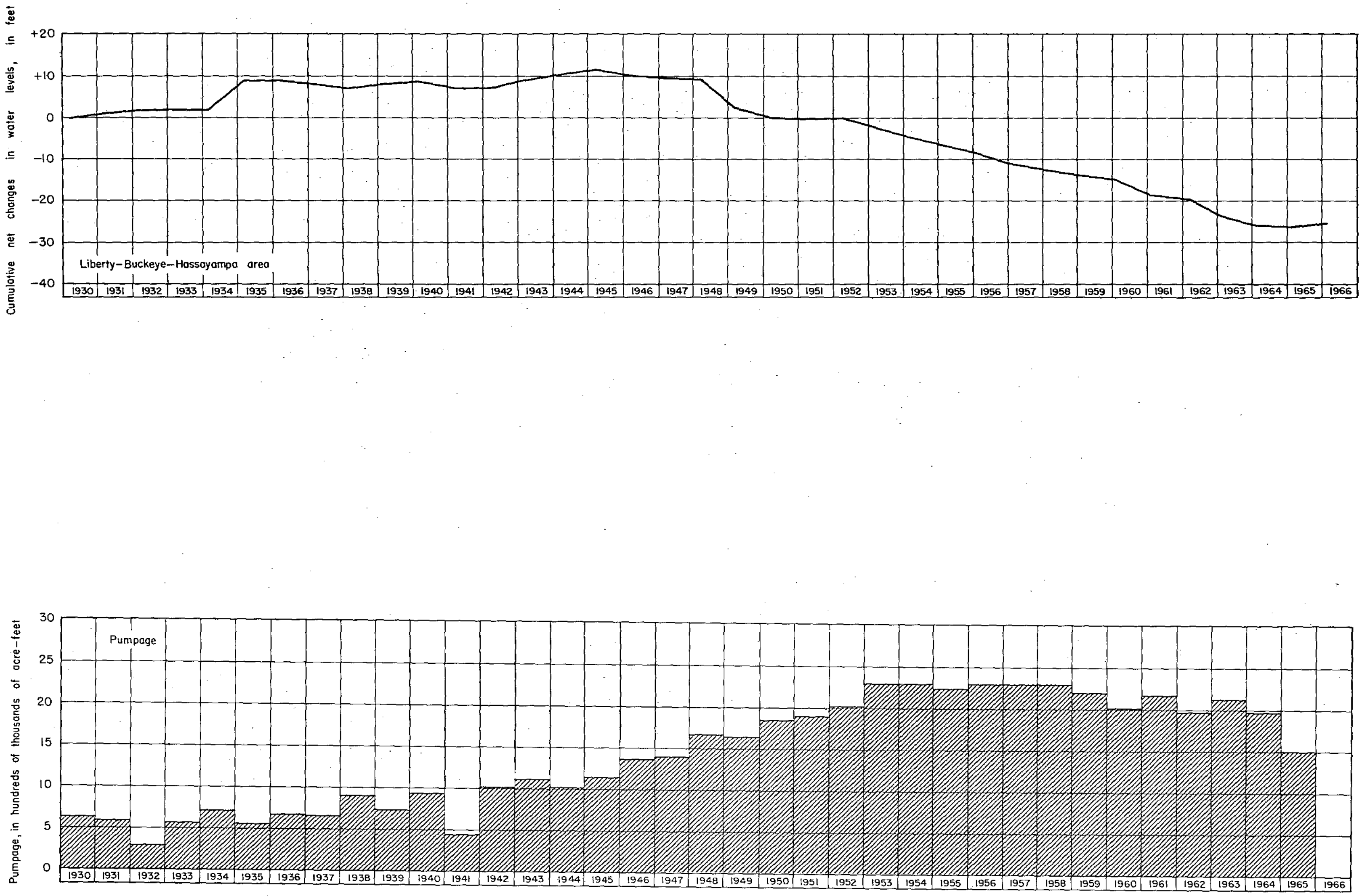


Figure 17.--Cumulative net changes in water levels in the Liberty—Buckeye—Hassayampa area and total annual pumpage in the Salt River Valley.

Waterman Wash Area

By

E. E. Denis

The Waterman Wash area (fig. 5, No. 14) is an area of about 400 square miles drained by the northwest-trending Waterman Wash. Only the northern part of the area has been developed for agriculture, and it is in this part that most of the water-level declines have occurred.

From spring 1965 to spring 1966 water levels continued to decline in response to excessive ground-water withdrawal. The water level in well (C-2-2)25 has declined more than 55 feet since 1956 (fig. 18). The maximum depth to water measured in January 1966 was 401 feet below land surface in a well at the south end of the area. A more comprehensive report describing ground-water conditions in the Waterman Wash area is being prepared and will be published in the near future.

Gila Bend Area

By

R. S. Stulik

The Gila Bend area (fig. 5, No. 15) is that part of the Gila River valley that extends from Gillespie Dam 36 miles downstream to Painted Rock Dam, a flood-control structure at the Painted Rock Narrows. The northeastern part of the Gila Bend area is known as Rainbow Valley.

The main factors that influenced water-level fluctuations in the Gila Bend area from spring 1965 to spring 1966 were pumping for irrigation and the spring floods in 1966. About 35,000 acres of land was cleared for cultivation in the area in 1965; however, less than 60 percent of this acreage was actually cultivated. Most of the water used to irrigate this acreage was pumped from ground-water storage. The floods in the Salt and Gila Rivers in January 1966 resulted in the temporary impoundment of about 200,000 acre-feet of water at Painted Rock Dam.

Water-level changes from spring 1965 to spring 1966 ranged from a decline of less than 1 foot in Rainbow Valley to a rise of more than 12 feet near Painted Rock Dam. The water level in well (C-4-4)9 (fig. 18) rose nearly 5 feet during this period. Periodic measurements in selected wells showed that the water levels rose throughout most of the interior part of the basin during January and February 1966. The depth to water in spring 1966 ranged from less than 10 to more than 400 feet below land surface.

