GROUND WATER IN THE SANTA CRUZ VALLEY

by

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INTRODUCTION

Ground water in the Santa Cruz Valley of Southern Arizona represents the only dependable supply of water for municipal, industrial and agricultural needs. The increasing popularity of the sunbelt coupled with an expanding mineral industry are placing greater demands upon an already overstressed water supply. Ground water levels in the Valley have been declining steadily for several years with more rapid declines resulting from recent increases in withdrawal. This paper presents a summary of water use for municipal, industrial and agricultural purposes in the Santa Cruz Valley along with estimates of annual recharge in a section of Rillito Creek. These data are essential to proper management of the water resources within the drainage basin of the Upper Santa Cruz River.

Since most wells in the Santa Cruz Valley do not monitor discharge, water levels, or pump performance, extensive ground water data are collected by the Department of Soils, Water and Engineering, College of Agriculture, University of Arizona. Annual water level measurements are taken in over 500 wells in the Valley. In addition, annual data on water use are compiled in the following manner. Municipal water use is determined from pumpage records supplied by the City of Tucson Department of Water and Sewers, private water companies, or estimated from population and per capita water use rates in areas not served by metered water supplies. Industrial water use is either obtained from individual and corporate pumpage records or estimated from annual production data and associated water demands for each particular industry. Agricultural consumptive water use is estimated by multiplying a crop water use requirement by the total crop acreage, as determined by a semiannual field survey.

To provide specific data on water use, the Santa Cruz Valley has been subdivided into four districts (see Figure 1) on the basis of aquifer characteristics (Schwalen and Shaw, 1957; Matlock et al, 1965; and Matlock and Davis, 1972). The Cortaro-Canada Del Oro District occupies the northern end of the basin lying north of Rillito Creek between the Santa Catalina Mountains and the Tucson Mountain foothills. The City of Tucson is located in the center of the Tucson District which extends from the Tucson Mountain Foothills on the west to the base of the Rincons on the east and from the Catalina Foothills on the north to San Xavier Mission on the south, including slopes of the Santa Rita and Rincon Mountains southeast of the City. The Sahuarita-Continental District, bounded on the north by the Tucson District and by the Pima-Santa Cruz County line on the south, occupies the bottom lands along the Santa Cruz River and adjacent valley slopes, or bajadas, between the Santa Rita Mountains on the east and the Sierrita Mountains on the west. The Santa Cruz County District is comprised primarily of narrow bottomlands along the Santa Cruz River from the Pima County line south to the Mexican boundary.

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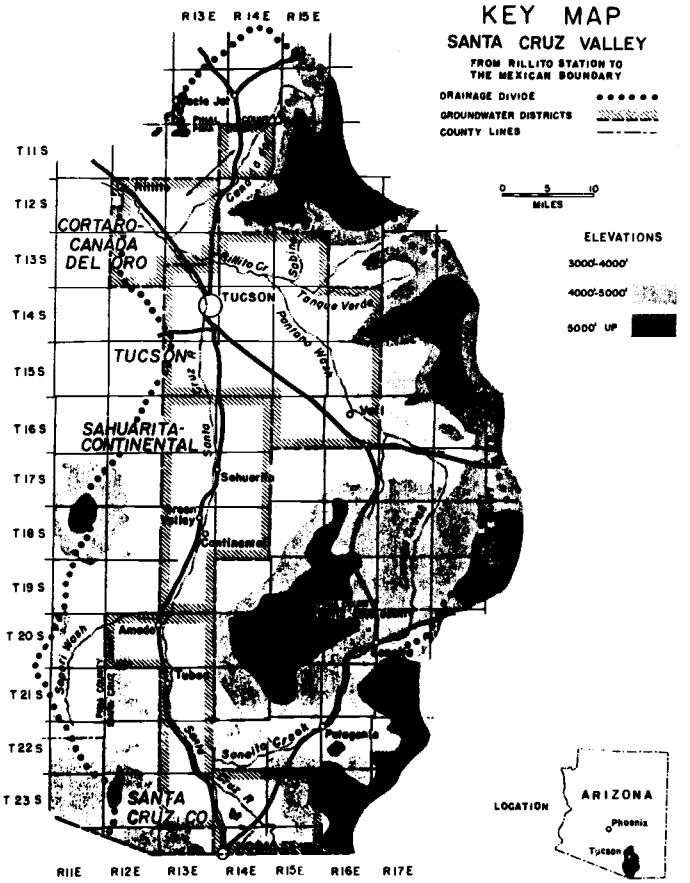
FIGURE 1. KEY MAP



LAND USE

The Santa Cruz Valley drainage area contains about 2240 square miles or two percent of Arizona land area; whereas Pima and Santa Cruz Counties combined comprise over nine percent (Arizona Crop and Livestock Reporting Service, 1977). The Valley occupies twenty-one percent of the area in these two counties. Land ownership by individual or private groups is 14% of Pima County land, 37% of Santa Cruz County land, and 17% for the two counties combined as compared to 18% for the state. The remainder of Arizona land is either publicly owned and administered by county, state and federal governments or by various Indian Reservations.

