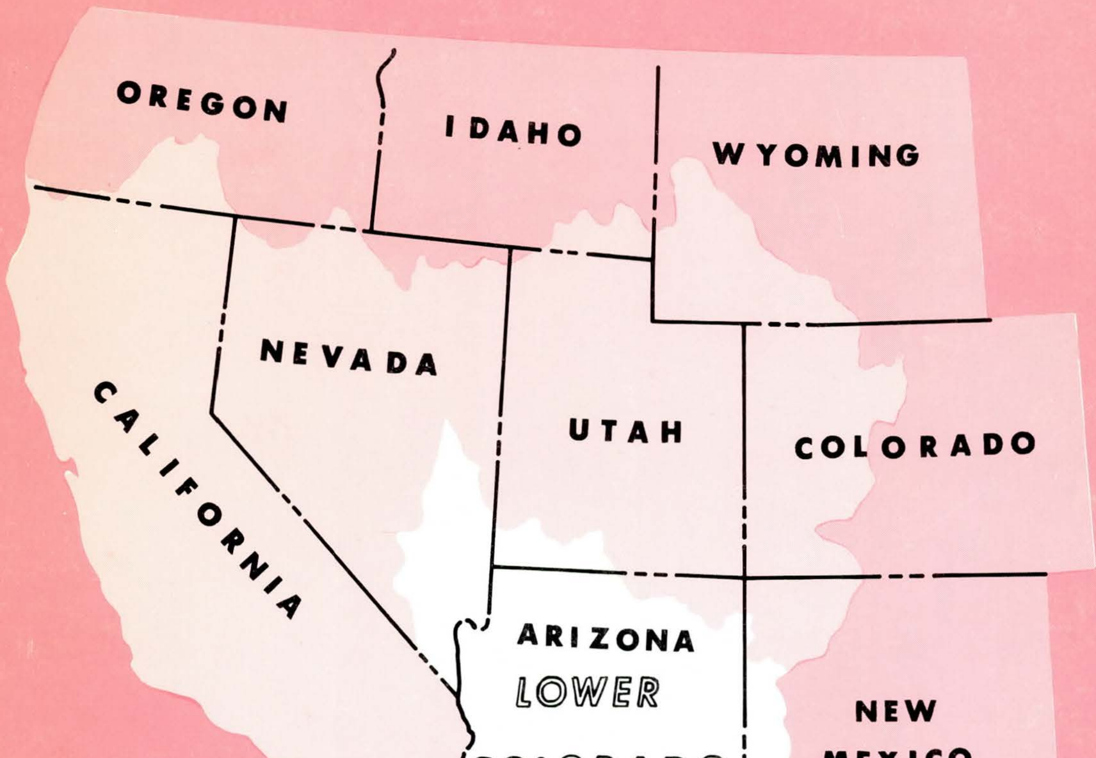
LOWER COLORADO REGION
Comprehensive Framework Study

APPENDIX XI
MUNICIPAL AND INDUSTRIAL WATER SUPPLY
JUNE 1971



PREPARED BY:

LOWER COLORADO REGION STATE—FEDERAL
INTERAGENCY GROUP FOR THE
PACIFIC SOUTHWEST INTERAGENCY COMMITTEE

APPENDIXES TO THE MAIN REPORT

LOWER COLORADO REGION

LOWER COLORADO REGION

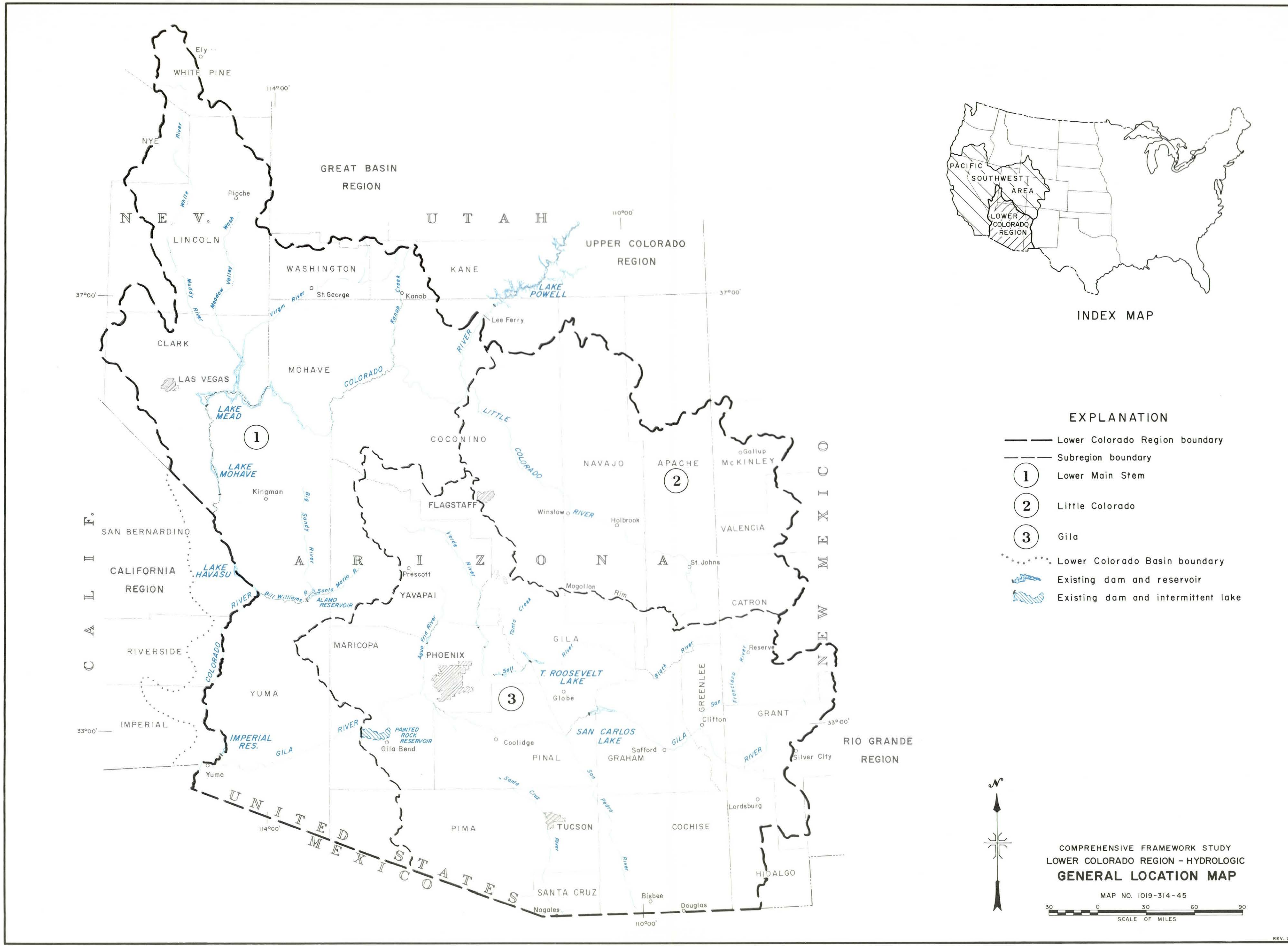
COMPREHENSIVE FRAMEWORK STUDY

APPENDIX XI

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

This report of the Lower Colorado Region Framework Study State-Federal Interagency Group was prepared at field-level and presents the water and related land resources of the Lower Colorado Region. This report is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected States, and by the Water Resources Council prior to its transmittal to the Congress for its consideration.