In the summer of 1965 and the spring of 1966 an extensive collection of basic hydrologic data was made by personnel of the U.S. Geological Survey. These

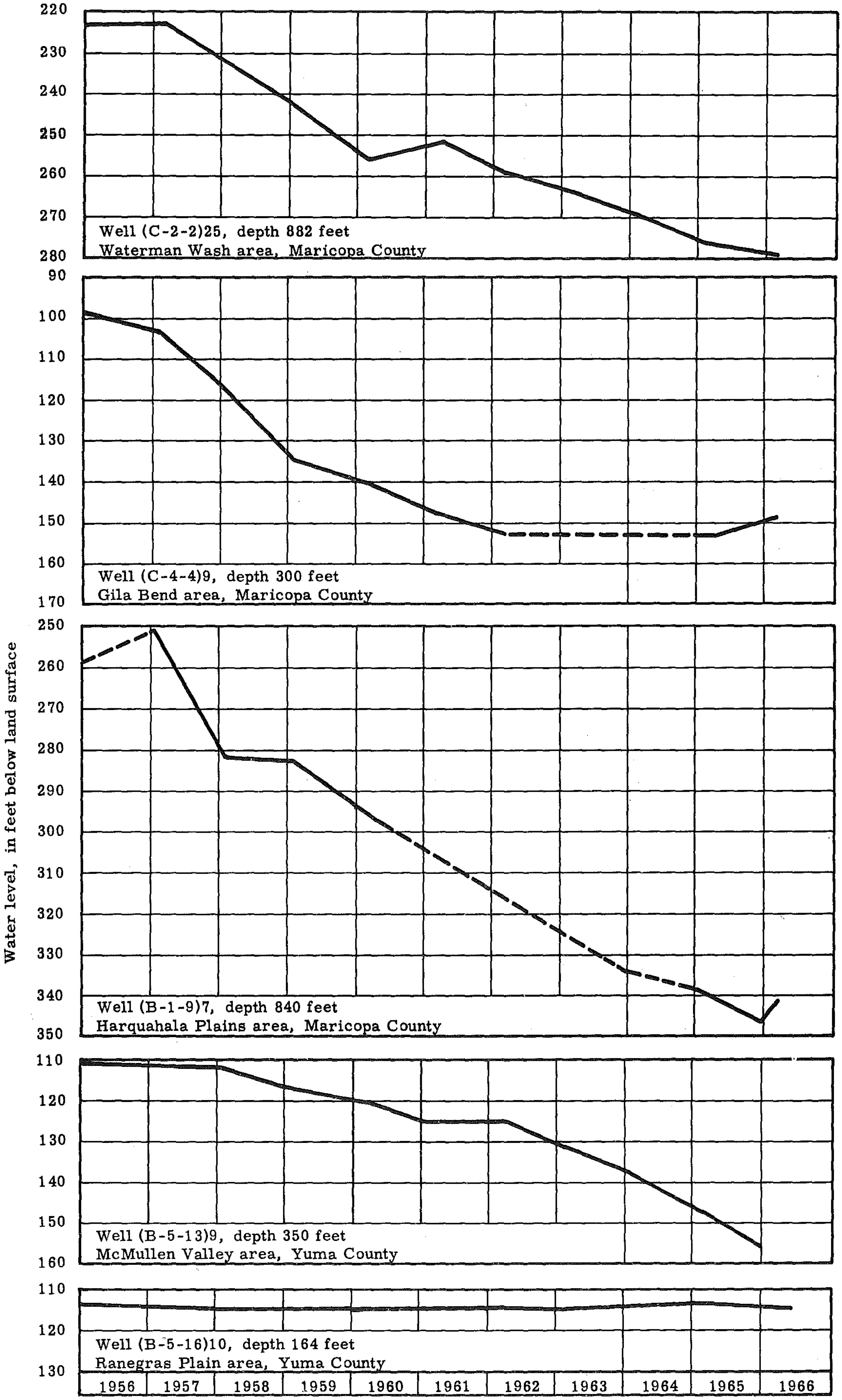


Figure 18. --Water levels in selected wells in several areas in the Basin and Range lowlands province.

data will be used to prepare a more comprehensive report on the hydrologic conditions in the Gila Bend area.

Harquahala Plains Area

By

P. C. Briggs

The Harquahala Plains area (fig. 5, No. 16) is a northwest-trending basin drained principally by Centennial Wash. The withdrawal of ground water for irrigation began in 1951; the withdrawal increased from 33,000 acre-feet in 1954 (Metzger, 1957) to about 200,000 acre-feet in 1963 (Stulik, 1964). Water levels declined as much as 200 feet from 1954 through 1963 and are continuing to decline. The hydrograph of the water level in well (B-1-9)7 (fig. 18) shows the decline in an irrigation well in the cultivated area. This well does not represent the maximum water-level decline in the basin, but it is probably indicative of the average decline. In spring 1966 the depth to water ranged from 94 to 450 feet below land surface.

McMullen Valley

By

P. C. Briggs

The McMullen Valley area (fig. 5, No. 17) is a northeast-trending valley about 48 miles long between the Harcuvar and Harquahala Mountains. There are two separate areas of irrigation development --the Aguila area and the Wenden-Salome area.

Water-level measurements show a decline of as much as 70 feet in the Aguila area and as much as 60 feet in the Wenden-Salome area from 1958 to 1966. The hydrograph of the water level in well (B-5-13)9 (fig. 18) shows the changes prior to and after utilization of ground-water supplies for irrigation. Ground-water pumpage for irrigation has increased from 6,000 acre-feet in 1953 to 87,000 acre-feet in 1965. The depth to water in spring 1966 ranged from 86 feet below land surface near Salome to 494 feet near Aguila. A more comprehensive report on ground-water conditions in McMullen Valley is in preparation.

Palomas Plain Area

By

R. S. Stulik

Palomas Plain (fig. 5, No. 18) is an alluvial area that extends northwestward from the Gila River between the Oatman and Face Mountains on the east and the Palomas, Tank, and Kofa Mountains on the west. A comprehensive report (Weist, 1965) on the geohydrology of a large area including part of the Palomas Plain has been released; in addition, data are available for several large-capacity wells that have been drilled in the area since the completion of the report.

From spring 1965 to spring 1966 water-level changes ranged from a rise of as much as 4 feet to a decline of more than 2 feet. In spring 1966 controlled releases of water from Painted Rock Dam caused the Gila River to flow for several months, which probably accounts, in part, for the water-level rises in wells in and near the flood plain. Depths to water in spring 1966 ranged from 22 feet to more than 200 feet below land surface. Water levels in the newly developed area north of Hyder were reported to be about 300 feet below land surface.

