TUCSON'S NEEDS FOR CENTRAL ARIZONA PROJECT STORAGE

Stephen E. Davis
Tucson Water
P.O. Box 27210
Tucson, Arizona 85726

Abstract

The future acceptance and utilization of Central Arizona Project water by the City of Tucson Water Utility present many complex technical, economic, institutional, and environmental problems. Since Congressional adoption of the Colorado River Basin Project Act in 1968, Tucson Water engineers have supported the concept of a large CAP raw water storage reservoir near Cat Mountain west of the City. The United States Bureau of Reclamation, in its Stage Two planning for Phase B of the Tucson Aqueduct, has identified four potential storage sites, including the Cat Mountain location, for economic and environmental evaluation in conjunction with two basic aqueduct alignments. Engineers of the municipal water utility have utilized available computer tools to develop a preferred CAP delivery location and elevation economically advantageous to water rate payers.

This paper discusses the various factors associated with Tucson's projected need for CAP water storage including reliability, operational flexibility, water quality, shortage, and power management. Each of these factors will affect the degree to which the water utility can successfully assimilate Central Arizona Project water into its groundwater supply system. Although a decision regarding storage location and volume has been postponed for the present, the initial years of CAP usage by the City of Tucson will provide sufficient test to justify the decision for no storage or prove its necessity.

Introduction

Eastern Pima County contains a wide diversity of water-using entities, each solely dependent upon groundwater for its current water needs. Groundwater pumpers include the City of Tucson, four mining companies south of the City, Farmers Investment Company (FICO), Cortaro-Marana Irrigation District, Avra Valley Irrigation District, private water companies, and private well owners. The collective impact of all users pumping groundwater five times in excess of natural recharge in the region is water table decline. Impacts of water table declines include increased energy costs, reduced well capacity, reduced water quality and increased potential for land subsidence. In portions of the Avra Valley and the Upper Santa Cruz basin water levels have dropped more than 120 feet over the last thirty years.

Statewide groundwater problems and the threat by the Federal Government to withhold funds to complete the Central Arizona Project encouraged the Arizona State Legislature to adopt the Groundwater Management Act on June 12, 1980. Primary elements of the Act affecting municipalities in general and the City of Tucson specifically have been discussed in a previous paper by this author (Davis, 1982). Four Active Management Areas (AMA's) were created by the statute including the Prescott, Phoenix, Pinal, and Tucson AMA's. The goal of the Tucson AMA is to attain safe yield (the long-term balance of groundwater withdrawals with natural and incidental recharge) by January 1, 2025. Staff of the Tucson AMA have recently prepared an updated baseline estimate and projection of existing and anticipated water uses and supplies from 1980 through 2025. This data, summarized in Table 1, demonstrates the groundwater mining problem which currently exists within the AMA and which will persist without effective management of all available water resources. Potential water supplies for the Tucson Active Management Area include Central Arizona Project water, reused wastewater, and natural and incidental recharge. In 1980, approximately 426,000 acre-feet of groundwater and wastewater effluent were used in the Tucson AMA. Analysis of Table 1 data indicates that 56.3 percent of the total 1980 water use was agricultural, 22.5 percent was municipal, 14.1 percent was mining, and 7.1 percent was industrial. Under this "no groundwater management scenario" prepared by Tucson AMA staff, overdraft is projected to decline from 261,000 acre-feet in 1980 to 111,000 acre-feet by 2025. Key assumptions include full utilization of wastewater effluent by 1990, gradual conversion of some private agricultural land to urban uses, new irrigation of 5,000 acres of San Xavier and 2,000 acres of Schuk Toak Papago Indian land after CAP delivery to Pima County, and full utilization of CAP water by requesting entities in the amount recommended by DWR and recently approved by Secretary of the Interior, James Watt.

Tucson Water is a municipally-owned and operated water utility providing domestic and industrial water service both inside and outside the corporate limits of Tucson. Water is provided to a service area of over 300 square miles having an elevation differential of over 1,500 feet. Presently, Tucson Water serves over 450,000 people through 131,000 active water services. This represents eighty percent of the Pima County population and over eighty-five percent of the metropolitan Tucson population. In 1981-82, Tucson Water actively pumped 186 wells from four wellfields serving the central metropolitan system and 23 wells serving 13 isolated systems. Sixty-six percent of the 83,000 acre-feet pumped by Tucson Water in 1981-82 was from the central, interior wellfield, and eleven percent was from the Avra

Valley west of Tucson. The remainder was pumped from the Southside and Santa Cruz wellfields near the riverbed south of Tucson.

