WATER RESOURCE ALTERNATIVES
FOR POWER GENERATION IN ARIZONA

by

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INTRODUCTION

Arizona's rapidly increasing urban population and expanding industrial capability will require the installation of additional electrical generation capacity during the years ahead. Associated with this increased capacity will be a demand for additional cooling water for the removal of waste heat from the generating plant condensers.

In this report, an examination of potential water sources for power plant cooling in Arizona is discussed. Additionally, information pertinent to Arizona's future water needs relative to electrical usage growth is presented.

WATER AND ENERGY IN ARIZONA

ARIZONA'S WATER BALANCE

Figure 1 presents a general summary of the origin and use of water in Arizona. It is estimated that rain and snowfall deposit approximately 80 million acre-feet per year (Ma-f/y) on Arizona land surfaces while rivers and other tributaries import an additional 2.8 Ma-f/y. Examination of Figure 1 reveals that less than 6 percent of this total input results in usable supply, the balance being lost to evaporation and transpiration (the process by which plants return moisture to the atmosphere) (Arizona Interstate Stream Commission, 1967).

For every acre-foot of water consumed in municipal or industrial applications, agriculture utilizes in excess of 14 acre-feet, with the total annual demand presently exceeding the dependable supply by approximately 3 Ma-f/y. The water necessary to cover this annual deficit is supplied by an overdraft of the groundwater reservoirs.

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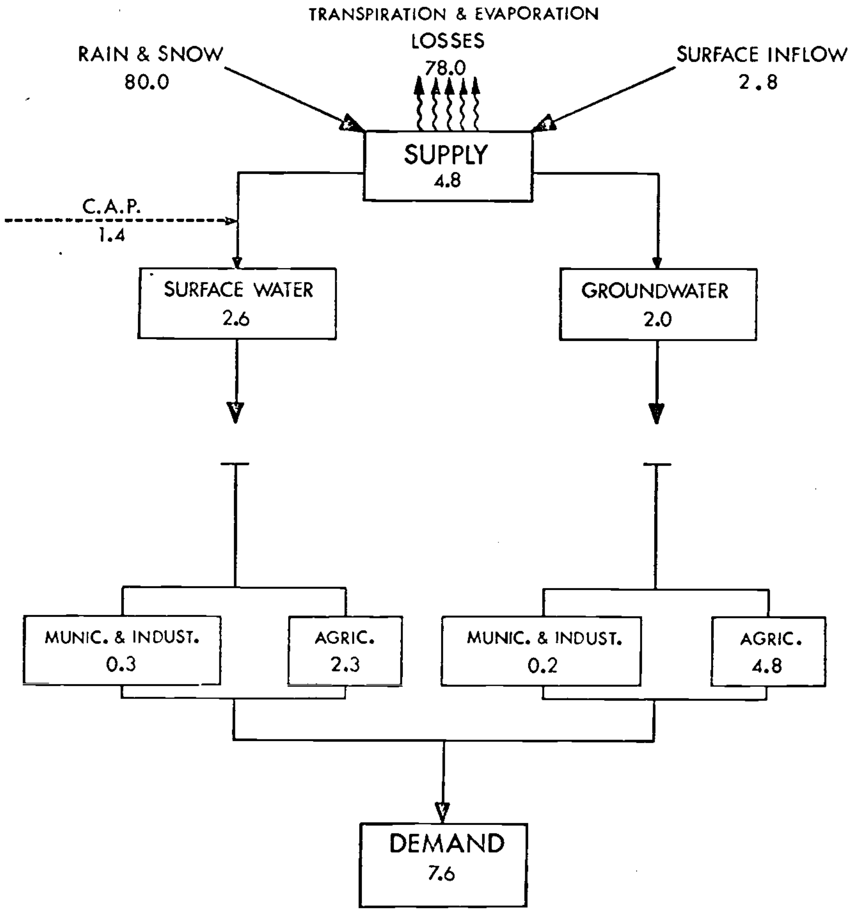
FIGURE 1

--ARIZONA WATER--

RESOURCE vs. DEMAND in 10^6 acre-feet/ year



This practice has resulted in a gradual decline in water levels in many areas throughout the State, with Tucson's water level dropping as much as 125 feet in some areas for the period 1940-1966. (Arizona Bureau of Mines, 1969). Arizona's rapidly growing population[1] will place increasing burden on groundwater and surface water supplies for the foreseeable future. While the Central Arizona Project is expected to add approximately 1.4 Ma-f/y by the 1980's (IAEA, 1969), this amount will be insufficient to compensate for the annual overdraft at present use rates.