Ranegras Plain Area

By

R. S. Stulik

Agricultural development and ground-water withdrawal in the Ranegras Plain area of northern Yuma County (fig. 5, No. 19) have remained virtually unchanged in the last several years; as a result, water-level changes have been slight. From spring 1965 to spring 1966 changes in water levels ranged from a rise of about 1 foot to a decline of about 2 feet. The hydrograph of the water level in well (B-5-16)10 (fig. 18) shows water-level changes typical of the undeveloped parts of the area. There has been no significant change in the water level in this well during the last 10 years. Depth to water in spring 1966 ranged from about 35 to 225 feet below land surface.

South Gila Valley, Yuma Mesa, and Yuma Valley Area

By

O. J. Loeltz

In the South Gila Valley, Yuma Mesa, and Yuma Valley area (fig. 5, No. 20), in the extreme southwest corner of Arizona, water levels are affected principally by the diversion of Colorado River water for irrigation and by the operation of drainage wells and surface drains.

The South Gila Valley is that part of the Gila River flood plain south of the Gila River and north of an extensive terrace known as Yuma Mesa. Beginning in May 1965, Colorado River water was substituted for ground water as the principal source of irrigation water. However, because an extensive drainage-well system was put into operation coincidental with the application of surface water, ground-water levels in the South Gila Valley were kept from rising. In 1966, water levels near Yuma Mesa and near the drainage wells generally declined a foot or more. The depth to water generally ranged from 5 to 20 feet below land surface.

Yuma Mesa is south of the South Gila Valley and east of Yuma Valley. It is bounded on the east by the Gila Mountains and on the south by the international boundary. The principal source of water for irrigation is the Colorado River. In 1965, the drilling of private wells for irrigation increased; however, the pumpage from wells for irrigation probably was only a few thousand acre-feet. The operation of additional drainage wells just beyond the north and west boundaries of Yuma Mesa caused the water levels beneath parts of the mesa to drop several feet below the water level of March 1965. Declines ranging from 1 to 4 feet were measured in an area of about 50 square miles. East and south of the area of decline—in an area of about 150 square miles—water levels rose, but generally only a few tenths of a foot. In the irrigated area, the depth to water ranged from about 7 to 35 feet below land surface. East and south of the irrigated area the depth to water increased. South of the irrigated area the depth to water ranged from 70 to 90 feet below land surface. East of the irrigated area the depth to water increased quite rapidly, because the slope of the water surface is eastward and the slope of the land surface is westward.

Yuma Valley is that part of the Colorado River flood plain in Arizona that is south and east of the Colorado River and west of Yuma Mesa. The Colorado River is the principal source of water for irrigation; only a few thousand acres of land between the river and the levee are irrigated with ground water. Water levels in the valley are controlled mainly by an extensive system of surface drains. In 1966 water levels generally ranged from 5 to 15 feet below the land surface. Along the international boundary section of the Colorado River water levels were about a foot higher in March 1966 than in March 1965. This rise compensates for the decline measured between March 1964 and March 1965 in the same area. Along the eastern margin of the valley near the drainage wells, water levels generally declined a foot or less. Elsewhere, the changes were less consistent and usually only a few tenths of a foot.

Big Sandy Valley

By

R. S. Stulik

The Big Sandy Valley (fig. 5, No. 21) is drained by the Big Sandy River, which receives water from Trout and Burro Creeks, Cottonwood and Little Sandy Washes, and many other washes. The valley is more than 60 miles long and is bounded by the Hualapai, Peacock, Rawhide, and Artillery Mountains on the west and the Cottonwood Cliffs and Aquarius Mountains on the east.

In parts of the area the Big Sandy River has cut into a series of predominantly fine-grained deposits of possible lake origin. Recently deposited coarse-grained alluvium that now underlies the present stream channel and the flood plain is the major source of ground water in the valley. For this reason most of the agricultural development in the area is along the flood plain of the Big Sandy River. Wells are shallow and readily affected by recharge from the river. The fine-grained deposits seem to yield very little water.

Other sources of ground water in the Big Sandy Valley are (1) the coarse-grained alluvial deposits other than those in the flood plain, (2) fracture zones in hard rock, and (3) springs. The amount of water obtained from these sources is generally adequate for domestic and stock supplies; however, they are not always dependable supplies during periods of below-normal precipitation.

From spring 1965 to spring 1966 water-level changes in wells in the Big Sandy Valley ranged from a rise of about 2 feet to a decline of about 3 feet. The hydrograph of the water level in well (B-16-13)36 (fig. 19) shows changes typical for this area. The depth to water in spring 1966 ranged from about 12 feet below land surface near Wickieup to about 375 feet in a stock well near the extreme north end of the area.

Sacramento and Hualapai Valleys

By

C. B. Bentley

Sacramento and Hualapai Valleys (fig. 5, Nos. 22 and 23) are north-south-trending alluvial-filled valleys in Mohave County. Sacramento Valley is drained by Sacramento Wash, which empties into the Colorado River at Topock. Hualapai Valley is a closed surface-water basin, but ground water flows beneath the surface-water divide at the north end of the Valley, thence to Lake Mead on the Colorado River.