Tucson Water pumpage statistics for the past ten years are listed in Table 2. The implementation of an increasing block, cost-of-service water rate structure, a winter-summer rate differential, the "Beat the Peak" summer demand management program, and public education through the news media have collectively reduced the Tucson per capita use from 205 gallons per day in 1973-74 to 165 gallons per day in 1981-82. Tucson Water uses population projections officially adopted by the Arizona Department of Economic Security and the Pima Association of Governments for Pima County. The December, 1981 DES figures indicate a County population of 536,000 in 1980 and a 2035 projection of 1,807,000. The corresponding Tucson Water population and water use projections are shown in Table 3. Water use for municipal purposes is projected to more than triple from an average of 68.5 million gallons per day in 1980 to 257.3 million gallons per day in 2035 based upon an assumed average daily per capita use of 160 gallons. To meet projected demands of existing and future customers, Tucson Water will have three primary supplies: groundwater, municipal wastewater effluent, and Central Arizona Project water. The focus of this paper is discussion of the incorporation of Central Arizona Project water into the Tucson Water domestic delivery system and the requirement that raw water storage be ultimately provided within the vicinity of metropolitan Tucson.

The Central Arizona Project

The completion of the Central Arizona Project (CAP) to the Tucson metropolitan area represents the primary ingredient to the formulation of a future water supply plan for the community (McLean and Davis, 1981). Legislation which ultimately resulted in federal approval for the CAP was enacted by Congress in 1921 when the seven Colorado River basin states were authorized to negotiate a compact for the apportionment of Colorado River water. It wasn't until 1944 that Arizona approved the 1923 Colorado River Compact and the 1928 Boulder Canyon Project Act allocating 2.8 million acre-feet of Colorado River's annual flow to Arizona. It wasn't until 1968 when President Lyndon Johnson signed Public Law 90-537, The Colorado River Basin Project Act, that the Central Arizona Project was finally authorized by Congress.

The CAP is a water delivery system which will furnish municipal, industrial, and irrigation water to urban, mining, and agricultural areas within Maricopa, Pinal, and Pima Counties. The CAP is a massive U.S. Bureau of Reclamation water resource development project designed to help solve central Arizona's problem of dwindling groundwater supplies, the overdraft of which exceeds two million acre-feet per year. The importation plan includes construction of a series of pumping plants and aqueducts to lift Colorado River water from Lake Havasu and carry it to the metropolitan areas of Phoenix and Tucson. The project will deliver an average of 1.2 million acre-feet per year via the main aqueduct systems. The Granite Reef Aqueduct will carry water in an open canal from Lake Havasu 190 miles to the Salt River just below the Granite Reef Dam. The concrete-lined canal will continue from the south side of the Salt River as the Salt-Gila Aqueduct for approximately 60 miles through agricultural areas of eastern Maricopa County and central Pinal County and terminate east of the Picacho Reservoir in southern Pinal County.

The Tucson Aqueduct consists of two segments, labelled Phase A and Phase B by the Bureau of Reclamation. Phase A planning is completed, and construction will commence in 1984 to bring the aqueduct southerly to the town of Rillito. Planning for Phase B continues in furtherance of meeting the USBR schedule shown below:

ACTION	DATE
Determine Alignment and Terminus	July, 1983
File Draft Environmental Impact Statement	November, 1984
File Final Environmental Impact Statement	August, 1985
Initiate Construction	Late 1985
Initiate Water Delivery	1991

Tucson Aqueduct-Phase B

Tucson Water has been intimately involved with the planning for the Tucson Aqueduct since 1978 when the Arizona Projects Office assigned a full-time planning engineer to study this major CAP feature. Advance planning for Phase B was initiated in May, 1981 through evaluation of numerous storage and alignment alternatives and preparation of preliminary economic, environmental, and institutional impacts. The number of alternatives were reduced significantly after public meetings in November, 1981. Since that time, the Arizona Projects Office, in conjunction with the major water users in Pima County, has performed further economic and environmental analyses leading to elimination of many Phase B alternatives from further consideration by the Bureau of Reclamation.

