STUDY OF THE ADEQUACY OF THE WATER SUPPLY FOR THE CAREFREE-CAVE CREEK AREA

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by

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INTRODUCTION

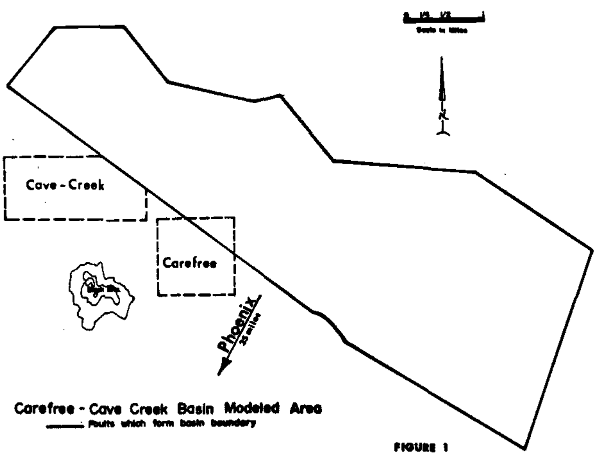
The water supply for the Carefree-Cave Creek area is derived solely from local groundwater sources. Groundwater began to be extensively pumped in the early 1960's for municipal and commercial uses. Prior to that time only a few ten's of acre-feet were pumped annually for local domestic and stock use. Present pumpage is approximately 1300 acre-feet per year. A result of the increased pumpage has been water level declines of up to 50 feet near Carefree. As a result of these declines and proposed extensive development within the obviously small groundwater basin, concern has been expressed about the future of the water supply for the Carefree-Cave Creek area.

PURPOSE AND SCOPE

The purpose of this study was to determine the adequacy of the water supply of the Carefree-Cave Creek area in general and of several proposed subdivisions in particular. The Water Commission had decided that, because of the small size of the area and the importance of long-term effects, a digital model could be used to good advantage to simulate the response to future water demand. Further, the digital model allows refinement of the data through simulation of known conditions, and facilitates location of areas where additional data are needed.

LOCATION AND PHYSICAL FEATURES

The Carefree-Cave Creek area, which includes the communities of Carefree and Cave Creek, is located approximately 30 miles north of Phoenix. The groundwater basin, which provides the bulk of the water supply, trends northwest, is approximately 7 miles long, and averages 2 miles in width. See Figure 1. The basin is surrounded by essentially impermeable hardrock boundaries with a small outflow section on the west side of Black Mountain. The area is within the Basin and Range Physiographic Province and New River-Cave Creek groundwater basin.



Carefree - Cave Creek Basin Modeled Area
Faults which form basin boundary

FIGURE 1

Geohydrology. Runoff from the surrounding mountains is the primary source of recharge to the water-bearing sediments in the Carefree-Cave Creek area. Only a small portion of the runoff reaches the groundwater reservoir where it moves northwestward downgradient toward Cave Creek.

Alluvial deposits, which form the principle aquifer in the area, were most probably derived from the adjacent mountains. These deposits appear to consist of a variably-cemented, heterogeneous mixture of silt, sand, gravel, cobbles and boulders. Because the sediments vary considerably in grain size over short distances both horizontally and vertically, the permeability of these deposits can vary considerably both areally and with depth. Regardless of this complexity, the saturated sediments in the study area probably respond to long periods of pumping as one unconfined groundwater system.

The aquifer system is considered to have been in approximate equilibrium prior to 1960, that is, inflow was roughly equal to outflow. Some groundwater was being pumped for domestic and stock purposes but not enough to significantly affect the water levels. Increasing pumpage after 1960 resulted in significant water level declines in the Carefree area.

MODELING OF THE HYDROLOGIC SYSTEM

The digital computer model used for this study is a modification of the one currently in use by the Water Resources Division, U. S. Geological Survey. The study area covers the entire Carefree-Cave Creek basin. The area modeled is as shown on Figure 1. All of the boundaries are the basin's natural boundaries as defined by the geology and extensive geophysical data. The model was programmed for water table conditions.