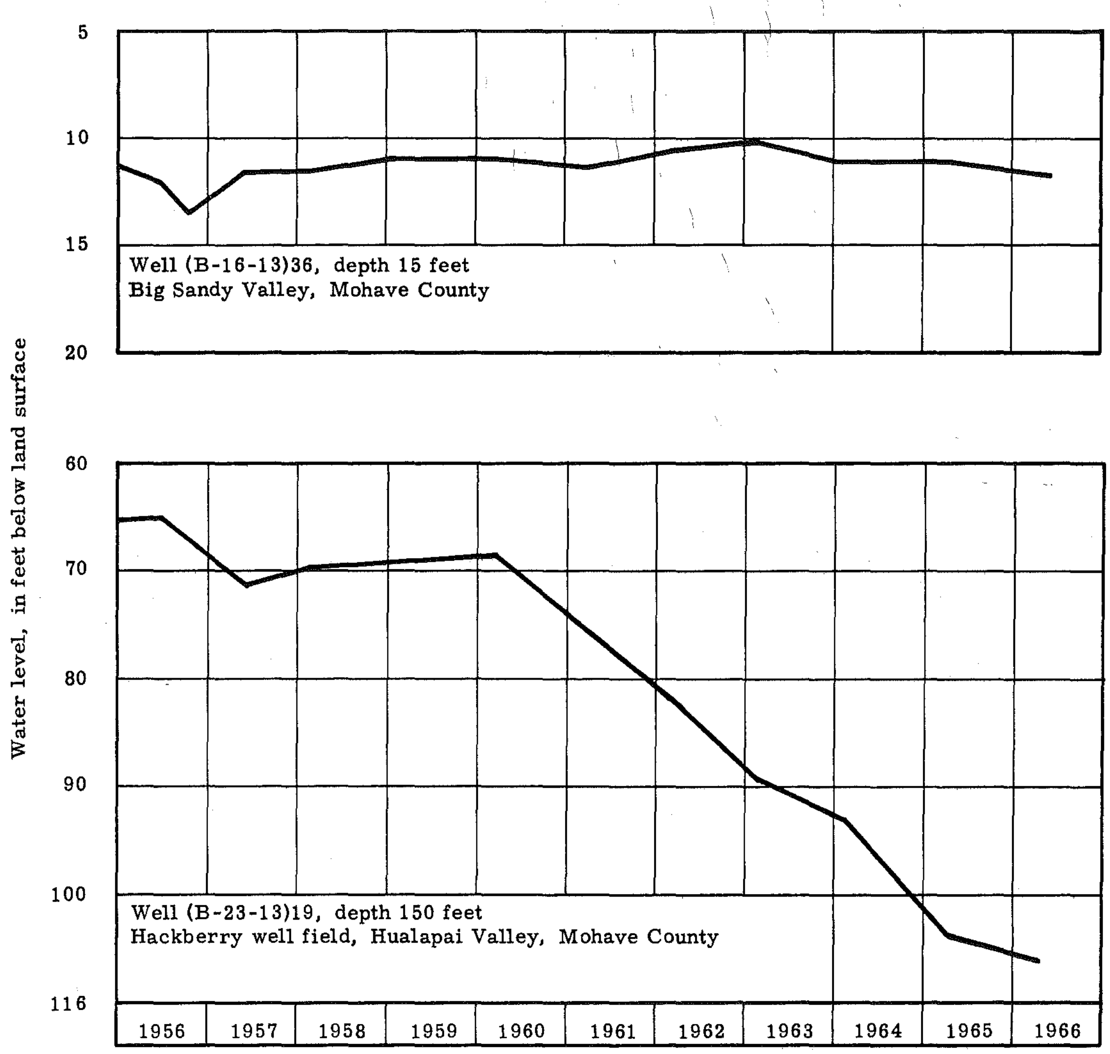


Figure 19. --Water levels in selected wells in Big Sandy and Hualapai Valleys.

In Sacramento Valley the depth to water in the valley fill ranges from about 300 feet below land surface at Yucca, 25 miles south of Kingman, to more than 1,200 feet at the north end of the valley. At Kingman the depth to water in the volcanic rocks and associated agglomerate beds is about 100 to 150 feet below land surface. The pumping levels in wells in the Duval Corp. well field near the north end of the valley have declined about 5 feet in the first 1½ years of operation (late 1964 to spring 1966). At Yucca the water level declined 2 feet from spring 1965 to spring 1966 in a well that was heavily pumped for construction purposes. Water levels in areas adjacent to these locations, however, have not been affected. For more than 20 years water levels at Kingman declined at the rate of about 1 foot per year; however, water levels remained at essentially the same level from 1963 to 1966.

From spring 1965 to spring 1966 water levels in the relatively undeveloped Hualapai Valley remained constant, except in the heavily pumped Hackberry area, which supplies water to Kingman. Water levels in the Hackberry well field have declined more than 35 feet in the last 6 years, as shown by the hydrograph of the water level in well (B-23-13)19 (fig. 19). The depth to water is about 250 feet below land surface at the north end of the valley and more than 600 feet at the south end, except at Hackberry where the water level ranges from about 90 to 200 feet below land surface.

Plateau Uplands Province

By

E. B. Hodges

The Plateau uplands province includes a variety of landforms--canyons, buttes, mesas, and volcanic mountains. The elevation ranges from about 4,000 to 13,000 feet above mean sea level but is mostly between 5,000 and 7,000 feet. In this province, water-bearing sandstone beds constitute a large storage reservoir for ground water, but well yields generally are small because the rocks are fine grained and do not transmit water freely. However, in a few areas faults and fractures increase the permeability of the formation, which permits water to move more freely, and well yields are large.

For the most part, the Plateau uplands province is undeveloped, and the amount of ground water pumped for irrigation or other purposes is small. Hence, there have been no sustained declines in water levels in this province to the present time. Slightly less than 35,000 acres of land was cultivated (Hillman, 1966) in the province in 1965. However, there has been some increase in the use of ground water for agriculture in the Snowflake area and near Tuba City, for operation of a pulp mill at Snowflake, and for municipal use in the Flagstaff area. The current ground-water conditions in the Plateau uplands province are discussed by counties because development is not concentrated in particular areas.

Apache County

By

E. L. Gillespie

Most wells in Apache County obtain water from fine-grained consolidated sandstone or from the alluvium in the larger valleys. The most extensive use of ground water for irrigation is near Hunt and St. Johns.

Wells in the irrigated areas are from 200 to more than 700 feet deep, and the static water levels range from 0 to 50 feet below land surface. Water levels in the Hunt area generally decline from 30 to 40 feet during the pumping season but, for the most part, recover when pumping ceases. A slight long-term decline in this area is shown by the hydrograph of the water level in well (A-14-26)18 (fig. 20). The hydrograph for well (A-13-28)27 near St. Johns indicates little change in the water level during the last 10 years (fig. 20).

Wells along the Puerco River, Chinle Wash, and Black Creek obtain water from the alluvium. The wells along Black Creek near Fort Defiance produce from 50 to 200 gpm (gallons per minute). Records for a nearby observation well indicate a water-level decline of about 3 feet in the last 4 years. Wells drilled along the Puerco River near the Navajo-Apache County line produce from 400 to 600 gpm of fair-quality water from pumping levels of 50 to 80 feet. Most ground-water development in this area has occurred in recent years, and no water-level declines have been noted. Irrigation wells produce about 500 gpm from alluvial deposits near Chinle. Several observation wells have been drilled; data from these wells should indicate the effect of additional development in the area.