JUNE 1971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This appendix prepared by the

MUNICIPAL AND INDUSTRIAL WATER SUPPLY WORKGROUP

of the

LOWER COLORADO REGION STATE-FEDERAL INTERAGENCY GROUP

for the

PACIFIC SOUTHWEST INTERAGENCY COMMITTEE

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SUMMARY OF FINDINGS

Municipal and industrial water uses included in this appendix are domestic, manufacturing, livestock, governmental, commercial and related uses. In the Lower Colorado Region municipal and industrial water withdrawal requirements were 463,800 acre-feet in 1965. The water depletion requirement for these uses was 203,700 acre-feet or 44 percent of the withdrawal requirement. The 2020 municipal and industrial withdrawals and depletion will require increases of 2,380,100 and 972,500 acre-feet per year, respectively.

A 270 percent increase in population between the years 1965 and 2020, a fifteenfold increase in the value of manufacturing output, a fourteenfold increase in economic activity in the Trade and Services sectors, and rising water-use rates by rural residents are reasons for the growth of municipal and industrial water requirements.

The increased municipal and industrial water needs of the Region could be met by developing authorized multi-purpose projects and ground water reserves, transferring irrigation water to urban uses, desalination of brackish supplies, wastewater reclamation and reuse, improved water management practices, and augmentation by importation from outside the Region. Availability of future municipal and industrial water supplies of suitable quality is predicated upon implementation of salinity improvement programs and adequate municipal and industrial wastewater treatment.

Total capital costs for development and treatment are projected to be $109.5, $178.9 and $139.6 million for the 1965-1980, 1980-2000 and 2000-2020 time frames, respectively. Included are the cost of ten desalting plants varying in size from 0.5 to 100 million gallons per day, surface water development by government agencies, development of ground water reserves, a small importation from the Upper Colorado Region, and water treatment plants to treat the total projected requirements. Costs of distribution systems from the treatment plant to the consumer are not included. Costs of federal multi-purpose projects that have a municipal and industrial water supply allocation, such as the Central Arizona Project, are also not included. Multi-purpose project costs are given in the General Program and Alternatives Appendix.

The municipal and industrial water demands in each of the three subregions were developed by correlating economic sectoral water use with the economic and demographic characteristics. Water-use coefficients, both withdrawal and depletion, were used to convert the economic and demographic data to municipal and industrial water demands. These coefficients were defined as gallons of water withdrawn and depleted per dollar of total gross output for the manufacturing, governmental, commercial and other water-use categories, the gallons withdrawn and depleted per capita per year for the domestic (household) category, and the water withdrawn and depleted per farm animal for the livestock category. Production, or output, data developed using interindustry economics, in conjunction with the developed water-use coefficients, was then used to estimate the water needs in each subregion for the years 1965, 1980, 2000, and 2020.

LOWER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDY

APPENDIX XI

MUNICIPAL AND INDUSTRIAL WATER SUPPLY

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CHAPTER A - INTRODUCTION

PURPOSE AND SCOPE

The purpose of the Municipal and Industrial Water Supply Appendix is to:

(1) Summarize the water volumes withdrawn and depleted for domestic, manufacturing, livestock, governmental, commercial and related purposes in the base year 1965;

(2) Determine the water required to meet the future demands based on the Modified Office of Business Economics-Economic Research Service (OBE-ERS) projections for 1980, 2000, and 2020;

(3) Compare future demands based on the Modified OBE-ERS projections with the available water supplies and system capacities and determine the opportunities and means available to satisfy these demands; and

(4) Determine the water required to meet the future demands based on the OBE-ERS projections dated March 1968 for 1980, 2000 and 2020 and compare with the Modified OBE-ERS requirements.

Domestic water use includes municipal and rural-domestic water requirements. Manufacturing water use includes water required for industrial purposes with the exception of water required for mineral extraction which is summarized in the Mineral Resources Appendix, and water required for power generation which is summarized in the Electric Power Appendix. Water consumed by livestock from surface and ground water sources make up the livestock water use. The evaporation from stock watering ponds is included in evaporation volumes given in the Water Resources Appendix. Wildlife water needs are included in the Fish and Wildlife Appendix. Governmental water use includes requirements for a wide range of federal, state, and local governmental activities. Commercial and other water use includes the requirements of various trades and services establishments as well as other miscellaneous related water requirements.

The study area is the Lower Colorado Region which includes most of Arizona and parts of Nevada, Utah, and New Mexico -- a total area of about 141,000 square miles. The Region is bounded on the east by the Continental Divide in New Mexico, on the west by the State of

California, and on the south by Mexico, and on the north at Lee Ferry, Arizona, the hydrologic boundary established by the Colorado River Compact to separate the Upper and Lower Colorado River Basins.

The Region is naturally divided into three major drainage areas -- the Lower Main Stem of the Colorado River and the Little Colorado and Gila Rivers -- which have been designated as hydrologic subregions as shown on the general location map.

The present status is based on the 1965 level of development, compiled from existing information and supplemented by judgment in areas where data were lacking or inadequate. Water uses and demands are presented by economic subregion, also delineated on the general location map. Analyses of smaller areas, primarily service areas, Standard Metropolitan Statistical Areas (SMSA), and other population centers, are shown where demands are critical and special problems could exist.

Projected demands have been compared with potential water supplies, and areas requiring additional water supplies are designated. Suggested means of satisfying future demands are specifically tied to the plan shown in the General Program and Alternatives Appendix. Research needs and additional data requirements are also identified.

The Modified OBE-ERS projections have been made to reflect both regional economic and regional hydrologic projections of population and economic activity. The projection level used through the initial computations presented in this appendix to develop future demands, identify problems, and evaluate means of meeting the needs is based on the regional economic projections. A conversion from the regional economic projections has been made to show demands and projections for the regional hydrologic boundaries. Regional Modified OBE-ERS population projections are 10, 13, and 5 percent larger than the OBE-ERS projections for 1980, 2000, and 2020, respectively. Future water requirements based on the OBE-ERS level of development are presented immediately following the Modified OBE-ERS level.

RELATIONSHIP TO OTHER APPENDIXES

The Municipal and Industrial Water Supply Appendix is one of several technical appendixes dealing with a particular phase of water development. Water requirements developed in the Municipal and Industrial Water Supply Appendix are summarized along with all other regional water requirements in the Water Resources Appendix.

