IMPACTS OF A NEW WATER RESOURCES MANAGEMENT PLAN FOR TUCSON, ARIZONA

by

R. Bruce Johnson
Tucson Water

ABSTRACT

Major events during the summer of 1974 led to the beginning of a new, progressive program of water resources management for the City of Tucson. Critical supply shortages during the 1974 peak demand period brought into sharp community focus the need to reassess the previously existing philosophy of meeting continually increasing demand for water with extensive capital construction.

An analysis of the impacts resultant from unmanaged peak demands, increased water level declines, potential land surface subsidence, projected increased operational costs and changes in water quality led staff and consultants to formulate and recommend the "Beat the Peak" program. A new philosophy on basin-wide groundwater withdrawals was implemented along with additional programs designed to evaluate the effect of our continued dependence on local groundwater sources. The results of this new management approach have been impressive. Per capita water consumption has been voluntarily reduced, total groundwater pumpage has been reduced and the potential for land surface subsidence is being actively evaluated resulting in direct benefits to Tucson Water and the customers it serves.

INTRODUCTION

Prior to the summer of 1974, the prevailing water service philosophy of the then Department of Water and Sewer had been to anticipate, and meet, the unmanaged peak demand requirements of the system by increased capital expenditures for expansion of the water system. The peak demand period of the summer of 1974 however proved to be one of the driest and hottest periods on record in Tucson. The City well system proved to be incapable of consistently meeting the prolonged peak demand periods the result of which were localized disruptions in service and chronic low pressures throughout the system. The experience of that summer convinced the staff of Tucson Water and their engineering consultants to evaluate and reassess the original service philosophy regarding meeting future unmanaged peak demand requirements.

In recognition of the need to reduce the high capital costs associated with meeting unmanaged peak demands, Tucson Water staff and consultants formulated and recommended a "Beat the Peak" program in the summer of 1977. This program was designed to manage these peak demand water use conditions. This voluntary program has proven to be a major success and has become one of the primary factors in the new water resources management plan which has resulted in substantial reductions in peak summer water use as well as reduced per capita water use by the single family residential user class supplied by Tucson Water.

POPULATION GROWTH FACTORS

The City of Tucson is situated in south central Arizona in what is geographically termed the northern extent of the Sonoran Desert. As a result of this Tucson enjoys a relatively mild climate with cool, mild winters and generally hot summers. Mean minimum temperatures during the winter range from 30°F to 33°F while during the summer temperatures often exceed 100°F. It is the water use associated with these summertime temperature extremes which create our peak demand water requirements.

Precipitation plays a minor role in terms of climate relief from the semi-arid environment surrounding Tucson. In fact precipitation is so minimal throughout

the Tucson area that it is not adequate in providing a source of surface water sufficient to meet the needs of our service population. Tucson annually receives about 10 inches of precipitation with approximately one-half of this amount occurring during the winter months. With the recognition, however that the average annual evaporation rates for the Tucson area range from 60 to 70 inches it becomes readily apparent that rainfall alone will not provide an adequate source of supply. Due in part to the minimal rainfall and the extreme variability in its occurrence, Tucson Water develops its entire supply from local groundwater sources. In that regard it is one of the largest municipalities in the United States to do so.

Collectively the positive factors of climate, recreational opportunities and local scenic beauty have combined to foster a phenomenal growth rate for the area. Tucson is now one of the fastest growing communities in the United States.

Table 1 has been prepared to show recent historic population figures as well as population projections for the Tucson Water service area to the year 2000, assuming an average annual growth rate of three percent.

TABLE 1

TUCSON WATER SERVICE AREA PROJECTIONS

End of Year	(1) Pima County Population	(2) Retail Service Population	(3) Active Services
1978	502,700	427,295	115,485
1979	521,300	443,105	119,758
1980	539,800	458,830	124,008
1985	606,300	515,355	139,285
1990	655,500	557,175	150,588
1995	727,100	618,035	167,036
2000	818,600	695,810	188,057

(1) From Arizona Department of Economic Security May, 1979. Adopted by PAG September 27, 1979 through the year 2000.
(2) Assumed to be 85 percent of County population.
(3) Assumed to be 3.7 persons per active retail service.

WATER USE PATTERNS

The patterns of water use for several of the various user classes supplied by Tucson Water are seasonal in nature. Water utility records indicate that water use during the winter months tends to be generally low and relatively constant while the summer months experience larger demands which usually peak in direct response to air temperatures and local precipitation patterns.