Navajo County

By

E. H. McGavock

Ground-water withdrawal in Navajo County has increased steadily during the last 5 years. The principal centers of ground-water usage are Holbrook, Joseph City, and the Snowflake-Taylor area, where water is withdrawn from fine-grained sandstone.

The hydrograph of the water level in well (A-17-20)10 (fig. 20) near Holbrook indicates little or no decline of the regional water table. A continuous water-level recorder was installed in this well in 1961, and, since that time, water-level declines have been reflected clearly in the hydrograph during the summer pumping season.

No long-term water-level declines have been noted near Joseph City. Water levels decline more than 20 feet during the summer in some closely spaced

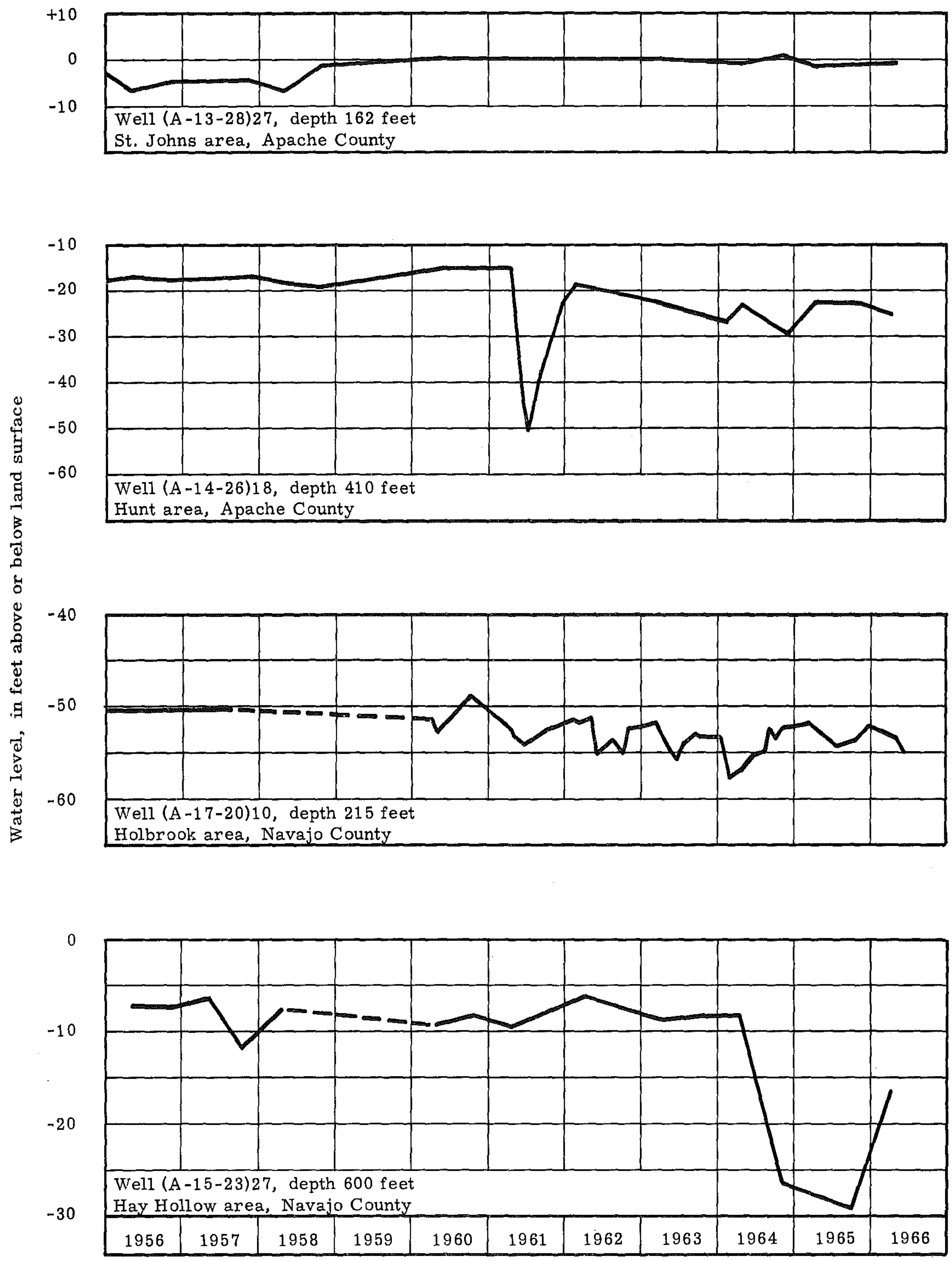


Figure 20. --Water levels in selected wells in Apache and Navajo Counties.

wells.

The hydrograph of the water level in well (A-15-23)27 near Hay Hollow shows a general decline (fig. 20). The decline is probably due to increased pumpage from new wells in the area.

A general water-level decline also is indicated in the Snowflake-Taylor area. The hydrographs of the water levels in wells (A-13-21)24 at Snowflake and (A-13-21)34 near Taylor show declines of about 12 to 19 feet in the last 5 years (fig. 21). The hydrograph of the water level in well (A-13-21)29 (fig. 21) west of Snowflake shows a decline of about 50 feet since 1960 because of pumping for industrial use.

Coconino County

By

E. H. McGavock

Ground water in Coconino County is withdrawn mainly from fine-grained sandstone aquifers. Water levels range from 200 to 2,000 feet below land surface in much of the area. The principal areas of ground-water withdrawal are municipal well fields near Flagstaff and Winslow. Water levels in the Winslow well field have remained relatively stable for the last 10 years, but the quality of water in 3 of the 5 wells has deteriorated steadily during this time. Intermittent pumping of wells in Flagstaff's Woody Mountain well field has caused a general decline of water levels within the well field. This trend is shown by the hydrograph of the water level in well (A-21-6)35 (fig. 21).

An increasing number of domestic and stock wells are being drilled into interbedded lava, sand, and clay in the Flagstaff area. Most of these wells are less than 500 feet deep and yield from 1 to 10 gpm. A few wells, however, produce 100 to 450 gpm.