The modeling procedure consisted of three steps: (1) collection and preparation of model input data (2) calibration and verification of model and (3) projection of future water level declines associated with the existing and proposed additional demands for groundwater.

MODEL INPUT DATA

The first step in the modeling procedure is the collection and preparation of data that defines the overall hydrologic system. For this study input data to the model included: (1) transmissivity and storage coefficient values which described the physical characteristics of the aquifer (2) natural recharge and discharge (3) water level elevations and (4) the amount and distribution of historic pumpage.

This study used transmissivity data obtained from three aquifer tests: One of these tests was conducted by the Arizona Water Commission staff in 1973, two were conducted by Manera and Associates, Consultants, in 1973 and 1974. The values of transmissivity from these tests ranged from 200 gpd/ft to 20,000 gpd/ft. [1/] One test was conducted in the extreme eastern part of the study area and two tests in the central part of the study area. No aquifer test was available from the western part of the study area. Data from these tests were of quite variable reliability because testing conditions were sometimes less than desirable.

Initial values of transmissivity assigned to the model were based on all of these tests, plus specific capacity data from twelve other wells. These initial T values were subsequently adjusted during the steady state calibration step.

Storage Coefficient. No aquifer tests with sufficient data to determine storage coefficient values were available in the study area. Initial assigned values ranging from 3 to 10 percent were assigned based on storage coefficients for similar basins in Arizona and with some modification following the T distribution. These storage coefficients were also subsequently adjusted during the non-steady state calibration step in order to have the model duplicate known conditions.

Natural Recharge. Recharge to the aquifer occurs primarily from streamflow generated by precipitation in the nearby mountains. Several ephemeral streams cross the basin and recharge was initially distributed according to the size of the respective drainage area which contributed to flows across the basin. This distribution was slightly modified during the steady state calibration step to make the model conform to known conditions. Recharge is estimated to be approximately 260-300 af/yr.

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1. The T value of 200 gpd/ft as reported is probably much smaller than the actual value because the well has only 30 feet of producing section.

Historic Pumpage. Historic pumpage data was available for the Carefree area from the records of the Carefree Water Company and the local golf course. Historical pumpage was distributed to the nodes based on the location of the wells within the basin and the relative production of each well. In addition to the pumpage of the water company and the golf course there was some unmeasured pumpage for the community of Cave Creek as well as from a few scattered domestic and stock wells in the basin. Because nothing was known about the latter pumpage amount or distribution it was not considered in the steady state portion of the modeling effort.

Water Level Elevations. Early water level data are scarce as there are only four wells that can be considered to have pre-pumpage water level data. These early water surface elevations, plus some water level data from wells which were only slightly affected by the early pumpage period were used in the steady state calibration step.

A set of post-pumpage water level measurements were obtained in late 1974 and early 1975. These water level data were used in the non-steady state calibration step. Even this data is sparse due to a lack of measurable wells in the area.

CALIBRATION OF MODEL

Model calibration using historic water levels, recharge, and pumpage is a prerequisite to use of the model for projection of future conditions. Normally an independent verification is also conducted using a different historic period to determine how adequately the model simulates future water level declines in response to projected pumpage. Lack of data prevented this step in this case. To partially compensate for this lack of an independent check the model was calibrated in two steps, i.e., pre and post-pumping periods. In addition, these steps allow the adjustment and refinement of the data, point out the sensitivity of the model to data inaccuracies, and help determine areas where more data is needed.

The model was structured with a constant head boundary on the western side, and by no-flow boundaries on the north, south and east sides. In this case recharge from Cave Creek was assumed to produce a constant head boundary along the entire western side of the model.