The major inputs to this appendix were from the Economics Base and Projections and Water Resources Appendixes. Outputs to other than the General Program and Alternatives Appendix, stem to the Water Resources Appendix. Water quality inputs were provided by the Water Quality, Pollution Control, and Health Factors Workgroup.

The demand for water and water-related services by the municipal and industrial sectors depends upon the population and the level and type of economic activity within the Region. Data on economic trends, projected output of goods and services and population projections are provided in the Economic Base and Projections Appendix.

Additional lands are required with industrial expansion and population growth. Thus, encroachment upon other land-use areas occurs. In most instances, encroachment is made upon agricultural lands which reduces at-site agricultural production and agricultural water requirements with a corresponding increase in the water supply available for municipal and industrial uses. Encroachment on land-use areas is discussed in the Land Resources and Use Appendix.

HISTORY

Water supply development to meet municipal and industrial requirements in the Lower Colorado Region has generally been adequate over the last one hundred years. This development can be illustrated in a brief summary of the water sources utilized by three large population centers, Phoenix, Tucson and Las Vegas; by one of the major industrial consumers, the copper industry; and by the Indian population.

In the years immediately preceding the close of the Civil War, pioneers settled in the Salt River Valley of Central Arizona. By 1867 they started to excavate the first canal which would eventually pass through what is now downtown Phoenix. By 1869 a few hundred acres were successfully irrigated, and the settlers were encouraged to construct more canals. By 1884, thirty-five thousand acres were under cultivation. Although farming was the prime activity in the Valley, urban communities developed to provide business centers and produce shipping facilities to and from the agricultural area. From this agricultural base the municipal area eventually expanded to include industrial, educational and resort activities. Farming has gradually declined as the prime activity in the Valley. The incorporation of five communities occurred as follows: Phoenix, 1881; Tempe, 1884; Glendale, 1910; Mesa, 1923; and Scottsdale, 1951.

As far as is known every Valley community obtained early domestic water from pumped wells, as they do today. Phoenix and Tempe also received water from surface supplies developed by the Salt River Project in addition to ground water. The original Phoenix wells were relatively shallow, and the water was salty. In the 1920's, to obtain better quality water, Phoenix developed the Verde River supply and water was brought to the city through a pipeline from an infiltration gallery on the Verde River. During the 1930's and 1940's wells were developed in the Scottsdale area to further supplement existing sources of supply. In the late 1940's high quality ground water was discovered in the Glendale area. Wells were drilled and this source was added to the overall supply of municipal water. By the end of 1952, the Phoenix water department could provide 110 million gallons of water per day during peak summer demand without resorting to the older wells in the downtown area. The rapid increase in population which started in the early 1950's was accompanied by gradual urbanization of much of the agricultural land. Irrigation water used on this land was converted to municipal uses. The City of Phoenix provided the core of the urban expansion and by 1960 Phoenix included 43,500 acres of Salt River Project lands which were formerly under irrigation.

The City of Tucson lies in the Upper Santa Cruz Valley near the confluence of the Santa Cruz River and the Rillito-Pantano drainage system. According to the first Federal Census in 1870, Tucson was the largest town in the territory and had a population of 3,200. Water was readily available from shallow wells and surface streams originating in the Catalina and Rincon Mountains to the north and east of the city. Completion of the Southern Pacific Railroad in 1879 brought an influx of new people and capital to the territory. At that time, the water table was at a shallow depth and pumps were becoming available so that drilling of new wells was relatively inexpensive. As the community grew, the water demand was met by development of additional wells along the Santa Cruz River and in the area between the Santa Cruz River and Rillito Creek.

After World War II, Tucson experienced rapid growth with the urban population increasing from 38,300 in 1945 to 212,892 in 1960, fifteen years later. The type of industries that were attracted to Tucson were moderate users of water and thus did not greatly increase the water demand. The huge population increase, however, caused more wells to be developed in and around the city. Tucson is the largest city in the Pacific Southwest to depend wholly upon ground water for its water supply.

Mormon pioneers settled in the Moapa Valley, Virgin Valley, and near large springs in Las Vegas Valley during the period 1855 to 1865. These settlements were basically self-sufficient depending on irrigation to produce their agricultural products. In 1903 the Stewart Ranch in Las Vegas Valley, which received its water supply from large springs, was purchased for the townsite of Las Vegas by the San Pedro, Los Angeles, and Salt Lake Railroad which later became the Union Pacific Railroad. The first flowing well of record in the Valley was completed in 1907. By 1911 there were 100 deep wells, 75 of which flowed naturally, and 25 shallow wells. By 1930, population in Las Vegas Valley increased as a result of employment for construction of Hoover Dam. Boulder City was established as a construction camp for Hoover Dam and Powerplant and continues to receive a portion of its water supply from Lake Mead through a pipeline constructed by the Bureau of Reclamation. During World War II, Nellis Air Force Base was established northeast of Las Vegas and continues to receive its water supply from wells. Also during this period the townsite of Henderson was established with an industrial complex including Basic Management Incorporated (BMI) electrochemical industries. BMI constructed and continues to operate a water supply pipeline from Lake Mead which supplies water to various industrial developments and the City of Henderson, Nevada. The Las Vegas Valley Water District has served Las Vegas and the surrounding service area for many years from well feilds. About 1956, the District contracted with BMI for a supply of surface water from Lake Mead which it continues to utilize. From 1941 until the present, ground water withdrawals in Las Vegas Valley have increased by considerable annual increments. Many wells and springs have stopped flowing and water levels have declined at an accelerating rate.

The mining industry has been and still continues to be one of the largest users of water in Arizona. The Phelps-Dodge Corporation copper mine at Morenci is one of the oldest established operations in Arizona. In 1873 the company completed its first smelter at Morenci to process copper ore obtained from a deep mine in the area. In 1937 open pit mining operations replaced the underground mine at Morenci. The demand for copper during World War II enabled the company to increase its production which in turn doubled the mine's water requirements. Faced with decreasing water supplies, the mining industry has made considerable progress in reducing its consumptive use requirement of water. Because of insufficient water supplies in the immediate area, the company decided to import water from Black River, a tributary of the Salt River System. Under an exchange agreement with the Salt River Project, over four billion gallons of water per year are pumped from the Black River and carried by pipeline into Willow Creek in the Gila River Basin which then carries the water to Morenci for domestic and industrial purposes.

From the time the United States took over this territory from Mexico the Indians generally have occupied the land which is now included within their reservations. The Navajos were generally nomadic in their habits, partly of necessity because of the scarcity of water and the need to find sufficient food for their flocks. Scattered small springs and intermittent streams were the only sources of water available to them. The Zuni Indians lived in villages located near permanent springs and along streams which supplied the water for domestic use as well as water to irrigate their small gardens. The Hopi Indians lived in villages located on high rocky plateaus overlooking the sandy valleys where they cultivated their gardens. Water for domestic use had to be hauled up to these villages from springs located in the valley. The Apaches inhabited the mountain areas which provided them with an abundance of grazing for their animals and pure mountain streams for domestic use. The Papagos lived in villages which were primarily watering places around which the people gathered for the sustenance that nature afforded them. The Pima and Maricopa Tribes along the Gila River and the tribes who inhabited the bottom lands along the Colorado River lived primarily from agriculture and were dependent upon these rivers for domestic water and water for irrigation of their crops.