Central Highlands Province

By

E. B. Hodges

The Central highlands consist mostly of rugged mountain masses made up of indurated igneous, metamorphic, and crystalline rocks and well-consolidated sedimentary rocks. These materials contain little space for the storage of ground water. Small amounts of ground water are stored in fractured and faulted zones; where the fractures are at the surface, ground water issues as springs. A few small valleys between the mountains contain varying thicknesses of alluvial deposits that store some ground water and are suitable for agricultural development. The large amount of precipitation in this province

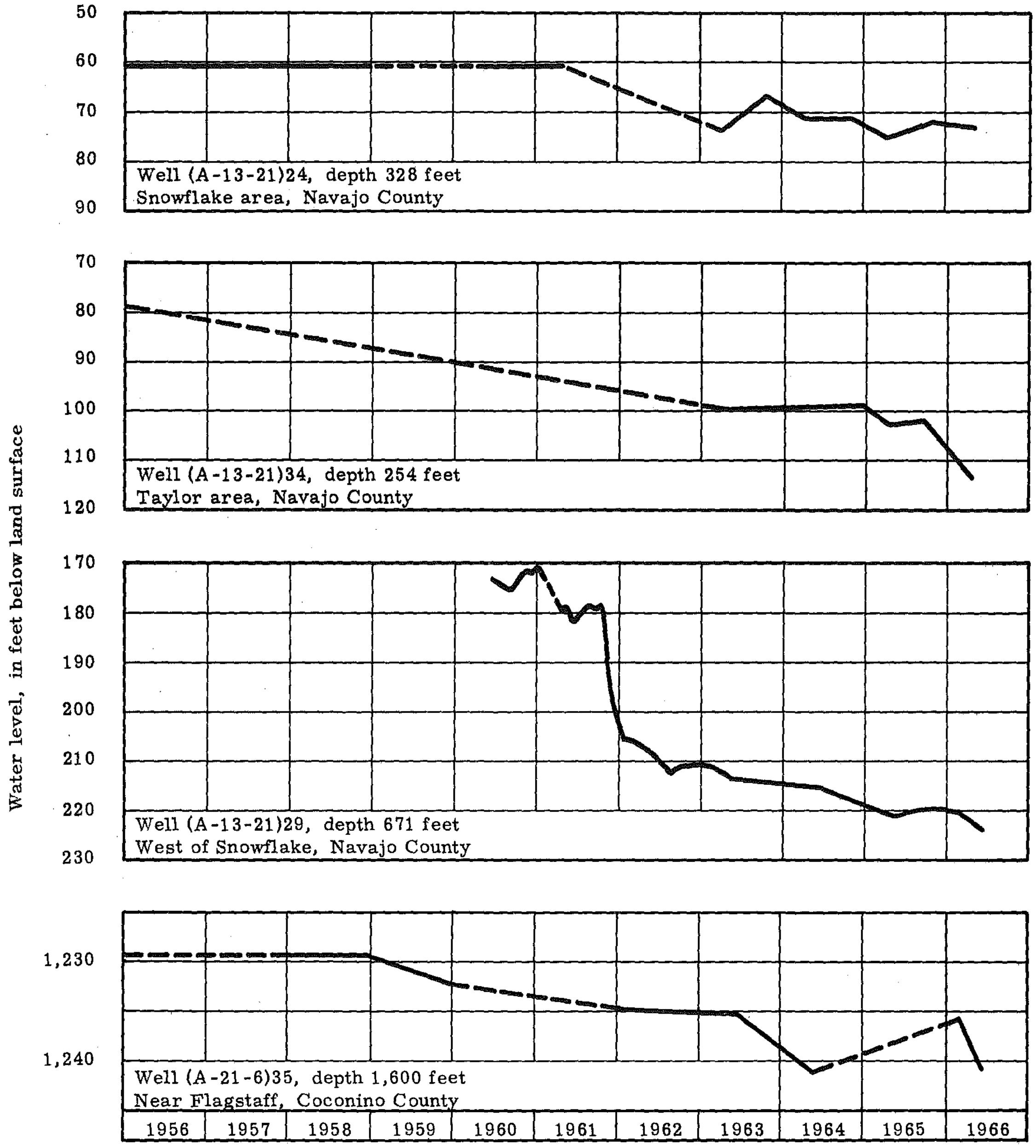


Figure 21.--Water levels in selected wells in Navajo and Coconino Counties.

is the source of streamflow that is utilized extensively for agricultural irrigation in the Phoenix basin.

Less than 15,000 acres of land was cultivated in the Central highlands province in 1965 (Hillman, 1966). Chino and Verde Valleys are the main areas of agricultural development and ground-water use in the province; in Verde Valley some surface water from the Verde River is used to irrigate crops. A small amount of land is developed for agriculture along the flood plains of the tributaries to the Gila and Salt River drainages in Gila County.

Chino Valley

By

H. W. Hjalmarson

Chino Valley (fig. 5, Nos. 24, 25, and 26), as described in this report, consists of three alluvial areas in Yavapai County north of Prescott—Big Chino Valley (No. 24), Little Chino Valley (No. 25), and Williamson Valley (No. 26). The physical geography of Chino Valley is similar to that of many areas in the Central highlands province of Arizona.

The alluvial-filled valleys contain water under artesian and water-table conditions. Water under water-table conditions is associated with alluvial sediments throughout the valley. Water under artesian conditions is associated with buried lava flows, which may be interbedded with volcanic ash, cinders, and alluvial deposits in many places in the valley; in other places water under artesian conditions is associated with interbedded layers of clay, sand, and gravel.

Big Chino Valley.--About 20,000 acre-feet of ground water was withdrawn from aquifers in Big Chino Valley for irrigation in 1965. The depth to water in artesian wells near the center of the valley was about 30 feet below land surface in spring 1966. The depth to water in water-table wells at the south end of the valley was about 130 feet below land surface. Water levels had been declining slightly during the last few years, but above-normal precipitation on the watershed in 1965 caused the water levels to rise from spring 1965 to spring 1966, as shown by the hydrograph for well (B-17-2)6 (fig. 22).

Little Chino Valley.--Ground water is under water-table and artesian conditions in Little Chino Valley. Near the south end of the valley, the depth to water in some artesian wells was as much as 350 feet below land surface in spring 1966. In the north end of the valley, artesian pressure is sufficient to cause some wells to flow. Water levels in artesian wells in the central part of the valley had been declining at an average rate of about 3 feet per year for the last few years; however, the rate of decline of the water levels decreased or the water levels rose from spring 1965 to spring 1966, as shown by the hydrographs of water levels in wells (B-16-2)21 and (B-16-2)35 (fig. 22).