The calibration step utilized both steady state and non-steady state conditions. The steady state condition was used to describe the water levels prior to 1960 when the aquifer was assumed to be under a stable natural condition, i.e., natural recharge is equal to natural discharge and both were assumed to be constant. To operate the model in this mode the storage coefficients for all nodes were set equal to zero. This constraint forced the model to change water level elevations in all nodes, except constant head nodes, until a configuration was obtained that balanced the inflow with the outflow for all nodes. This portion of the calibration step allows analysis and adjustment of the distribution and magnitude of T and recharge using the measured early water surface elevations as a target. A correlary goal was that during adjustment of T and recharge the values remained within the expected range for the basin.

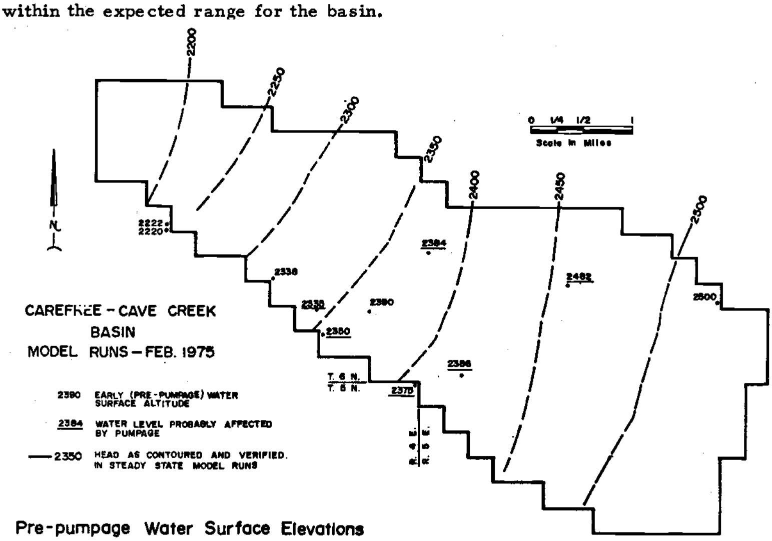
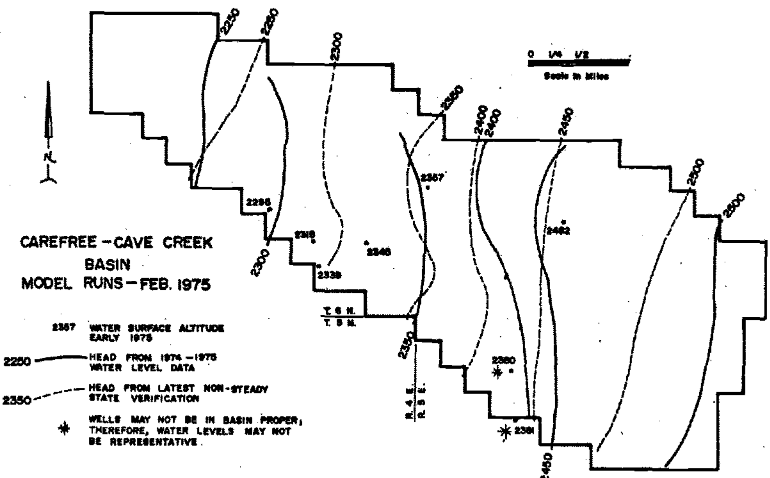


FIGURE 2

The final simulated pre-1960 steady state water level configuration is shown on Figure 2. As data was too sparse to draw an early contour map the model's nodal elevations were only compared with available data points. In the remainder of the area the elevations were thought to simulate a possible solution which was not unreasonable. Although the results shown on Figure 2 do not comprise a unique solution to the problem, they form a probable solution and one which can be used as a starting point for the non-steady state step.