In early 1982, the Southern Arizona Water Resources Association (SAWARA) was formed to assist the community in the assurance of a stable, long-term water supply and effective management thereof for the Tucson Active Management Area. A major objective is to support the timely completion of the Central Arizona Project for the benefit of all the people of the State. In June, 1982, SAWARA was approached by the Bureau to assist in the development of consensus relative to the elements of alignment, terminus and storage associated with Phase B. In response, the Committee on Alignment, Terminus, and Storage (CATS) was formed in August, 1982. Initially, the Bureau presented the CATS with seven plans for its review and consideration as indicated below:

SUMMARY OF USBR PLANS
TUCSON AQUEDUCT-PHASE B

Designation	Alignment	Reservoir	Volume
Plan 1	West of Tucson Mtns.	San Joaquin	10,000 A-Ft
Plan 2	West of Tucson Mtns.	Cat Mountain	10,000
Plan 3	West of Tucson Mtns.	None	0
Plan 4	East of Tucson Mtns.	Marana	10,000
Plan 5	East of Tucson Mtns.	Cat Mountain	35,000
Plan 6	East of Tucson Mtns.	None	0
Plan 7	-No Action Alternative-		

In an attempt to assist the Mayor and Council develop a position with regard to the seven Bureau plans, Tucson Water staff utilized its computerized hydraulic modeling capability to evaluate the annual capital and operating costs associated with delivery of its CAP water to various locations and elevations (Davis, 1980). Assumptions used to generate model results included a fifty-year planning horizon (2035), Arizona Department of Economic Security population projections for Pima County, a per capita daily water use of 160 gallons, peak day demand condition, average day of the peak month supply condition, an annual municipal CAP allocation of 159,000 acre-feet, and a water treatment plant capacity of 190 million gallons per day for single plant alternatives and a hydraulic equivalent for dual plant alternatives. Figure 1 indicates the locations and elevations assumed by staff for Tucson's CAP water treatment plant or plants consistent with the seven plans proposed by the Bureau. Four single plant and two dual plant options were modeled. On the basis of model results, capital and operational cost impacts of various treatment plant alternatives are indicated in Table 4. The least expensive treatment plant location is the Cat Mountain site at an elevation of 2750 feet from both a total capital cost standpoint (in 1982 dollars) and an operational cost standpoint (based on 1982 power rates and 2035 water delivery). This computation, together with storage, blending, and flexibility considerations, has prompted staff to favor the USBR Plan 5 alternative for an east side alignment and a 35,000 acre-foot Cat Mountain Reservoir.

Raw Water Storage Considerations

The Colorado River Basin Project Act of 1968 authorized the construction of the Charleston Dam and Reservoir and the San Pedro Aqueduct partly as a supplemental source of water to serve Tucson. In 1978, Congress was notified by the Commissioner of the USBR that the San Pedro Aqueduct had been eliminated from the Tucson Division of the CAP due to anticipated growth of the Fort Huachuca-Sierra Vista area. At that time it was proposed to extend the Tucson Aqueduct to the south and to add terminal storage to facilitate improved operation of the Tucson Aqueduct and its integration with the Tucson Water system. In view of the aforementioned, Tucson Water staff reviewed the four storage alternatives proposed by the USBR to determine which met Tucson's requirements for reliability, operational flexibility, water quality, and buffer against CAP shortage. Additionally, the future opportunity for power management on the part of the Central Arizona Water Conservation District was evaluated.

As previously discussed, the USBR presented three storage volumes for consideration: 35,000 acre-feet, 10,000 acre-feet, and no surface water storage for which Tucson's water wells would be used to satisfy the criteria heretofore delineated. Under the no surface water storage alternative it was assumed by the USBR that Tucson's wells could be used to provide supply reliability for the period in which CAP delivery is interrupted. The USBR assumed the potential for a two week delivery interruption due to power outage, subsidence cracking affecting the delivery facility, or other maintenance requirements. In 2025, Central Arizona Project water is projected to meet two-thirds of the water demand anticipated for the growing Tucson Water service area. The loss of supply in this amount at the single location of the treatment plant would cause significant pressure problems, potential water outages, and a reduction in fire suppression capability if the CAP outage occurred in the summertime. In addition, new wells drilled in strategic locations would be required at considerable utility cost and constrained by as yet undefined well drilling limitations of the Tucson Active Management Area under the Arizona Groundwater Management Act. For these reasons, storage in some significant quantity must be provided by the USBR, particularly as CAP becomes the primary source of potable supply for the community.