The situation today regarding Indian water supplies and uses in some areas may not be much different than it was many years ago. Many government programs, however, have been carried out to develop new agricultural, domestic, and stock water supplies. The early work on these programs included spring development, digging of shallow wells and construction of dams for storage of water. Later development included drilling of deep wells, excavation of stock tanks and construction of catchment facilities with storage tanks. Measures have been taken in recent years to provide each Indian community with an improved domestic water system including wells, storage tanks and distribution lines. The emphasis on this has become increasingly important with the establishment of industries on reservations and improvement in Indian housing which is now underway. Much still remains to be done for the Indian families not living in communities who must haul domestic water to their place of abode from community wells, springs and other sources.

PRESENT STATUS

CHAPTER B - PRESENT STATUS

WATER SUPPLY REQUIREMENTS - QUANTITY

Region

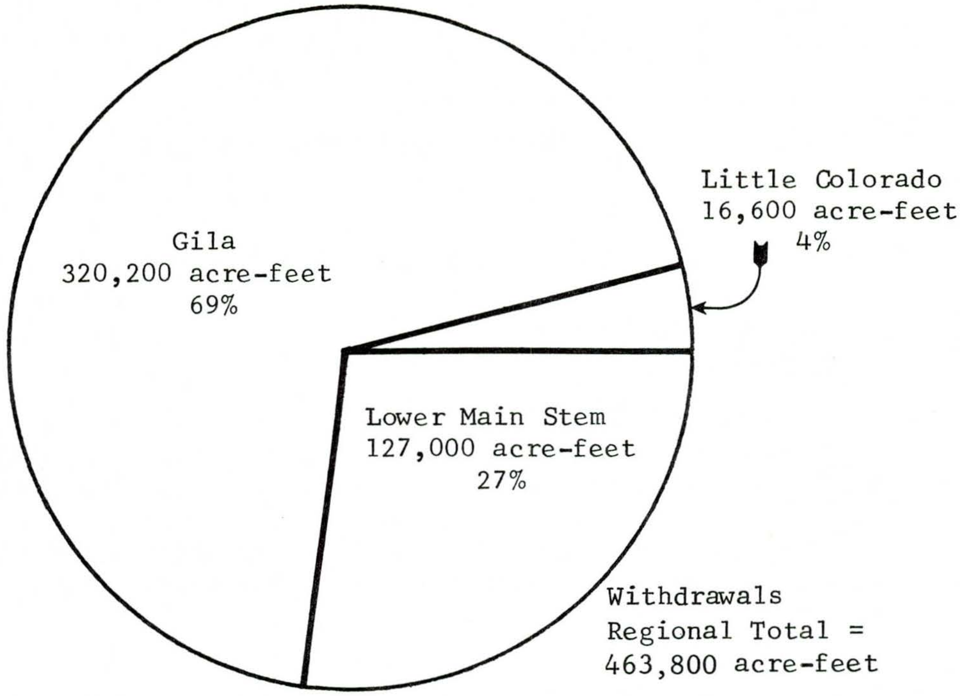
Water withdrawal requirements for municipal and industrial (M&I) water uses in the Lower Colorado Region amounted to 463,800 acre-feet in 1965. The water depletion requirement for these uses was 203,700 acre-feet amounting to 44 percent of the withdrawal requirement. Regional withdrawal and depletion requirements for municipal and industrial water uses are summarized in Table 1.

TABLE 1
REGIONAL SUMMARY OF 1965 MUNICIPAL AND INDUSTRIAL WITHDRAWAL AND DEPLETION WATER REQUIREMENTS BY ECONOMIC SUBREGIONS

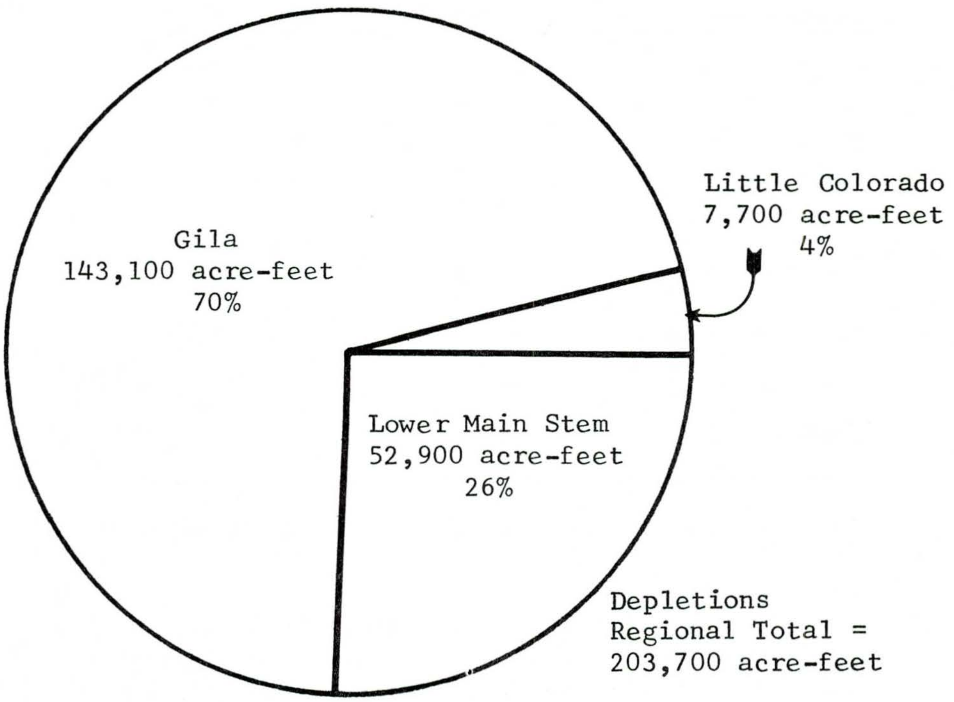
Water-Use	Withdrawal (acre-feet)	Percent of Regional Total	Depletion (acre-feet)	Percent of Regional Total
Domestic	273,300	59	137,500	68
Manufacturing	24,300	5	12,900	6
Livestock 1/	16,900	4	16,900	8
Governmental	52,100	11	5,200	3
Commercial and Other	97,200	21	31,200	15
Regional Total	463,800	100	203,700	100

1/ Does not include evaporation from stockponds

Distribution of the regional M&I water requirements by subregions is shown in Figure 1. The Gila Subregion had the largest M&I requirements due to the location of the Phoenix and Tucson metropolitan areas within the subregion. The Las Vegas metropolitan area is located in the Lower Main Stem Subregion. There



WITHDRAWAL REQUIREMENTS



DEPLETIONS

Figure 1 - 1965 Municipal and Industrial Withdrawal
Water Requirements and Depletions

are no large cities in the Little Colorado Subregion.