ARIZONA'S ENERGY USAGE

The comparative per capita demand of electrical energy for Arizona and the United States is shown in Table 1 (U S Census, 1973), along with the average increase in electrical generation for the period 1971-1972. Latest obtainable figures for installed capacity for the United States (Fed. Power Comm., 1972) and Arizona (WINB, 1971) are also presented.

It has been estimated that the current national rate of growth of total energy consumption is approximately 4.2% per year (National Petroleum Council, 1971). The growth of electrical power demand is more rapid, with Arizona's estimated compound growth rate averaging 7.9% per year for the period 1970-1990. As a result of this rate of growth, it has been projected that Arizona's peak electrical power demands in 1980 and 1990 will exceed that of 1970 by some 5000 MW(e) and 16000 MW(e) respectively (WINB, 1971).

FUTURE ENERGY AND WATER REQUIREMENTS

At present, the bulk of the electrical energy generated in the Western states originates at hydroelectric installations such as Hoover and Horseshoe Dams. While many sites remain which could be developed for hydroelectric generation, environmental and ecological pressures are making it increasingly difficult to exploit the potential. With the decreasing abundance of natural gas and oil, nuclear power is forecast as the generating source which will assume the greatest importance until at least the end of the century. The projected trend for electrical generation by source is presented in Figure 2, which reflects the decreasing importance of hydroelectricity, natural gas, and oil as energy sources (WINB, 1974).

Utilization of conventional light-water nuclear reactors for power generation requires a cooling water supply in excess of that which would be required for a comparable fossil-fueled plant. This disparity arises as a result of the inherent difference in plant efficiencies. While the fossil-fuel power plant operates at temperatures approximating

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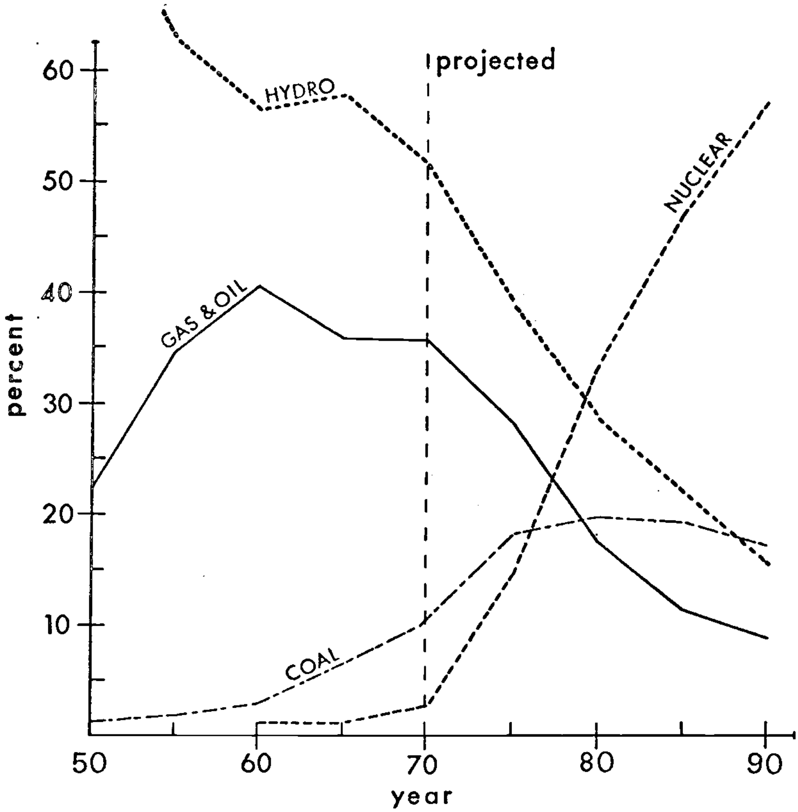
1. Arizona ranks first in the nation in terms of rate of population increase.