In 1965 about 12,000 acre-feet of water was withdrawn for irrigation and about

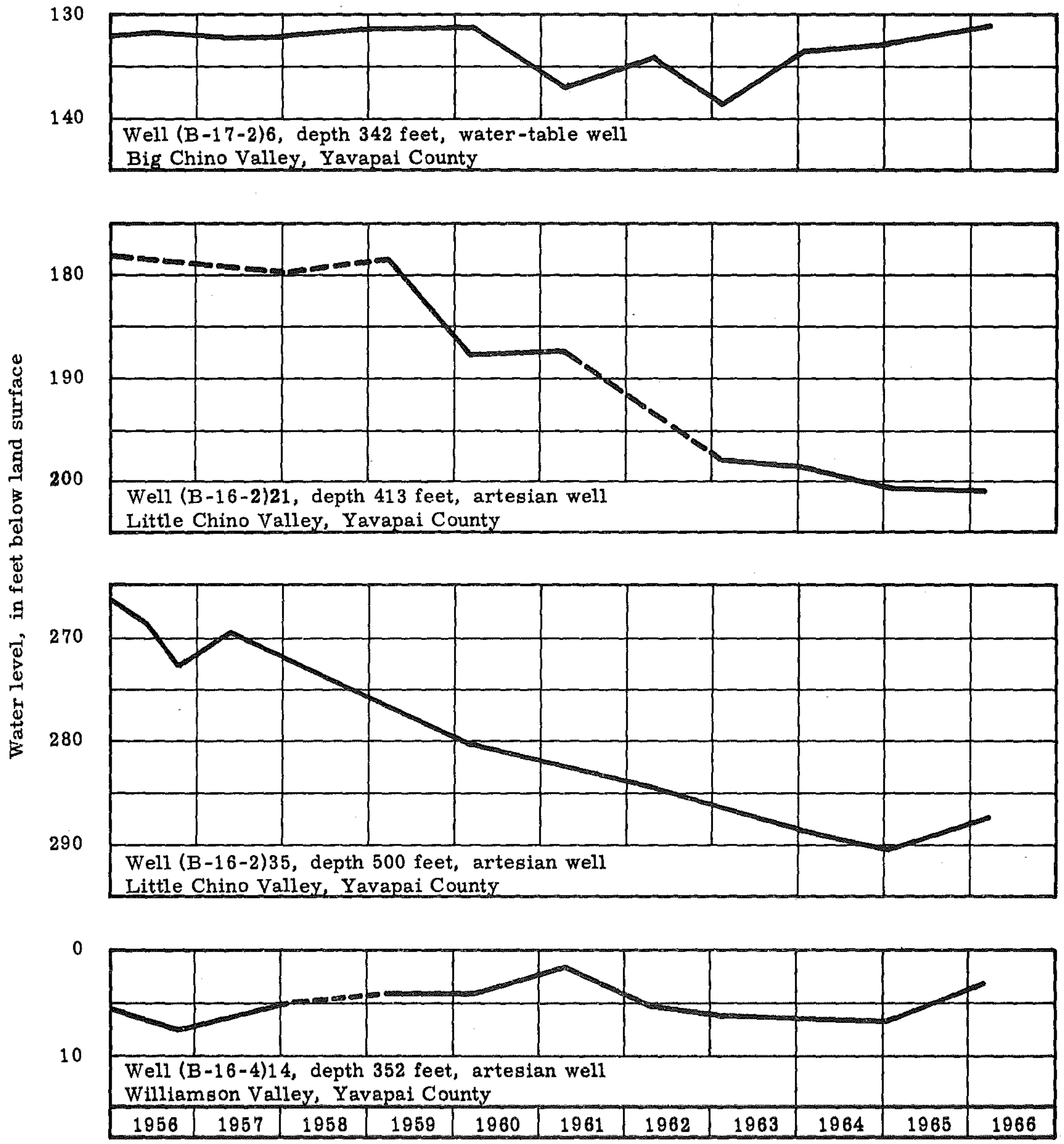


Figure 22.--Water levels in selected wells in Chino Valley.

1,600 acre-feet for municipal use by Prescott from the aquifers in Little Chino Valley. In addition, about 500 acres of land was irrigated with water from Watson Lake and Willow Creek Reservoir. The geology and water resources of the Prescott area near the south end of the valley have been described in a report by Krieger (1965).

Williamson Valley.--In 1965 about 2,000 acre-feet of water was withdrawn from artesian and water-table aquifers for irrigation in Williamson Valley. For the most part, water levels in the valley are shallow, and in the central part some wells flow. In general, water levels have fluctuated slightly during the last 10 years. The depth to water in artesian well (B-16-4)14 (fig. 22) was slightly more than 3 feet below land surface in spring 1966. The water level in this well rose nearly 4 feet from spring 1965 to spring 1966.

Verde Valley

By

H. W. Hjalmarson

The Verde Valley (fig. 5, No. 27) trends northwestward from the junction of Fossil Creek and the Verde River to Perkinsville. The valley is divided into the Clarkdale-Cottonwood-Camp Verde area and the Sedona area. A comprehensive discussion of the geology and ground water in the Verde Valley is contained in a report by Twenter and Metzger (1963).

Clarkdale-Cottonwood-Camp Verde area.--The principal source of ground water in the Clarkdale-Cottonwood-Camp Verde area is the limestone units. For the most part, ground water is under artesian conditions in these limestone units. Where the limestone units are confined above and below by aquicludes, they are not hydrologically connected; thus, the depth to water depends on the particular limestone unit or units penetrated. Some wells are flowing; in nonflowing wells the depth to water ranges from a few feet to more than 200 feet below land surface. Water levels generally fluctuated only slightly from spring 1965 to spring 1966, except in a well at Montezuma Castle National Monument where the water level rose 27 feet.

Sedona area.--More than 190 acre-feet of ground water was withdrawn from this area for domestic use during 1965. Water-level changes were minor from spring 1965 to spring 1966; the maximum depth to water was 571 feet below land surface.

Gila County

By

E. B. Hodges

Water levels generally are measured annually in three areas in Gila County—(1) near Globe, (2) in Dripping Springs Valley, and (3) in the San Carlos Indian Reservation. Water levels are shallow and tend to fluctuate in response to flow in nearby streams. A comparison of water levels in spring 1966 with those of spring 1965 showed erratic changes; for the most part, water levels rose considerably because of increased streamflow. Water-level changes were minor where they were unaffected by streamflow.