The population densities in Santa Cruz and Pima Counties are, respectively, 14.1 and 50.7 persons per square mile (Valley National Bank, 1977). Considering the relatively small proportion and spatial distribution of the private lands in Pima and Santa Cruz Counties, over 70% of the population resides within the Santa Cruz Valley and particularly in and around Tucson. The historical and projected populations for this area are given in Table 1. The population data reflect the migration of people from the northeast and midwest to the sunbelt states and emphasize the need for water management.

TABLE 1. POPULATION DATA

County	1940	1950	1960	1970	1977
Pima	72,838	141,216	265,660	351,667	468,100
Santa Cruz	9,482	9,344	10,808	13,966	17,600
TOTAL	82,320	150,560	276,468	365,633	485,700

County	1980	1985	1990	1995	2000
Pima	520,000	584,800	651,000	700,700	746,000
Santa Cruz	19,300	21,800	24,400	27,200	30,400
TOTAL	539,300	606,600	675,400	727,900	776,400

SOURCE: Bureau of the Census and Arizona Department of Economic Security

The Santa Cruz Valley was settled as an agricultural area with diversions for irrigation initially coming from the surface flows of the Santa Cruz River and later from an extensive network of wells. Irrigated acreage in each district of the Valley varies from year to year as influenced by agricultural prices and federal acreage regulations. The cropped acreages for each district for the years 1970 and 1977 are given in Table 2 below along with the average for this time span and the percentage in each district of the total average acreage. A decrease in irrigated acreage from 1970 to 1977 reflects the increasing cost of ground water pumpage due to water level declines and higher energy costs. These two factors can create an unfavorable economic situation for irrigated agriculture in the Valley. The bulk of the irrigated acreage is composed of various grains and cotton. It should be noted that a considerably larger irrigated area, within Pima County but outside the confines of the Santa Cruz Valley, exists west of Tucson in the Avra-Altar Valley.

TABLE 2. IRRIGATED ACRES

District	1970	1977	Average 1970-1977	Percent of Total
Cortaro-Canada Del Oro	2620	3720	2500	14
Tucson	2620	2620	2700	15
Sahuarita-Continental	10080	7040	8300	45
Santa Cruz Valley in Pima County	15330	13370	13400	74
Santa Cruz County	5230	2830	4800	26
TOTAL - Santa Cruz Valley	20560	16200	18200	100

WATER USE

Ground water in the Santa Cruz Valley is used in increasing quantities to supply municipal, industrial and agricultural demands. A water use summary is given in Table 3 and includes data compiled for 1970 and 1977. Water use for domestic and industrial purposes show an increase which is associated with the increase in population as discussed previously. Domestic water use in the Tucson District showed a significant decline in 1977 when compared to 1976 data, which is attributed to a substantial water price increase and the City of Tucson's "Beat the Peak" program. Of particular note is the distribution of water use within each district. Water use in the Tucson District shows the heavily urbanized character of this district whereas in Santa Cruz County almost the entire quantity of water used is for agricultural purposes. Comparing the total water use in the Santa Cruz Valley for 1970 and 1977 shows a definite trend away from agriculture toward an increased domestic water demand in agreement with the population statistics and irrigated acreage data presented in the previous section.

TABLE 3. WATER USE SUMMARY

District	Use[1]	1970 Water Use, acre-feet	1970 % of District Total	1970 % of Valley Total	1977 Water Use, acre-feet	1977 % of District Total	1977 % of Valley Total
Cortaro-Canada Del Oro	D	1740	17	1	5500	31	3
	I	450	5	<1	940	5	1
	A	7720	78	4	11290	64	6
	T	9910	100	6	17730	100	10
Tucson	D	50670	76	29	56660	76	30
	I	6650	10	4	8660	12	5
	A	9500	14	5	9260	12	5
	T	66820	100	38	74580	100	40
Sahuarita-Continental	D	13680	18	8	15880	23	8
	I	30910	40	17	29340	42	16
	A	32780	42	19	24000	35	13
	T	77370	100	44	69220	100	37
Santa Cruz Valley in Pima County[2]	D	66340	42	38	88930	51	48
	I	41390	26	24	41840	24	23
	A	50000	32	28	44560	25	24
	T	157730	100	90	175330	100	95
Santa Cruz County[2]	D	80	1	<1	300	3	<1
	I	0	0	0	0	0	0
	A	17790	99	10	9950	97	5
	T	17870	100	10	10250	100	5
TOTAL Santa Cruz Valley	D	66420	38	38	89230	48	48
	I	41390	24	24	41840	23	23
	A	67790	38	38	54510	29	29
	T	175600	100	100	185580	100	100

[1] D = Domestic; I = Industrial; A = Irrigation; T = Total.