Domestic Water Use

Regional domestic uses of water, including municipal-domestic and rural-domestic, had the largest requirements of the M&I water uses. A population of 1,877,000 within the regional economic boundary had an average domestic withdrawal requirement of 129 gallons per capita per day (gpcd) and an average domestic depletion requirement of 65 gpcd. Domestic depletion requirements were 50 percent of domestic withdrawal requirements. The Gila Subregion had the largest subregional domestic requirement.

There are numerous factors affecting domestic water requirements. Such factors as available water supply, metering, water pricing policy, water-use regulations, land-use regulations, personal per capita income, lot size, population density, family size, sewering, number of plumbing facilities, and climate are significant. 1/ The relative significance of these various factors is variable depending on location. The policies of municipalities and water distribution agencies relating to metering, water pricing, water-use regulations, and land-use regulations can act as controls on municipal domestic water use. 2/ Metering of municipal domestic water is common practice throughout the Region. It is significant that the domestic water requirements of the rural population are largely influenced by the availability of adequate plumbing facilities.

Uses of domestic water are generally categorized as being exterior or interior. Exterior uses include lawn and plant watering, swimming pools and car washing. Interior uses include laundering, dishwashing, garbage disposal operations, cooking and food preparation, house cleaning and air conditioning (when water cooled) as well as personal uses such as toilet flushing, bathing and drinking. Domestic uses of water have been increasing as technology makes an increasing number of water-using appliances available and economically attractive.

Most interior domestic uses of water do not have high depletion requirements. Water used for lawns, plants, and car washing is virtually all depleted, which accounts for the large domestic per capita depletion requirement. Desert landscaping which would

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1/ References: 5, 24, 25, 29, 37, 47
2/ References: 1, 5, 24, 27, 37

eliminate the large requirement for lawn and plant watering was of minor significance in 1965. The aesthetic values of the population will have to change before desert landscaping becomes important as a water conservation alternative.

Domestic air conditioning which relies upon the evaporation of water for cooling can have a high depletion requirement. Developments in air conditioning technology have largely resulted in the replacement of evaporative cooled equipment with refrigerant cooled equipment. Presumably, there has been a resultant decrease in the consumptive use of water.

Domestic water requirements exhibit definite seasonal variations. Withdrawal requirements vary from a maximum during the summer months of about 170 percent of the average monthly withdrawal requirement to a minimum during the winter months of about 40 percent. Peak demands occur primarily during the months of June, July, and August.

Manufacturing Water Use

Manufacturing depletion requirements were 53 percent of manufacturing withdrawal requirements in 1965. The Gila Subregion had the largest subregional manufacturing water requirements.

Manufacturing water requirements vary significantly between different industries. There are also significant variances among manufacturing plants within a particular industry. Among the many factors which affect manufacturing water requirements are withdrawal water cost, operating rate of production, technological change, quality of raw product inputs, waste effluent controls, size, age and location of the plant climate, and water management practices (recirculation). Indications are that manufacturing water requirements are particularly responsive to various economic factors. As the cost of water to manufacturing industries increases, either through increased withdrawal water costs or increased waste disposal costs, water management practices such as recirculation will be used to decrease outside water requirements[5] [7].

Manufacturing industries require water for a variety of uses including cooling, steam generation, process, sanitary and other water uses. Water for cooling and steam generation is required in most manufacturing industries. Cooling water is used to absorb and carry away waste heat. Cooling water which is distributed in once-through cooling systems is passed through heat exchange equipment once and then discharged back to the stream system or reused for other needs. Very little water is depleted in the once-through system although large quantities of withdrawal water are required.

Cooling water used in recirculating systems is passed through heat exchange equipment where heat is absorbed and then passed through a cooling tower or spray pond where the heat is lost before recirculation. Water is depleted in recirculating systems by evaporation, leakage, and windage and must be replaced by make-up withdrawal water. Withdrawal requirements for recirculating cooling systems are significantly less than for once-through systems. 1/

Water quantity requirements for manufacturing process water uses vary widely. 2/ The Food and Kindred Products industry includes food canning and freezing firms which generally require process water for washing, cleaning, blanching, cooking, sterilizing, and transporting foodstuffs. Meat packing firms require water for a variety of processes including carcass dressing and rendering, hair removal, washing and cleaning. Soft drink bottling firms, brewers, wineries and ice manufacturing firms use water as a raw material in the final product. Dairies use large quantities of water for washing and cleaning, and cooling milk and milk products after pasteurization.

The Lumber and Wood Products industry requires water for the preparation of wood preserving solutions and other minor uses. Because mill ponds are virtually non-existent, spraying to prevent logs from cracking is not widespread. Air jets and mechanical debarking methods, rather than water jets are used to debark logs. Water requirements for the Lumber and Wood Products sector, therefore, are significantly lower in this region than are national requirements. The requirements for water in wood harvesting and processing is expected to increase both on a per unit and total basis. This is based on the following assumptions: projections indicate a substantial increase of forest products from the commercial timber lands; manufacturing trends point toward production of more fiber products; and environmental requirements will require increased use of water to minimize air pollution, particularly in timber harvesting operations.

The Furniture and Fixtures industry requires a minimal quantity of process water for the blending of self-made glues.

Those firms in the Paper and Pulp industry which convert raw

1/ References: 6, 18, 36, 40
2/ References: 4, 18, 23, 26, 27, 30, 36, 38, 40, 43, 44, 49, 50, 51

wood products to finished paper customarily use substantial amounts of water. However, the relatively high levels of water reuse for this industry in the Lower Colorado Region results in less water withdrawals and returns than normally expected. These firms utilize water in various mechanical and chemical pulping processes, for transporting raw material, washing and refining of wood chips and pulp, and preparing chemicals used for cooking and bleaching. Other firms in the Paper and Pulp industry which fabricate paper products require a minimal amount of water.

The Chemical industry generally requires process water as a reactant and as a solvent in washing and rinsing operations. Water in the form of steam is used to supply heat to chemical processes. The Primary Metals industry requires virtually all of its water for cooling and steam generation and has minor process water requirements. The Printing and Publishing industry has essentially no water requirements other than for personal, sanitary purposes.

The Fabricated Metals industry in the Region is composed primarily of sheet metal and electroplating firms. Sheet metal firms require process water primarily for conditioning molding sands, washing, and cooling. Electroplating firms use process water for cleaning metal surfaces and rinsing plated products, and in electrolytic solutions.

The textiles and Apparel industry in the Region requires water for sanitary purposes only, since no textile mill products are produced which require large quantities of process water. The Leather and Leather Goods industry is a very minor industry requiring a minimal amount of water for soaking, washing, pickling and dyeing hides. Firms in the Stone, Clay and Glass industry which make brick, structural clay tile, concrete products and ready-mix concrete require large quantities of water for incorporation in the product. Cement manufacturing firms require water primarily for cooling kilns and lubricants and for dust control.