To analyze the overall impact which these fluctuating demands have on the operation of Tucson's water system it is necessary to establish and verify the peaking factors appropriate to our system. Table 2 shows the tabulation of the ratio of average daily pumpage to the peak day pumpage for the most recent 10 years of record for the Tucson Water utility.

TABLE 2

HISTORICAL AVERAGE AND PEAK DAY PUMPAGE

Fiscal Year	Average Day Pumpage (MG)	Peak Day Pumpage (MG)	Peak/Average
70-71	54.1	110.2	2.04
71-72	57.8	112.3	1.94
72-73	60.1	118.8	1.98
73-74	75.4	130.4	1.73
74-75	67.6	115.2	1.70
75-76	70.0	117.6	1.68
76-77	60.5	131.1	2.17
77-78	59.4	112.1	1.89
78-79	60.8	113.8	1.87
79-80	61.1(a)	110.0(b)	1.80

(a) Extrapolated based upon first six months. (b) Summer 1979

An analysis of the data presented in Table 2 indicates the ratio of peak day pumpage is around two. Historically, the ratio of peak day pumpage to the average daily winter pumpage has been between three and five. It is anticipated that the peaking factor of two for the ratio of peak day pumpage to average day pumpage will decline somewhat as the demand management program "Beat the Peak" receives a wider acceptance and understanding by the service population.

Similarly, a review of past ratios for the average day of the peak month to the average day of the year indicates a relatively constant relationship. Figure 1 illustrates this by a comparison of the peaking characteristics of the Water Utility for the year 1928 and 1978, a 50-year time span.

Although the actual quantity of groundwater pumped during 1928 was significantly less than that produced during 1978, the peaking factor for each year is remarkably consistent. Also note in each year the peak monthly water usage occurred during the month of June with a secondary peak period in September. This fact is interesting in that lifestyles are now quite different than they were in 1928, and there has been a tremendous growth in both the Water Utility service area and the population served. The relationship between the average day of the peak month to the average day of the year, however, remains very close to the value of the 1.5 as presently used by the Tucson Water Planning Division.

SEASONAL WATER USE

The data plotted on Figure 1 illustrates the seasonal variability in water use for the Tucson Water Utility as a whole. During the months of December, January and February, water use is at its lowest point of the year. With the coming of summer, however, water usage climbs to the peak demand period which is usually experienced during the month of June with the peak day of the year generally occurring between June 20 and July 10. However, not all water users demonstrate the extreme seasonal fluctuation in usage as shown by the systemwide averages plotted in Figure 1.

An analysis of average daily water usage for each of the five principal customer classes served by the Water Utility indicates that each user class has a varying impact on any given peak demand period.

Shown on Figure 2 is the metered water usage for individual customer classes served by the Water Utility during 1979. While each user class (excepting Duplex-Triplex) displays the pronounced seasonal trend of maximum water use during the summer, each user class exhibits its own unique peaking factor. Figure 2 demonstrates that by far the largest proportionate share of any peak water use condition, can be ascribed to the peak demand of the single family residential user class. As a result, reduction of peak water use by this class would have the greatest impact in reducing the immediate need for providing increased system capacity to meet peak demand periods.

PEAK DEMAND WATER USE

That the greatest proportion of water required during peak demand periods occurs outside the home is shown in Figure 3. The estimated monthly volume of sewage flow relates principally to that quantity of water which supplies inside household uses such as bathing, laundry, dishwashing, etc. Historically, metered sewer flows tributary to the treatment facilities have shown little increase through the summer months (May through September) indicating that it is outdoor water use which is the primary contributing factor to our peak demand periods.

For the single family residential user group, this corresponds to the watering of lawns and decorative plantings, and it is this segment of water use which has been significantly changed by the implementation of the "Beat the Peak" demand management program.

"BEAT THE PEAK"

Early in 1977, the consultant firm of Black and Veatch, together with the Water Utility staff, initiated a study of the potential effects peak management programs might have on various capital improvement programs required to meet anticipated peak demand requirements. Developing two demand projections, Black and Veatch (1977) demonstrated that a properly coordinated demand management program could significantly lessen the need for immediate system expansion. Results could be realized in reducing projected increases to rates then in existence as well as forestalling the need for