The Bureau of Reclamation has provided two storage volumes for economic and environmental evaluation at three potential sites. The 10,000 acre-foot alternative was computed by the Bureau to be that volume capable of meeting municipal CAP water demands in the Tucson area for a two-week period. This reliability storage would have to remain untouched throughout the year, preserved to meet any CAP delivery interruption. Tucson Water has no operational flexibility with this amount of storage unless allowed by Bureau or Central Arizona Water Conservation District operating policy. Storage volumes larger than 10,000 acre-feet would allow the Utility to take water from storage when customer demands are greater than CAP aqueduct deliveries and to put water into the reservoir when demands are reduced at night or when it rains, for example. Storage for operational flexibility provides a buffer source to the water treatment plant when projections of CAP water need vary from actual customer requirements. The examination of raw water storage facilities of several similarwater agencies in the southwest suggests provision of two to three months storage for the Tucson area. This results in a recommended volume of 30,000 to 50,000 acre-feet.

Another benefit of storage in excess of that required for emergencies is water quality enhancement. A raw water storage reservoir provides for decreased fluctuation in water treatment plant influent water quality and, therefore, increased operational stability. Reservoirs often reduce turbidity, color and coliform levels. With storage, the potential exists for constructing a direct filtration plant rather than a conventional water treatment plant at a savings of as much as twenty percent in construction costs. This type of treatment process would also yield decreased chemical requirements and sludge production. If blending of groundwater with CAP water is required throughout the year to assure a more uniform water quality as delivered to the customer, then storage is necessary to deposit and withdraw the exact amount of CAP water to effectuate a consistent blend.

A fourth consideration for storage is the potential for CAP water shortages. The Bureau has indicated that shortages in the Colorado River system can be expected after the year 2000. Under the Colorado River Basin Project Act of 1968, Arizona bears the burden of these shortages. If a shortage occurs in 2035, Tucson's allocation of CAP water will be reduced from 150,000 acre-feet per year to approximately 70,000 acre-feet per year under the Bureau's proposed shortage operational mode. With this assumption, and full utilization of locally-developed groundwater sources, an additional 28,000 acre-feet of CAP water drafted from storage would be required for one year. If shortage persists, mandatory conservation is the only alternative. With a large reservoir, Tucson's customers will have the minimal time required to acclimate themselves to a major change in water use habits.

A fifth consideration for storage in the Tucson area is the potential for power management by the Bureau of Reclamation. To pump water from Lake Havasu the Federal Government has purchased 24.3 percent of the Navajo Generating Station in the Four Corners Region. This power has greater value if it can be sold for other uses in the summertime. This is the primary justification for large storage at the proposed New Waddel dam site near Lake Pleasant northwest of Phoenix. The Bureau's large storage option for Phase B would serve a similar purpose near Tucson. The reservoir could be filled in the wintertime and drained in the summertime for use by Tucson. The power savings could help offset the reservoir construction costs.

For all the reasons heretofor presented, on November 8, 1982, the Tucson Mayor and Council unanimously adopted a position in favor of construction of a 35,000 acre-foot reservoir at the Cat Mountain site as an element of Phase B of the Tucson Aqueduct. Additionally, it was recommended that the Bureau deliver water to Tucson at the Cat Mountain site at an elevation of 2750 feet, the most economical location and elevation for Tucson Water customers.

CATS Recommendations

The Committee on Alignment, Terminus, and Storage (CATS), per direction from its parent organization, the Southern Arizona Water Resources Association (SAWARA), adopted a consensus position on the Tucson Aqueduct Phase B on April 15, 1983. These recommendations were forwarded to the Bureau of Reclamation and the Central Arizona Water Conservation District for their mutual consideration. These proposals are included herein for information and future reference.