Water requirements of the manufacturing industry are met by withdrawals and by recirculation and reuse. Withdrawals by manufacturing industries in the Colorado River Basin (including the Upper and Lower Colorado Regions) are increasing as shown in Table 2. There is a trend to meet more water requirements by recirculation and reuse. This trend is indicated by the relatively high recirculation ratio shown in Table 2. The recirculation ratio in the Colorado Basin was almost three times as high as the national average in 1964. Water conservation measures are necessary because there is not an abundance of water available to permit wasteful practices.

The manufacturing demand for water exhibits seasonal variations; however, seasonal patterns are not as predictable as for domestic water use. Some manufacturing industries require significant increases during the summer months for seasonal process water.

TABLE 2
WITHDRAWALS, GROSS WATER USED, AND RECIRCULATION RATIOS FOR THE MANUFACTURING INDUSTRIES[8] [9] [10]

	1954	1959	1964
Upper and Lower Colorado Regions			
Withdrawals (bil gal)	16	19	23
Gross Water Used 1/ (bil gal)	53	127	148
Recirculation Ratio 2/	3.3	6.7	6.4
United States			
Recirculation Ratio	1.9	2.2	2.2

1/ The total quantity of water which would have been needed if no water was recirculated or reused.
2/ Gross Water Used divided by Withdrawals.

Other manufacturing industries such as some firms in the Food and Kindred Products industry require major increases when raw food products are available for processing. Generally, however, manufacturing industrial water demands vary from a maximum of 120 percent of the average monthly withdrawal requirement during the summer months to a minimum of 80 percent of the average monthly withdrawal requirements during the winter months.

Livestock Water Use

Livestock water requirements depend upon climatic factors such as temperature and precipitation; number, species, age and condition of the animal; nature of the diet; and upon water management practices[23] [36]. Virtually all of the water withdrawn for livestock purposes is depleted by the animals, and by evaporation from stock ponds.

Livestock water requirements are seasonal in nature. Maximum water requirements generally occur during the month of August and amount to 125 percent of the average monthly requirement.

Governmental Water Use

Governmental depletion requirements were 10 percent of governmental withdrawal requirements. The Gila Subregion had the largest subregional governmental water requirements.

Governmental requirements for water result from a wide range of federal, state, and local governmental activities. A variety of factors affect these requirements; size of cities and climate are probably the most significant factors, and cost of water the least significant[5]. Some of the governmental uses of water include supplies for public buildings such as post offices, schools, hospitals, and office buildings; military installations; watering public lawns, parks, and golf courses; fire control; street cleaning; public swimming pools; and various research activities. There are eight military installations in the Region, all of which have significant water requirements. Governmental water requirements are seasonal in nature and will be the largest during the summer months.

Commercial and Other Water Use

Depletion requirements for commercial and other water uses were 32 percent of withdrawal requirements. The Gila Subregion had the largest subregional commercial and other water use requirements.

Commercial requirements for water are largely associated with the trade and service industries. These requirements depend primarily upon three factors; size of resident population, its per capita income, and the extent to which commercial services are provided for a transient population[5]. This latter factor is particularly relevant in the Lower Colorado Region which supports a large tourist industry.

Commercial uses of water are varied and closely approximate the domestic uses of water. The use of water in commercial establishments such as restaurants, service stations, laundries, hotels and motels is important in the provision of goods and services. In other commercial establishments such as dry goods stores, grocery stores, department stores, and automobile dealerships, however, the use of water is small and incidental to the provision of goods and services. Commercial water uses exhibit seasonal variations with a maximum during the summer months of 120 to 180 percent of the average monthly withdrawal requirements. Minimum requirements during the winter months range from 50 to 80 percent of the average monthly withdrawal requirement.

Water requirements for the contract construction industry have been included in the commercial and other uses category. Water uses in the contract construction industry include dust control, batching of concrete and various processes.

Lower Main Stem Subregion

Municipal and industrial water uses in the Lower Main Stem Subregion had a withdrawal requirement of 127,000 acre-feet in 1965. The depletion requirement for these uses was 52,900 acre-feet which amounted to approximately 42 percent of the withdrawal requirement. The subregional requirements for M&I water uses are summarized in Table 3.

TABLE 3
SUMMARY OF 1965 WITHDRAWAL AND DEPLETION WATER REQUIREMENTS
LOWER MAIN STEM ECONOMIC SUBREGION

Water Use	Withdrawal (acre-feet)	Percent of Subregional M&I Total	Percent of Regional M&I Total	Depletion (acre-feet)	Percent of Subregional M&I Total	Percent of Regional M&I Total
Domestic	71,900	57	15.5	36,000	68	17.7
Manufacturing	3,700	3	0.8	2,400	5	1.2
Livestock	4,300	3	0.9	4,300	8	2.1
Governmental	11,600	9	2.5	1,200	2	0.6
Commercial & Other	35,500	28	7.7	9,000	17	4.4
Subregional Total	127,000	100	27.4	52,900	100	26.0

Subregional water requirements are mainly concentrated in Clark County, Nevada which is classified as a standard metropolitan statistical area (SMSA) by the U. S. Bureau of the Budget and contains the central city of Las Vegas. This area is the center of economic activity in the subregion.

Domestic uses of water had the largest subregional M&I requirement. A population of 345,200 people within the subregional economic boundaries had an average domestic withdrawal requirement of 186 gpcd. The average domestic depletion requirement was 93 gpcd. Domestic depletion requirements were 50 percent of domestic withdrawal requirements.

Manufacturing depletion requirements were 65 percent of manufacturing withdrawal requirements. This high depletion-withdrawal ratio is due principally to the high degree of recirculation that is common to the subregion. Manufacturing water requirements in the subregion were required primarily by soft drink bottlers, manufacturing ice firms, and dairies in the Food and Kindred Products industry; by saw mills and planing mills in the Lumber and Wood Products industry; by various agricultural chemical manufacturing firms; and by ready-mix concrete and concrete block manufacturers in the Stone, Clay and Glass industry.

Of the remaining requirements, commercial and other water requirements were significant in the subregion. The large tourist industry in the subregion had a major impact on the water requirements of the various commercial sectors. Livestock requirements reflect only the consumption by farm animals. Evaporation from stock watering ponds is not included.

Little Colorado Subregion

Municipal and industrial water uses in the Little Colorado Subregion had a withdrawal requirement of 16,600 acre-feet in 1965. The depletion requirement for these uses was 7,700 acre-feet, amounting to approximately 46 percent of the withdrawal requirement. The subregional requirements for M&I water uses are summarized in Table 4.