TABLE 1

ELECTRICAL POWER USAGE FOR
THE UNITED STATES AND ARIZONA

U. S. POPULATION JUNE 1, '72 (EST)	2.08×10^8
AVG.MONTHLY ELEC. GENERATION (U.S.)	1.51×10^{11} KWH (72)
U. S. AVG. PER CAPITA POWER DEMAND	1.0 KW (APPROX.)
AVG. PER CAPITA INSTALLED CAPACITY	2.0 KW (72)
INSTALLED CAPACITY (DEC. 1972)	4.2×10^8 KW
AVG. GENERATION INCREASE (72/71)	8.2 %
ARIZ. POPULATION JULY 1, '72 (EST)	1,963,000
AVG. MONTHLY ELEC. GENERATION (ARIZ)	1.43×10^9 KWH (72)
ARIZ. AVG. PER CAPITA POWER USE (72)	0.995 KW
INSTALLED CAPACITY, ARIZ. 1970	
HYDROELECTRIC	900 KW (APPROX.)
THERMAL	2830 KW (APPROX.)
TOTAL	3730 KW

FIGURE 2



PERCENTAGE DISTRIBUTION BY ENERGY SOURCE
FOR ELECTRICAL GENERATION IN THE WEST

1200°F, safety considerations limit reactor operating temperatures to approximately 650°F, with an associated penalty in efficiency. Total efficiencies for nuclear power plants reach approximately 32% with the result that for every kilowatt of electrical energy generated, somewhat more than two kilowatts of waste heat must be rejected to the environment.

When employing "wet" cooling methods, large amounts of water must be supplied in order to remove waste heat from the plant condensers. Table 2 presents typical data for water consumption in three types of power facilities. It should be noted that an additional source of water consumption exists for the fossil plant in the form of water necessary for the operation of scrubbers. Inclusion of this use places the fossil plant in close proximity to the HTGR in terms of total water consumption.

SOURCES OF COOLING WATER

Currently, there are no uncommitted surface water sources within Arizona of capacity sufficient to provide for the cooling requirements of a 1000 MW(e) nuclear power plant. It was necessary, therefore, to consider two alternative supplies, groundwater and reclaimed wastewaters.

Allowing for the consideration of several methods of heat dissipation, an average value of 22.4×10^6 gallons/day may be stated as representative of the consumptive use of a 1000 MW(e) power facility (Fazzolare, 1973). This figure represents the daily domestic consumption of about 195,000 persons or the annual irrigation requirements of approximately 5400 acres.

At the same time, the per capita production of sewage in Arizona may be estimated at approximately 100 gallons/day, of which in excess of 99.5% is water (City of Tucson, 1973). It can thus be seen that a population center of 224,000 persons would provide a supply of water sufficient to satisfy the requirements of a 1000 MW(e) plant, which in turn would provide electrical power to serve the per capita needs of 625,000 persons.[2]

SITE EVALUATION

The ten Arizona sites shown in Figure 3 have been examined in an effort to arrive at an estimate of the economic advantage, if any, associated with the use of reclaimed sewage water as opposed to the pumping of water from the groundwater supplies associated with these areas. Sites were selected on the basis of present existence of a sewage flow rate adequate to satisfy 10 percent of the cooling requirements of a 500 MW(e) conventional LWR. Only two of the sites examined had effluent flows large enough to supply the total demand of such a plant.

2. Includes 30% reserve capacity and no losses.

TABLE 2

WATER CONSUMPTION FOR POWER PLANT DESIGNS**

IN ACRE-FEET / YEAR

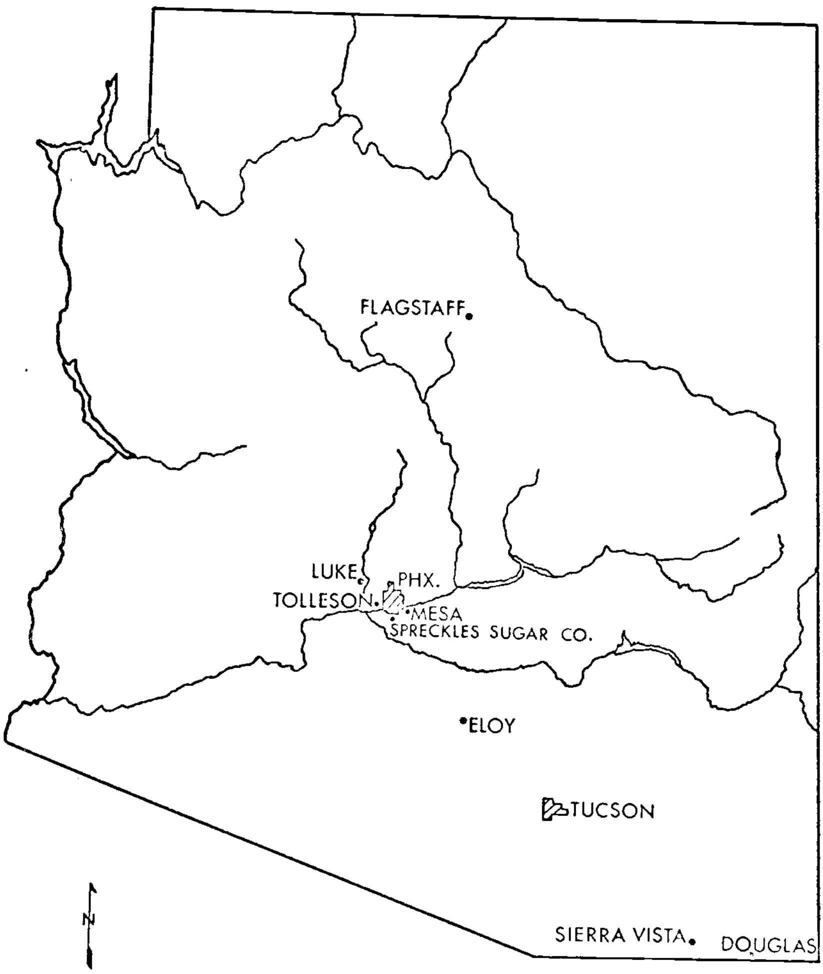
PLANT TYPE	EVAP. LOSSES	BLOWDOWN	TOTAL
FOSSIL	11,500	2,250	13,750
HTGR[A]	14,300	2,910	17,200
LWR[B]	18,800	3,710	22,510