The non-steady state calibration step consisted of simulating the thirteen year pumpage history, using a post-pumpage water level configuration determined from the 1974-75 round of water level measurements as the target. The non-steady state runs were primarily used for manipulation of the initially assigned storage coefficient. This step allows analysis and adjustment of the magnitude and distribution of storage coefficient. Slight adjustment to the other parameters were also made in order to make the model better conform to observed conditions. After such changes were made the model was again run in the steady state condition to determine if any gross changes had occurred. No significant changes of steady state conditions were seen to occur which provided a semi-independent verification of the parameters of T and recharge. As can be seen on Figure 3



1974 - 75 Water Surface Elevations

FIGURE 3

the model as finally calibrated was able to duplicate the water level configuration with good accuracy especially in the area of the most significant amount of pumpage, the center of the basin. Data was sparse in the eastern portion of the basin so the accuracy in this portion of the basin is difficult to assess. Thus, although less than perfect, the model was judged to be adequate for use in projecting impacts of future pumpage on the groundwater resources in the basin.

PROJECTION OF FUTURE EFFECTS

After the model was calibrated it was used to project the effects of the presently committed pumpage plus the initial 1900 lot phase of the proposed Carefree Ranch project for 20 and 100 year periods. Committed pumpage included the supply for the communities of Carefree and Cave Creek, all recorded lots in these areas not currently developed that would be served by wells in the basin, plus the demand for another small development in the extreme eastern end of the basin. See Table 1.

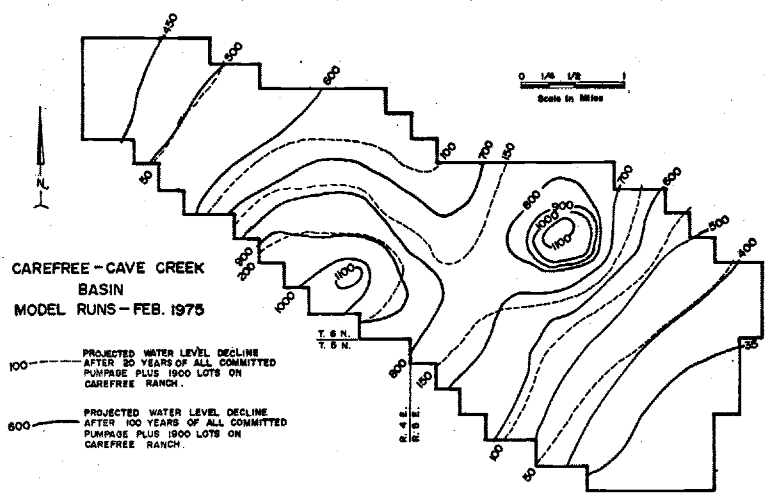
The unit demand for the 1900 lots was assumed to be the same as the present municipal and industrial demand in the area served by the Carefree Water Company. It should be noted that only a portion of the Ranch overlies the groundwater basin, thus the actual location of the pumpage center is restricted to this area. The results of the projection runs for periods of 20 and 100 years are shown on Figure 4. Declines of over 1100 feet in 100 years were projected for small areas centered on the Ranch field, and under Carefree. This would result in water levels of 1300 to 1400 feet.

The results of this run show that the effects of the pumpage for this portion of the Ranch will extend throughout the entire basin. Declines near the basin margins exceed 400 feet in the 100-year period. Portions of the aquifer system, notably along the basin margins, are relatively thin. Those portions of the basin, most notably the areas of Cave Creek and Carefree, may be

Table 1

Pumpage for Carefree - Cave Creek Area

	Source of Demand	Demand - Acre Feet/Year
Present	Carefree) 3000 persons Cave Creek)	600
	Desert Forest Golf Course	550
	Miscellaneous	150
		1300
Projected	Boulders Golf Course	550
	Carefree Hills Subdivision	40
	Undeveloped lots, Carefree	560
	Carefree Ranch, Phase I	950
	(1900 lots, 4750 persons)	2100
	TOTAL COMMITTED & PROJECTED	3400



Projection Runs

FIGURE 4

dewatered by the combined effects of the committed and proposed increased draft on the aquifer. Large areas of sufficient saturated thickness will remain in other areas, however, allowing room for a redistribution and management of the well fields to maintain production in this eventuality. Still, these effects are substantial and must be considered in planning the area's future.