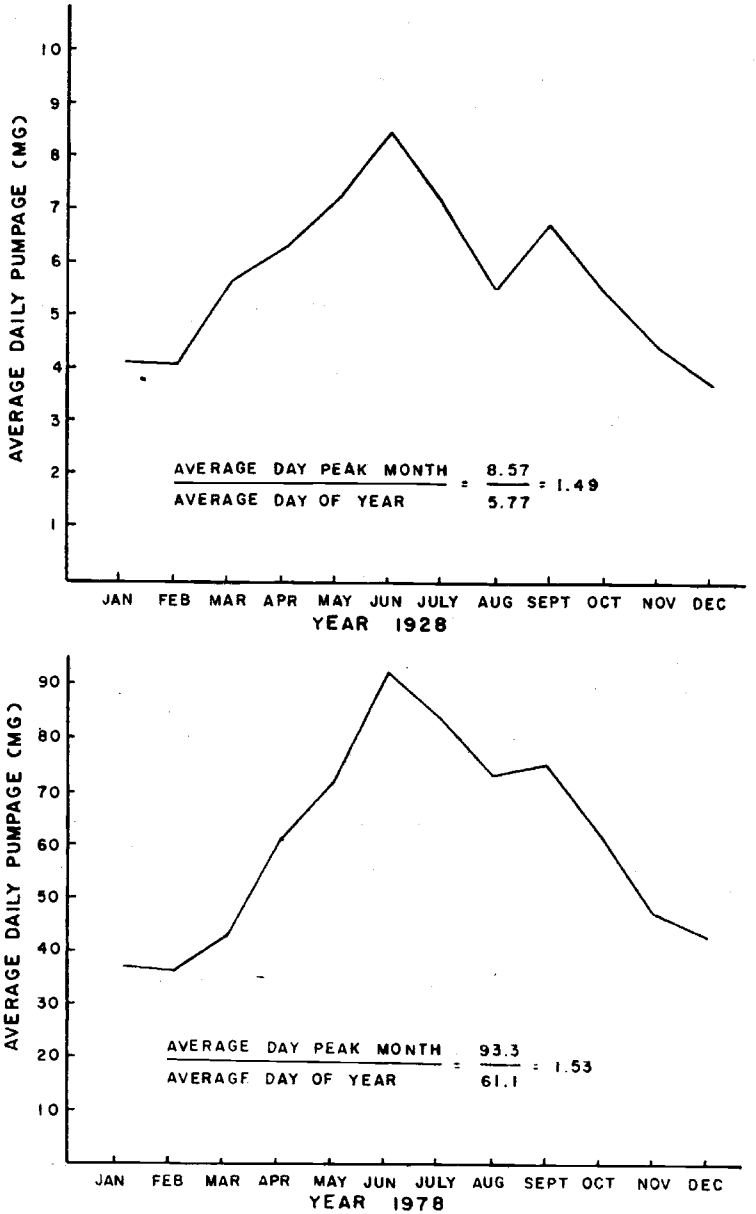

FIGURE 1: **COMPARISON OF METERED WATER USE 1974 and 1979**

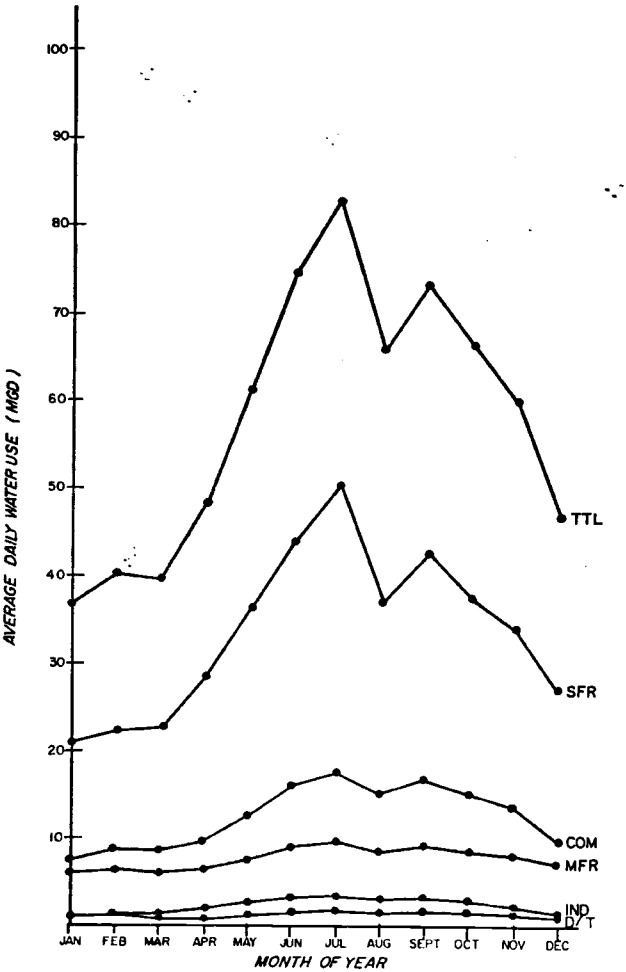

FIGURE 2: **METERED WATER USE BY CUSTOMER CLASS 1979**

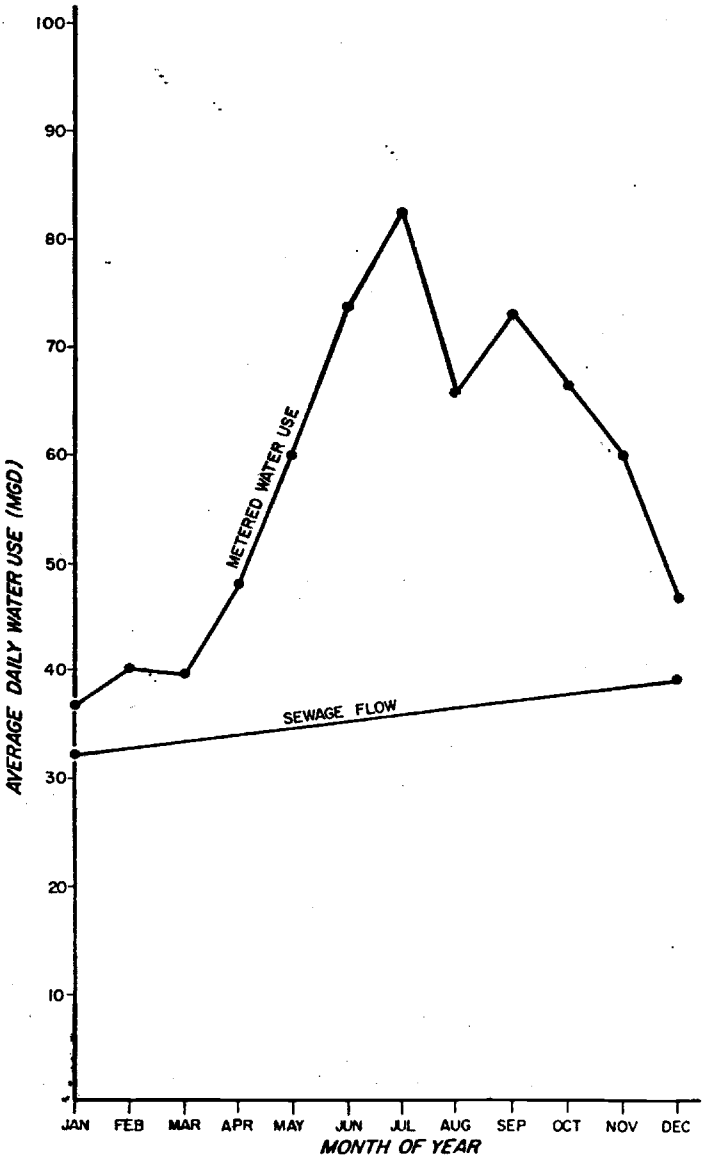

FIGURE 3: **METERED WATER USE vs SEWER FLOW 1979**

additional capital construction to meet larger use conditions. Rate payers would be the direct beneficiaries of such a program.

With no peak management program it was projected that the required well system capacity would be 200 million gallons (757,576 m^3) per day by 1983. If a reduction of 25 percent in the outdoor water use could be effected on the peak day, well capacity requirements could be reduced to 166 million gallons (628,434 m^3) per day. Further, projections assuming no reduction in peak demands indicated the need for a substantial increase in system well capacity prior to 1979.

Providing for the additional well system capacity as required in these projections would have involved a massive capital spending program. Additional supplies were best obtained from Avra Valley some 12 miles (19.35 km) west of Tucson and separated from the City by the Tucson Mountains. Black and Veatch (1977) estimated a six-year capital improvement program at a cost of $140 million for projected needs based on the status quo. By effecting a 25 percent reduction in peak outdoor watering demands, the required capital program was estimated to cost only $100 million. Under these circumstances, the City of Tucson initiated a public information and education program entitled "Beat the Peak."

The program was initiated with public appearances by the Mayor and City Councilmembers on June 1, 1977, prior to the anticipated peak demand period of the summer season. The essential elements of this program consist of voluntary outdoor watering on alternate days based upon customer street address and date and a voluntary limitation of outdoor watering between 4:00 p.m. and 8:00 p.m. Excellent media coverage of the program was afforded by daily news reporting of reservoir levels, total pumpage, and per capita consumption during June, July and August compared with similar system parameters experienced during the same time periods for the previous year.