> Alignment Considerations - CATS recommends that Phase B of the Tucson Aqueduct of the CAP follow a route west of the Tucson Mountain Park described by the Bureau as Route 6. It is further recommended that the aqueduct be split into two segments. One segment of the CAP aqueduct at 350 cfs would deliver municipal water to the desired elevation of 2750 feet at the City of Tucson treatment plant. The other segment of the CAP aqueduct would deliver water to the Papagos, mines and other southerly water users at the south boundary of the San Xavier Indian Reservation.
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> Terminus Considerations - As a consequence of the alignment recommendations, CATS recommends that two termini be designated - one at the south boundary of the San Xavier Indian Reservation and another at the City of Tucson water treatment plant site.
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> Storage Considerations - CATS recommends that no further considerations by the Bureau be given to storage in the Cat Mountain area. We make this recommendation with the recognition that as the community becomes increasingly dependent upon CAP water to meet its domestic needs, there will be a need for surface storage of not less than 10,000 acre-feet in the future. This need will occur sometime after the year 2000 when it is projected that there will no longer be sufficient well capacity to meet the municipal needs should CAP fail to deliver water to the Tucson area. Prior to the occurrence of this situation, a cost/benefit analysis for different storage volumes and locations should be conducted.

It is apparent that the above recommendations will be adopted and implemented by both the U.S. Bureau of Reclamation and the Central Arizona Water Conservation District. Tucson's long-held position favoring large storage in the Cat Mountain area has been abandoned as a compromise to achieve desireable delivery location and elevation at federal cost. Only time will test the decision to forego storage initially. Ultimately, CAP storage in the Tucson area will prove to be both necessary and cost-effective.

References Cited

Davis, Stephen E., "Impacts of the Arizona Groundwater Act on Tucson Water," Hydrology and Water Resources in Arizona and the Southwest, Volume 12, 1982.

McLean, Thomas M. and Stephen E. Davis, "The Alternatives and Impacts Associated with a Future Water Source Transition for Tucson Water," Hydrology and Water Resources in Arizona and the Southwest, Volume 11, 1981.

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TABLE 1

TUCSON ACTIVE MANAGEMENT AREA
WATER USES AND DEPENDABLE SUPPLIES
(APRIL, 1983)

	1980		2000		2025	
POPULATION	536,400		936,400		1,587,900	
IRRIGATED ACREAGE	48,000		43,000		31,500	
TOTAL WATER USE (A-FT)		%		%		%
MUNICIPAL	96,000	22.5	168,000	33.3	285,000	47.4
INDUSTRIAL	30,000	7.1	52,000	10.3	89,000	14.8
MINING	60,000	14.1	69,000	13.7	69,000	11.5
AGRICULTURAL	240,000	56.3	215,000	42.7	158,000	26.3
TOTAL	426,000	100.0	504,000	100.0	601,000	100.0
CONSUMPTIVE USE (A-FT)	336,000		373,000		425,000	
DEPENDABLE SUPPLIES (A-FT)		%		%		%
CENTRAL ARIZONA PROJECT						
MUNICIPAL/INDUSTRIAL	--		92,000	23.5	173,000	35.3
AGRICULTURAL	--		55,000	14.1	28,000	5.7
INDIAN	--		38,000	9.7	38,000	7.8
REUSED WASTEWATER	9,000	5.4	80,000	20.5	136,000	27.8
NATURAL RECHARGE	75,000	45.5	75,000	19.2	75,000	15.3
INCIDENTAL RECHARGE	81,000	49.1	51,000	13.0	40,000	8.1
TOTAL	165,000	100.0	391,000	100.0	490,000	100.0
OVERDRAFT (A-FT)	261,000		113,000		111,000	

TABLE 2

TUCSON WATER PUMPAGE STATISTICS

Fiscal Year	Peak Day Pumpage (MG)	Average Day Pumpage (MG)	Active Services	Service Population	Pumpage Per Capita Per Day
72-73	118.8	60.1	95,105	351,889	170.8
73-74	130.4	75.4	99,604	368,614	204.6
74-75	115.2	67.6	102,813	380,408	177.7
75-76	117.6	70.0	105,595	369,583	189.4
76-77	123.7	60.5	109,480	383,180	157.9
77-78	112.1	59.4	113,105	395,868	150.1
78-79	113.2	60.8	117,777	412,220	147.5
79-80	110.0	66.2	122,514	428,799	154.4
80-81	120.6	69.7	125,367	438,785	158.8
81-82	119.1	74.0	127,650	446,775	165.5

TABLE 3

TUCSON WATER SERVICE AREA PROJECTIONS

(1980-2035)