USE OF GROUND WATER

By

E. B. Hodges

About 4.0 million acre-feet of ground water was withdrawn from the underground reservoirs in Arizona in 1965—compared to about 4.5 million acre-feet per year for the last several years. The decrease in pumpage may be attributed, in part, to the conversion of some lands to crops that require less water and to the greater winter precipitation that reduced the need for normal pre-planting irrigation. The chief use of ground water in the State is for the irrigation of crops. About 1,160,000 acres of land was cropped in Arizona in 1965 (Hillman, 1966). Although these crops are irrigated with ground water for the most part, about 2.6 million acre-feet of surface water was diverted for use in the State during 1965. Most of the ground water is withdrawn and used in the Basin and Range lowlands province, and two areas—the Salt River Valley and lower Santa Cruz basin—account for more than 60 percent of the total amount of ground water withdrawn in the State.

Salt River Valley

Slightly more than 1,500,000 acre-feet of ground water was pumped from underground storage in the Salt River Valley during 1965, compared with nearly 2,000,000 acre-feet in 1964. The amount of ground water withdrawn in 1965 was less than that for any year since 1947. Of the total amount of ground water pumped, less than 100,000 acre-feet was for municipal and industrial purposes; the rest was used to irrigate crops. About 500,000 acres of land was cropped in 1965 in the Salt River Valley—the largest agricultural area in the State. About two-thirds of the irrigation pumpage was in the areas east of the Agua Fria River; the other third was in the areas west of the Agua Fria River. In addition to ground water, more than 760,000 acre-feet of surface water was diverted from the Salt and Verde Rivers in 1965. Of this amount, 60,000 acre-feet was for municipal use by the city of Phoenix; the rest was used to irrigate crops.

Lower Santa Cruz Basin

Data from utility companies show that more than 1,500 irrigation wells were in use in the lower Santa Cruz basin in Pinal County during the 1965 irrigation season; more than 1,000 were electrically powered and slightly less than 500 were powered by natural gas. On the basis of field tests of power and fuel consumption at 82 wells, it is estimated that about 910,000 acre-feet of ground water was pumped for irrigation in 1965. Pumpage in 1965 was less than that for any year since 1947. In 1965, 247,000 acres of land was cropped in Pinal County (Hillman, 1966), most of which was in the lower Santa Cruz basin. Only ground water is used for irrigation or other purposes in the Eloy and Stanfield-Maricopa areas, but in the Casa Grande-Florence area ground water is supplemented by a small amount of surface water from the Gila River. In 1965 about 137,000 acre-feet of surface water was diverted for use in the area.

Upper Santa Cruz Basin

About 200,000 acre-feet of water was pumped from the ground-water reservoir in the upper Santa Cruz basin in 1965. Ground water is the principal source of water supply in the basin. The use of water for irrigation continues to exceed the use for other purposes; however, the use of water for municipal, industrial, and domestic purposes is increasing. In 1965 about 70,000 acre-feet of ground water was withdrawn for nonirrigation uses, of which nearly 45,000 acre-feet was pumped from wells operated by the city of Tucson for use in the metropolitan area.

Avra Valley

In 1965 about 125,000 acre-feet of ground water was pumped to irrigate crops in the Avra-Marana area—slightly more then in 1964. The area is highly developed for agriculture, and ground water is the only water supply for the 30,000 acres of land under cultivation.

Willcox Basin

Only ground water is used to irrigate crops in the Willcox basin; the use of water for other purposes is minor. It is estimated that nearly 250,000 acre-feet of ground water was pumped from the ground-water reservoir in the Willcox basin in 1965.

Douglas Basin

About 90,000 acre-feet of water was withdrawn from the ground-water reservoir in the Douglas basin in 1965; this is 50 percent more than in 1964. Ground water is the only available source of water supply in the basin; the main use of water is for the irrigation of crops. Many new wells were drilled in 1965; from 40,000 to 50,000 acres of land was under cultivation or was cleared for cultivation in the Douglas basin in 1965. The irrigated acreage is expected to continue to increase for the next few years.

San Simon Basin

Ground water is used for irrigation in three general areas in the San Simon basin—the Bowie area, the San Simon area, and the Rodeo area. About 70,000 acre-feet of water was pumped in the basin in 1965; about a third of this amount was pumped in each of the three developed areas.

Other Areas

In the Safford basin ground water is used to supplement surface water for the irrigation of crops. In addition to the 90,000 acre-feet of surface water diverted in 1965, about 150,000 acre-feet of ground water was pumped for all uses in the basin. For 1965, pumpage in Safford basin was calculated on the basis of discharge measurments and power records; previously, pumpage was estimated from known decreed acreage and the availability of surface water.

In the Gila Bend area, which includes Rainbow Valley in its northeastern part, less than 120,000 acre-feet of ground water was pumped in 1965—a decrease in pumpage from previous years. Most of the decrease was in the Rainbow Valley part of the area.

In McMullen Valley land under cultivation and the amount of ground water pumped have been increasing gradually for the last several years. In 1965 slightly less than 90,000 acre-feet of ground water was withdrawn for all uses in this area.

In the Waterman Wash area ground water has been developed for irrigation only in the northern part; in the southern part there are a few wells that pump water for stock and domestic uses. In 1965 slightly less than 45,000 acre-feet of ground water was withdrawn for all uses in the area.

In Chino Valley ground water is withdrawn from artesian and water-table aquifers in three areas—Big Chino Valley, Little Chino Valley, and Williamson Valley. Most of the water is used for irrigation, except for the small amount used for municipal supply by the city of Prescott. Prescott is not geographically within Chino Valley, but a part of its water supply is withdrawn from artesian aquifers in Little Chino Valley. The amount of ground water withdrawn for all uses in Chino Valley was slightly more than 35,000 acre-feet in 1965.

Other areas in Arizona--such as Duncan basin, San Pedro Valley, Harquahala Plains area, Palomas Plain area, Ranegras Plain area, South Gila Valley, Big Sandy Valley, Sacramento Valley, Hualapai Valley, and Verde Valley—also use ground water for the irrigation of crops and other purposes. Although it is known that some of these areas use fairly large amounts of ground water, data are insufficient to compute the amount pumped for each area. The amount of ground water withdrawn in these areas and in other smaller areas in the State is estimated to have been about 425,000 acre-feet in 1965.

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