That the "Beat the Peak" program continues to be a success is evidenced in Figure 4 which provides a comparison between 1974 and 1979 metered water usage for all customer classes in the aggregate and the single family residential class, individually. In 1974 the total single family residential usage amounted to about 66 percent of the total system water use. For the total system, average daily water use during the peak month went from 100 million gallons in 1974 to 83 million gallons in 1979, while the average daily water use during the peak summer months for the single family residential class continues to show a twenty-three percent reduction over the same time period.

PROGRAM RESULTS

The success of the "Beat the Peak" program has been greater than either the consultant or Tucson Water staff had anticipated. As a result of changed water usage patterns total pumpage of groundwater has been reduced. Table 3 below documents system-wide pumpage for the utility during the last several years.

TABLE 3

ANNUAL PUMPAGE BY WELLFIELD (ACRE-FEET)

Fiscal Year	Santa Cruz Wellfield	Southside Wellfield	Avra Valley Wellfield	Interior Wellfield	System Total
71-72	15,178	5,030	1,449	43,282	64,939
72-73	15,634	5,535	3,248	42,828	67,244
73-74	16,574	7,018	5,361	55,498	84,452
74-75	16,614	4,846	7,245	47,041	75,745
75-76	15,031	4,919	8,715	49,916	78,580
76-77	14,397	2,737	9,623	41,043	67,800
77-78	14,593	2,868	9,703	39,293	66,457
78-79	15,209	2,192	15,382	35,305	68,088

The figures presented in Table 3 indicate that system-wide pumpage for the Utility during fiscal year 1978-79 is comparable to that experienced in fiscal year 1972-73 in spite of the annual growth rate of about 3% during that time frame. Although the "Beat the Peak" program was not devised as a conservation program our service customers have reduced their overall per capita consumption. This reduction may be explained in part by increased awareness of the local water resource problems on the part of the consumer and by newly adopted rate making philosophies incorporating an inverted rate feature.