TABLE 4
SUMMARY OF 1965 WITHDRAWAL AND DEPLETION WATER REQUIREMENTS
LITTLE COLORADO ECONOMIC SUBREGION

Water Use	Withdrawal (acre-feet)	Percent of Subregional M&I Total	Percent of Regional M&I Total	Depletion (acre-feet)	Percent of Subregional M&I Total	Percent of Regional M&I Total
Domestic	7,600	46	1.6	3,800	49	1.9
Manufacturing	1,600	10	0.3	600	8	0.3
Livestock	2,200	13	0.5	2,200	28	1.1
Governmental	2,300	14	0.6	200	3	0.1
Commercial & Other	2,900	17	0.6	900	12	0.4
Subregional Total	16,600	100	3.6	7,700	100	3.8

There are no large cities in the Little Colorado Subregion although there are ten towns with a population over 1,000. Flagstaff, Arizona in Conconino County and Gallup, New Mexico in McKinley County are the centers of economic activity. A population of 125,000 people within the subregional economic boundaries had an average domestic withdrawal requirement of 54 gpcd. The average domestic depletion requirement was 27 gpcd. Domestic depletion requirements were 50 percent of domestic withdrawal requirements. These relatively low per capita requirements can be attributed to the predominance of a large Indian population within the subregion amounting to almost 46 percent of the total subregion population. The per capita water requirement for the Indian population living on or near the Navajo, Hopi, and Zuni Reservations is low. The average withdrawal requirement for the Indian population is 28 gpcd and the average depletion requirement is estimated at 21 gpcd. These low requirements can be attributed in large part to insufficient plumbing facilities.

Manufacturing depletion requirements were 38 percent of manufacturing withdrawal requirements. Manufacturing requirements in the subregion were required chiefly by soft drink bottlers and dairies in the Food and Kindred Products industry; by saw mills and planing mills in the Lumber and Wood Products industry; and by a pulp and paper mill in the Pulp and Paper industry.

The livestock industry is important to the economy of this subregion. The tourist industry supports the economy of many of the subregion's municipalities and results in demands for water by various commercial establishments.

Gila Subregion

Municipal and industrial water uses in the Gila Subregion had a withdrawal requirement of 320,200 acre-feet in 1965. The depletion requirement for these uses was 143,100 acre-feet which amounted to 45 percent of the withdrawal requirement. The subregional requirements for M&I water uses are summarized in Table 5.

TABLE 5
SUMMARY OF 1965 WITHDRAWAL AND DEPLETION WATER REQUIREMENTS
GILA ECONOMIC SUBREGION

Water Use	Withdrawal (acre-feet)	Percent of Subregional M&I Total	Percent of Regional M&I Total	Depletion (acre-feet)	Percent of Subregional M&I Total	Percent of Regional M&I Total
Domestic	193,800	61	41.8	97,700	68	47.9
Manufacturing	19,000	6	4.1	9,900	7	4.8
Livestock	10,400	3	2.3	10,400	7	5.1
Governmental	38,200	12	8.2	3,800	3	1.9
Commercial & Other	58,800	18	12.6	21,300	15	10.5
Subregional Total	320,200	100	69.0	143,100	100	70.2

Subregional water requirements are concentrated in Maricopa County, Arizona with Phoenix as the metropolitan center and Pima County, Arizona with Tucson as the metropolitan center. Both of these counties are classified as standard metropolitan statistical areas and are the centers of economic activity in the subregion.

Domestic uses of water had the largest subregional M&I requirements. A population of 1,406,800 people within the subregional economic boundaries had an average domestic withdrawal requirement of 123 gpcd. The average domestic depletion requirement was 62 gpcd. Domestic depletion requirements were 50 percent of domestic withdrawal requirements.

Manufacturing depletion requirements were 52 percent of manufacturing withdrawal requirements. Manufacturing water requirements were required mainly by breweries, ice manufacturing firms, dairies, meat packing plants and soft drink bottlers in the Food and Kindred Products industry; by various chemical firms; by primary metals firms with smelting operations; by electroplating firms in the Fabricated Metals industry; and by cement manufacturing firms, ready-mix concrete plants and concrete block firms in the Stone, Clay and Glass industry.

Tourism in the subregion is important to the economy, and commercial establishments such as motels, hotels, service stations, laundries, and restaurants have large water requirements. The livestock industry is also an important economic activity, and water requirements reflect only consumption by farm animals. Evaporation from stock ponds is not included in this appendix.

WATER SUPPLY REQUIREMENTS - QUALITY

The physical, chemical, and biological qualities of water for M&I water uses must be controlled to prevent undesirable esthetic, physiological and economic effects. The quality requirements for all of these uses are generally satisfied by water of quality meeting the recommended limits of the Public Health Service Drinking Water Standards[45]. Water of higher quality is required for many manufacturing water uses. Water of lower quality may be satisfactory for some manufacturing water uses, livestock water use, and lawn irrigation. The water quality requirements for the various uses are discussed briefly below. Additional detail including a discussion and presentation of the state-federal water quality standards which provide for protection of surface water supplies are presented on the Water Quality Pollution Control and Health Factors Appendix.

Domestic Water Use

Domestic water use requires a safe, clear, potable, and esthetically pleasing water supply which meets the recommended limits of the Public Health Service Drinking Water Standards. These standards for physical, chemical and biological characteristics reflect our national values and attitudes toward domestic water quality criteria. In order to help meet the quality requirements, domestic supplies should be provided from the best existing high quality water.

Physical qualities include the turbidity, color, taste, odor, and temperature of water which must be satisfactory to be acceptable for domestic use. Turbidity is caused by the presence of suspended and colloidal matter which affects the clearness of water and the penetrability of light, and should be limited to less than 5 turbidity units.

Color is caused by substances and material of natural mineral or vegetable origin and by inorganic or organic soluble wastes[36]. Color makes drinking water less acceptable, causes dullness in clothes, and stains food, fixtures and utensils. Color should be limited to less than 15 color units.

Undesirable tastes and odors can be caused by decaying organic matter, waste products and the presence of living organisms. Objectionable tastes and odors should be virtually absent from domestic water supplies, and odors should be limited to a threshold odor number of 3.

Temperature increases are caused by natural climatic phenomena or by discharged wastewaters. Water becomes less palatable and less useful for cooling purposes as temperature increases. The most desirable range of temperature for domestic water use is between 10^{o} and 15^{o} C[36].

The recommended limits of chemical quality by the Public Health Service Drinking Water Standards are shown in Table 6.

The dissolved solids in water consist mainly of carbonates, bicarbonates, chlorides, sulfates, phosphates and possibly nitrates of calcium, magnesium, sodium and potassium, with traces of iron, manganese and other substances[36]. Waters which have excessive concentrations of dissolved solids may not be palatable and may have a laxative effect on new users. Sodium sulfate and magnesium sulfate are well known laxatives. The presence of excessive concentrations of nitrates can have serious physiological effects causing infant methemoglobinemia.