A. HIGH TEMPERATURE GAS COOLED REACTOR

B. LIGHT WATER REACTOR

** BASED ON A 1000 MW(E) DESIGN

FIGURE 3



POTENTIAL POWER PLANT SITES FOR ARIZONA

A summary of the site examination is presented in Table 3. Population data for 1970 and growth rate over 1960 have been recorded in an attempt to identify those sites having the greatest future potential for electrical need as well as wastewater production. Secondly, current rate of effluent outfall and its comparison to the total cooling requirement of a 500 MW(e) plant are tabulated. Since the purchase price of sewage is an unknown, two cost figures of 5 and 10 dollars per acre-foot have been used in calculating the expense of the purchase of all sewage produced by the waste treatment facility. In case of a plant production in excess of 100% of the need of a 500 MW(e) power facility, it has been assumed that 12,000 acre-feet/year of sewage is purchased.

Hydrological factors considered for each site include static lift, drawdown, and dynamic lift. While in actuality large pumpages would be distributed among a number of wells, equivalent drawdown for a single well was utilized as a simplification. United States Geological Survey well data were used for all groundwater level calculations.

Cost per acre-foot of groundwater at associated lifts has been estimated, inclusive of fixed and variable pumping costs. "Sewage cost Equivalent" in Table 3 indicates the annual charge of pumping an amount of groundwater equivalent to the amount of effluent available at the associated site. The difference reported is the annual savings accrued as a result of the use of wastewater rather than groundwater. This cost comparison applies to the cost of acquisition only; treatment costs for plant input water, such as water softening, would be incurred for both sources of water.

CONCLUSIONS

It is concluded that the utilization of reclaimed wastewater is a viable and attractive alternative to groundwater pumpage from both economic and ecological standpoints. In all sites considered, use of wastewater resulted in significant savings over use of groundwater. Benefits arise from conservation of fuel normally required to operate well pumps, costs of well placement are not required, and a previously unused resource is effectively recycled. Furthermore, quantities of fresh water would be released for consumption by alternate users.

TABLE 3

SAMPLE OF SITE EXAMINATION

		TUCSON		FLAGSTAFF
SITE	ELEVATION	2200 FEET		6780 FEET
	POPULATION	262,933 '70		26,117 '70
	POP. INCREASE	23.5 % 60-70		43.4 % 60-70
SEWAGE	PRODUCTION MG/D	36.0		3.0
	ACRE-FEET / YEAR	40,741		3,414
	% OF COOLING OF 500 MWE. PLANT	340		28.4
	COST/YEAR @ $ 5	$ 60,000		$ 17,070
	@ $ 10	$ 120,000		$ 34,140
HYDROLOGY EC.	STATIC LIFT	369 FEET		1221 FEET
	DRAWDOWN	733 FEET		208 FEET
	DYNAMIC LIFT	1102 FEET		1429 FEET
	COST PER ACRE-FT WATER AT THIS LIFT	$ 30.50		$ 39.40
	SEWAGE COST EQV.	$ 366,000		$ 135,000
	DIFFERENCE	$ 246,000		$ 101,000

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