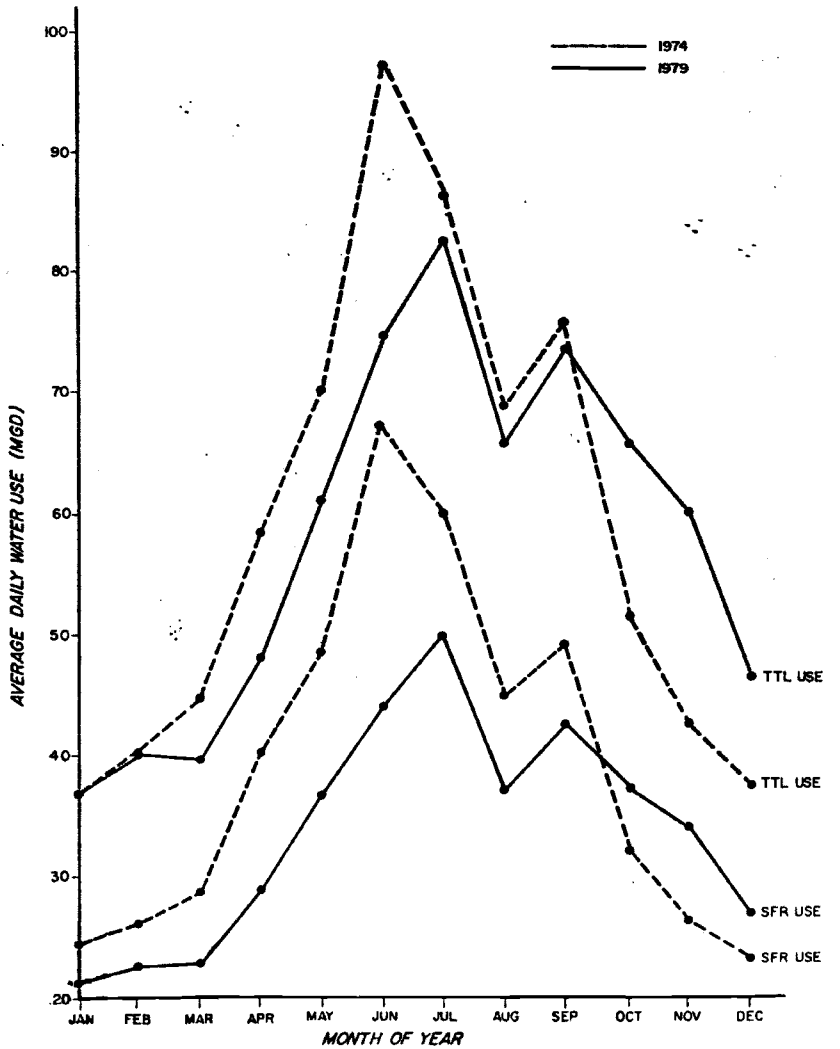

FIGURE 4: **COMPARISON OF PEAKING FACTORS 1928 vs 1978**

Table 4 shows the degree to which our various customer classes as a whole have altered their usage habits to effect the marked reduction in per capita pumpage figures observed since fiscal year 1974-75.

TABLE 4

Fiscal Year	Average Daily Pumpage (MG)	Active Services	Service Population	Pumpage Per Capita/Day
69-70	51.2	71,241	263,592	194.2
70-71	54.1	78,177	289,255	187.0
71-72	57.8	84,816	313,819	184.2
72-73	60.1	95,105	351,889	170.8
73-74	75.4	99,604	368,535	204.6
74-75	67.6	102,813	380,408	177.7
75-76	70.0	105,595	390,702	179.2
76-77	60.5	109,480	405,076	149.4
77-78	59.4	113,105	418,489	141.9
78-79	60.8	117,777	435,775	139.5

From the figures shown in Table 4 it can be seen that the per capita pumpage for the system has been reduced from a high of about 205 gpcpd during fiscal year 1974-75 to about 140 gpcpd during fiscal year 1978-79. This reduction would be important on its own merits considering a static service population but with the realization that the service area population has shown an increase of 67,240 during that interval makes the impact all the more significant.

Analysis of the data contained in Tables 3 and 4 also reveals that Tucson Water through the success of the "Beat the Peak" demand management program has been able to initiate the management of its presently available water resources in answer to major concerns for land surface subsidence, cost of water production and water quality. As developed in previous discussions by Davis (1978) and Johnson (1978) Tucson Water is beginning a major source shift to more effectively manage its available supplies and to prepare the system for major imported water supplies. The "Beat the Peak" program has allowed pumpage of the interior wellfield to be reduced while pumpage from Avra Valley has been increased. Such an option would not have been possible without a developed alternative supply if per capita demands had continued to increase as anticipated prior to initiation of "Beat the Peak."

CONCLUSION

Collectively, individual user classes have modified their usage patterns principally in their outdoor water habits. Substantial numbers of multi-family living units and single family residences have removed lawns and plantings and replaced them with low water use desert landscaping. Living units with these low maintenance, low water consumption features have become prime selling points to the local real estate market which further encourages individual users to cooperate with the program. The City of Tucson has done much to promote the program by serving as an example. Street medians, formerly planted in grasses and other high water use plantings, have been replaced with attractive and low water-consuming desert vegetation. Also, the local building industry has made greater use of low flow water fixtures in many new developments as well as making these fixtures available for voluntary retrofitting at the individual homeowners option.

The success of the "Beat the Peak" program cannot be completely ascribed to a one time public education effort on the part of the City. The awareness of the individual user has been enhanced by increased media understanding of the problem and increased involvement by interested community groups. These efforts, coupled with changes in water rate philosophies incorporating increased unit rates for water, have done much to perpetuate customer support for the program. Deferral of capital projects has allowed the Water Utility time to resolve numerous technical and institutional problems associated with the establishment of a long-term water supply plan for Tucson. The complex variables involved with such a plan are difficult to resolve. It is believed that continuing the "Beat the Peak" management program will allow rational, planned solutions to these problems.

ACKNOWLEDGEMENT

The assistance rendered by co-workers of Tucson Water during the preparation of this paper is gratefully acknowledged.

REFERENCES CITED

Black and Veatch Consulting Engineers, 1977. Report on Capital Improvement Program, Revenue Requirements, and Water Rates. City of Tucson Water Utility.

Davis, Stephen E., Tucson's Tools for Demand Management, 1977. Proceedings, Arizona Academy of Science, Hydrology and Water Resources in Arizona and the Southwest, Volume 8, pp. 9-15.

Johnson, R. Bruce, Hydrologic Factors Affecting Groundwater Management for the City of Tucson, Arizona. Proceedings, Arizona Academy of Science, Hydrology and Water Resources in Arizona and the Southwest, Volume 8, pp. 1-8. (1978)