[2] Includes some non-district data.

WATER RESOURCES

Although the Santa Cruz Valley is underlain by an aquifer extending to a depth of 1,000 feet in at least part of the basin, the ground water supply continues to be depleted. Additionally, there is evidence that the quality of ground water deteriorates at increasing depth in the central portion of the Tucson District as evidenced by some wells drilled to over 1,000 feet (Schwalen and Shaw, 1957). In general, however, the ground water elevations are declining on the average at the rate of about two feet per year with five feet per year not uncommon. The particular decline in a given well increases as the distance to one of the ephemeral streams increases. Only the major streams provide natural recharge during periods of extended streamflow. A ground water mound is created under the streams by the recharge.

The Arizona Water Commission (1975) has estimated recharge to the Upper Santa Cruz Basin in addition to estimating the quantity of ground water in storage within 700 and 1,200 feet of the ground surface. These estimates are shown in Table 4 and are used in conjunction with the 1977 water use data, presented in the previous section, to determine an annual water balance (i.e. deficit) for the Santa Cruz Valley. The water use and estimated recharge data indicate that water is being used at approximately three times the recharge rate. This fact shows the serious need for water management for the Santa Cruz Valley and explains the decline in aquifer levels.

TABLE 4. WATER BALANCE

	Use[1]	1977 Water Use	Estimated Recharge[2]	Annual Deficit	Estimated Ground Water in Storage[2] <1200 ft	<700 ft
		----------	1,000 acre-feet	----------	----------	----------
Santa Cruz Valley	D	89				
	I	42				
	A	55				
	T	186	65	121	56,000	28,000

[1] D = Domestic; I = Industrial; A = Irrigation; T = Total.

[2] Estimates from Arizona Water Commission (1975).

ANNUAL RECHARGE

Annual ground water level measurements have been used in combination with annual water pumpage data to compute recharge along a 14.5 mile reach of Rillito Creek in the Tucson District (Flug et al, 1978). These data were used in a complete mass balance of flow along the stream section as follows:

$$(V_F - V_I)\, S = R + Q + \Delta I$$

where

V_F = volume of saturated porous media at the end of a one-year period;

V_I = volume of saturated porous media at the beginning of the period;

S = storage coefficient;

R = recharge volume within a one-year period;

Q = volume of water pumped; and

ΔI = net inflow volume.

The convention taken is that R, Q, ΔI are positive if fluid is being added to the system.

Using annual water level data, V_F and V_I are estimated by a modified use of the Thiessen polygon method (Matlock and Davis, 1971; Diskin, 1970); data on Q are available from the water use information and S is assumed to be 0.1 for this alluvial section of Rillito Creek (Matlock et al, 1965). The net inflow was estimated by using Darcy's law in a discretized form across small sections of the closed region, and adopting transmissivity values from a calibrated digital model of the Tucson Basin (Fogg, 1978). Results of the available estimated recharge are summarized in Table 5.

TABLE 5. ESTIMATED RECHARGE IN 14.5 MILES OF RILLITO CREEK

Year	1961	1962	1963	1964	1965	1966	1967	1968	1971	1974
Recharge Ac-Ft	4830	18670	11120	15200	21590	18710	67750	44960	35000	22540

The average annual recharge for the ten years was 26,000 acre-feet or about 1,800 acre-feet per mile of channel. (Due to missing data recharge could not be calculated for 1969, '70, '72, and '73.) These results have been shown to be in good agreement with other estimates of recharge for Rillito Creek. A detailed analysis of recharge has not, however, been performed for all streams within the Santa Cruz Valley. The potential for recharge in the basin is great with an average annual rainfall of 1,800,000 acre-feet falling within the drainage area boundary (Schwalen and Shaw, 1957).

SUMMARY AND CONCLUSIONS

The Santa Cruz Valley, which depends entirely on ground water for supplying municipal, industrial and agricultural water demands, is presently in a serious overdraft situation. Ground water use is three times the estimated annual recharge with population projections indicating a continuous increase in domestic and associated industrial water use. As ground water levels continue to decline, most agricultural uses of water will become economically prohibitive. However, the present domestic water demands alone surpass estimated annual recharge.

Many of the predictions about water use and supply in the Santa Cruz Valley depend upon estimated parameters including population projections, water withdrawals, water use efficiencies, storage coefficients, transmissivities, and stochastic events such as the distribution and intensity of rainfall. Although many of these parameters have been studied in detail, a comprehensive analysis of their effects on the entire Santa Cruz Valley has not been performed. However, the data clearly indicate that a long range solution for supplying the water needs of the Santa Cruz Valley has not been found. Although temporary relief of the water deficit problem will be provided by water deliveries from the Central Arizona Project when completed, some areas in the Valley will continue to exhibit water level declines.

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