YEAR	PIMA CO. POPULATION	TUCSON WATER SERVICE POPULATION	AVERAGE DAILY WATER DEMAND
1980	536,100	428,344	68.54 MGD
1985	620,000	493,852	79.02
1990	710,100	599,275	95.88
1995	810,700	684,612	109.54
2000	921,900	822,293	131.57
2005	1,048,400	935,754	149.72
2010	1,174,900	1,047,803	167.65
2015	1,301,400	1,159,852	185.58
2020	1,427,900	1,271,903	203.50
2025	1,554,400	1,383,952	221.43
2030	1,680,900	1,496,001	239.36
2035	1,807,400	1,608,051	257.29

TABLE 4

ECONOMIC EVALUATION OF TUCSON DELIVERY ALTERNATIVES

ALTERNATIVE	CAT MTN. I	CAT MTN. /TANGR.	SAN JOAQUIN	MARANA	CAT MTN. /MARANA	CAT MTN. II
DEL. ELEVATION	2617	2617	2400	2060	2617/2060	2750
WTP. CAPACITY	190 mgd	166/77 mgd	190 mgd	190 mgd	166/77 mgd	190 mgd
			CAPITAL COSTS			
WTR. SYSTEM	$183.3m	$187.9m	$204.8m	$247.9m	$196.6m	$173.3m
WTP	41.2	55.8	41.2	41.2	55.8	41.2
TOTAL	$224.5m	$243.7m	$246.0m	$289.1m	$252.4m	$214.5m
			OPERATIONAL COSTS			
WTR. TREATMENT	$ 2.43m	$ 5.46m	$ 2.43m	$ 2.43m	$ 5.46m	$ 2.43m
BOOSTER POWER	4.11	4.24	7.85	12.18	6.12	2.99
TOTAL	$ 6.54m	$ 9.70m	$ 10.28m	$ 14.61m	$ 11.58m	$ 5.42m

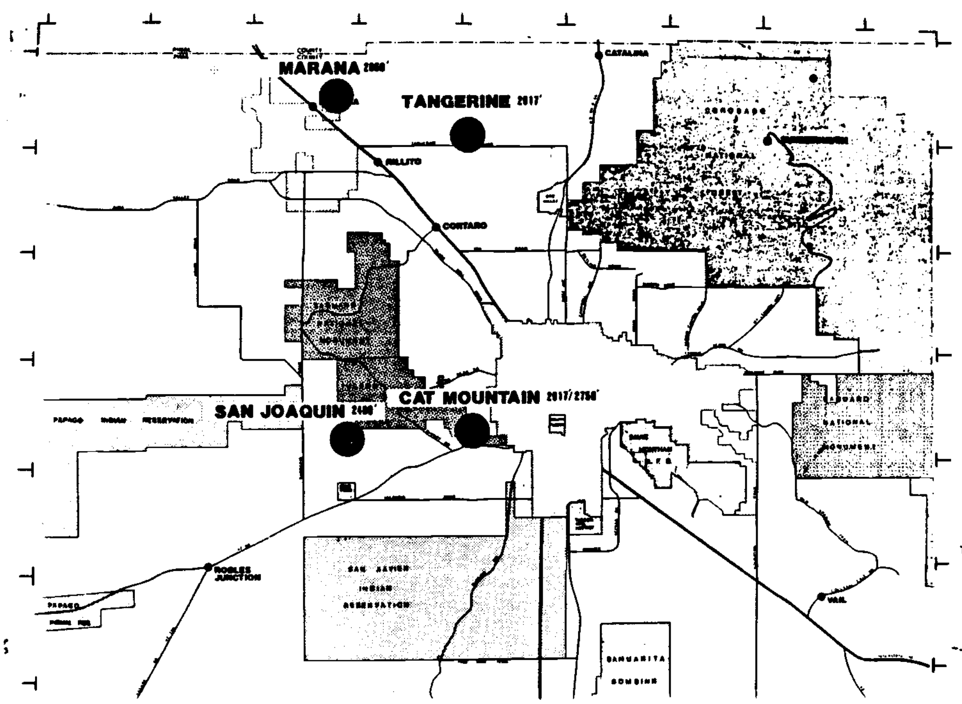

FIGURE 1. MAP OF MODELED CAP TREATMENT PLANT LOCATIONS