SUMMARY

The Carefree-Cave Creek area's water supply is derived solely from groundwater. The basin from which the water is drawn is relatively small and the water supply is finite. Data within the study area are scanty and lacking in many areas but fortunately, the greatest concentration of fairly reliable data is in the vicinity of the greatest potential demand, the center of the basin.

The calibration-verification phase of the modeling effort was hampered by the lack of water level data prior to 1960 as well as the lack of parameters describing the aquifer. Of particular concern was the lack of data describing the magnitude and distribution of storage coefficients in the study area; these and other parameters were estimated and adjusted within reasonable values during the calibration of the model so as to best duplicate known conditions. The model does not perfectly duplicate the actual 1975 water levels but is reasonably close. The model comes within 5 to 10 feet of duplicating the decline in the central portion of the basin from 1961 to 1974. This close duplication of measured water levels and water level changes indicates that in the center of the basin the model can give reasonable projections of water level changes resulting from future water demand.

The projected impacts of the proposed development of 1900 lots on the Carefree Ranch as indicated by the results of the projection run indicate that the drawdown will be large even for Arizona. As would be expected, because these are the major centers of pumpage, the Carefree area and the southern portion of the proposed Carefree Ranch development show the maximum amounts of drawdown. Results of the projection runs can be seen on Figure 4. The average maximum decline was approximately 11 feet per year. Redistribution and/or dispersal of the pumpage would likely diminish the maximum decline.

In general, the simulated declines over the projection periods are at the extreme end of normal practices in Arizona. It is probable that the large withdrawals for the proposed Ranch project plus the already committed demand for the Carefree-Cave Creek area as specified in the model, would lower water levels throughout the entire Carefree-Cave Creek basin. Areas near the margin of the basin may be entirely dewatered. The severity of this impact would depend upon the actual thickness of the aquifer in a given area.

CONCLUSIONS

The conclusions presented in this report regarding the groundwater supplies of the Carefree-Cave Creek area and the proposed Carefree Ranch project are drawn from model studies that will continue to be perfected and upgraded with the addition of new data that should improve the accuracy of predictions. The conclusions have been arrived at, and therefore must be judged, considering the accuracy of the available data and the modeling effort. The effects of the predicted impact should be considered in conjunction with the safety factors of remaining saturated thickness and operational water management options available to the area. The following conclusions have been drawn:

1. The digital model of the groundwater reservoir in the Carefree-Cave Creek area, primarily due to data and time constraints, has not yet been verified to the degree that permits unequivocal reliance. Nevertheless, it is concluded that the model as presently developed is able to give a reasonable prediction of the possible effects of the future demands for water on the groundwater resources.

2. On the basis of studies to date, it is evident that the effects of the projected groundwater demands for the demand levels considered have a substantial impact on the groundwater reservoir. The impacts of the proposed development of 1900 lots on the Carefree Ranch are within the range of experience elsewhere in Arizona, but would cause drawdowns in water levels which are at the extreme margin of what can be considered as normal. Therefore the conclusion of the Arizona Water Commission is that the groundwater supply of the Carefree-Cave Creek basin area is adequate for the proposed 1900 lot first phase of Carefree Ranch.

3. It is obvious that under existing demands and the studied projected demands, the basin's water resources will be heavily exploited. Future proposals for development should be carefully analyzed as to their impact on the area's water resources, both to existing users and the proposal's own water supply adequacy. Further substantial development of the available land base would probably lead to the failure of the area's water supply. Thus, development of the Ranch to the projected population of 26,000 would be judged, at this time, to be infeasible as the demands on the basin, under present conditions, would be excessive.

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