TABLE 6
PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS

Elements or Group	Recommended Limit of 1962 Standards (Parts per million)
Alkyl Benzene Sulfonate	0.5
Arsenic	0.01 - 0.05 1/
Barium	1.0 1/
Cadmium	0.01 1/
Carbon chloroform extracts	0.2
Chloride	250
Chromium hexavalent	0.05 1/
Copper	1.0
Cyanide	0.01 - 0.2 1/
Fluoride	0.8 - 1.7 2/
Iron	0.3
Lead	0.05 1/
Manganese	0.05
Nitrate	45
Phenols	0.001
Selenium	0.01 1/
Silver	0.05 1/
Sulfate	250
Total Dissolved Solids	500
Zinc	5
Radium	3 pc/1 3/
Strontium	10 pc/1 3/
Gross beta	1,000 pc/1 3/
Other Chemical Standards 4/	
Boron	1.0
Detergents (Methylene Blue Active Substances)	0.5
Mercury	0.005
Uranyl ion (UO_2^{++})	5.0

1/ Amounts in excess of this figure constitute grounds for rejection of supply.
2/ The limit for any locality depends upon the annual average of maximum daily air temperatures.
3/ pc/1 = picocuries per liter
4/ These have been adopted on an interim basis since 1962 and do not appear in the 1962 Standards.

Hardness of water has usually been described as the soap consuming capacity of water, a characteristic of water mainly attributable to the presence of calcium and magnesium ions. Besides soap consumption, hardness causes scums and curds, and formation of scale on boiler surfaces, heaters, pipes and utensils. Limiting amounts vary considerably and depend upon the particular use. It is generally accepted that hardness concentrations greater than 120 ppm (as $CaCO_3$) should be softened in order to save money and produce a better result in laundering operations.

Some chemical constituents in water such as iron, copper, zinc and possibly manganese are essential for human nutrition. However, concentrations of these chemicals in water sufficient to meet nutritional requirements can be esthetically or economically undesirable by causing tastes, stains, and deposits. Since most diets provide ample amounts of these chemicals to satisfy nutritional requirements, the recommended limits of these chemicals are set to prevent the undesirable esthetic and economic effects.

Excessive concentrations of virtually all chemical constituents in water have toxic physiological effects on humans if consumed in a short period of time. The detrimental effects on domestic water uses of pesticidal chemicals such as DDT, dieldrin, and endrin, which are consumed continuously over long periods of time, are uncertain, but indications are that they may have toxic effects and may cause taste and odor problems. Chemical constituents such as lead, arsenic, mercury and cadmium are toxic cumulative poisons which are not readily eliminated from the body. The toxic effects of these chemicals result from continuous consumption over a long period of time. Fluoride is toxic to humans in excessive concentrations, but in small concentrations it has the beneficial effect of reducing dental decay, especially in small children.

Radiation exposure can have harmful effects on humans. Radioactivity intake from all sources such as water, food and air must be limited. Water within the radiation limits shown in Table 6 is acceptable without further consideration of other sources of radiation.

The biological and microbiological characteristics of domestic water must be limited to prevent harmful esthetic and physiological effects. Saprophytic bacteria found in natural waters perform a variety of beneficial functions including the dissolution of decaying organic matter and the concentration of elements essential to life. The presence of these bacteria in domestic water, however, can cause undesirable tastes, odors, and colors. Domestic water should be free of pathogenic bacteria which can cause such diseases as dysentery, typhoid fever, parathyphoid fevers, cholera, and gastroentenitis. Domestic water should also be free of enteroviruses such as coxsackie viruses, polioviruses, and infectious hepatitis virus. Man is the primary source of pathogenic bacteria and enteroviruses. Parasitic worms such as hookworms, flukes, and tapeworms and freeliving worms such as chironomids and tubifex must be absent from domestic water.

Manufacturing Water Use

Water of quality acceptable for domestic use is generally acceptable for manufacturing use. Water quality requirements vary significantly between different manufacturing industries. Even within a given manufacturing plant, water may have several different uses with different quality requirements for each.

Cooling water is required in virtually every manufacturing industry. The initial temperature of the intake water should be low, particularly if a once-through cooling system is used. Low initial temperature is desirable if a closed or recirculating cooling system is used, although the water will eventually be cooled by some mechanism such as a cooling tower.

Wooden cooling towers are subject to physical, chemical, and biological deterioration. High temperature water can cause physical deterioration. Chemical deterioration is caused primarily by high chlorine residuals and high alkalinity concentrations. Biological growth and slime in cooling system water can cause biological deterioration of wooden cooling towers and corrosion and loss of heat transfer within the cooling system.

Corrosion and scale formation are significant detrimental effects of water quality on cooling and steam generation systems. Corrosion is caused by the chemical or electrochemical attack on a metal by its environment. High oxygen and carbon dioxide concentrations and low pH are the primary quality characteristics contributing to the corrosion of ferrous metals[6]. Low pH, ammonia, cyanides, hydrogen sulfide and sulfur compounds are the principal contributors to the corrosion of nonferrous metals. Because of evaporation and resulting concentration of chemical constituents, corrosion is a more acute problem in closed and recirculation cooling systems than in once-through open cooling systems.

Scale formation results from the crystallization or precipitation of salts from solution. As temperature increases, the solubilities of scale forming salts decreases, making scale formation a major problem in cooling and steam generation systems. Many other factors such as operating pressure, boiler design, make-up rates and steam uses affect boiler scale formation[23]. The primary detrimental effects of scale formation are the retardation of heat transfer and the overheating of boilers resulting in failures. Calcium carbonate, magnesium silicate, and calcium sulfate are the principal chemical constituents of scale formation(6).

Water quality requirements for manufacturing process water uses vary widely. The Food and Kindred Products industry requires process water which is free of pathogenic bacteria and enteroviruses and free of saprophytic organisms that may cause spoilage. Various chemical constituents must be limited to prevent undesirable tastes, odors, colors, deposits, toughening or deterioration of quality or vitamin content(36). Some chemical constituents in water produce desirable and beneficial reactions.

The Lumber and Wood Products industry generally requires process water which is free of suspended solids greater than 3mm in diameter which may damage equipment. The pH should be between 5 and 9 to prevent equipment corrosion. Water for preparation of solutions for treatment of the lumber should be reasonably free of turbidity and those ions which might react to form precipitates(23).

The Pulp and Paper industry requires a minimum of hardness in process waters to prevent detrimental chemical reactions and scale formation. Suspended solids should be virtually absent from process waters to insure product quality. Dissolved gases which cause corrosion are undesirable. Micro-organisms may cause detrimental physical effects such as discoloration and odor(36).

The Chemicals industry may require water as a reactant (a substance that contributes its atoms to the final product) or as a solvent(4). Chemical constituents of the water which might cause adverse chemical reactions must be limited.

Water quality is of particular concern for electroplating firms in the Fabricated Metals industry. High concentrations of dissolved solids can be detrimental in rinse waters and electrolytic plating solutions. Demineralized water is a virtual necessity for final rinsing before coating. Calcium, magnesium and iron can be particularly detrimental in plating solutions causing undesirable deposits and affecting plating efficiency and the protective value of the coating(36).

The Leather and Leather Goods industry requires process water which is generally free of suspended matter, turbidity, color, iron, manganese, hardness and organic matter. The primary detrimental effects are staining and discoloration and interference with dyeing operations.

Firms in the Stone, Clay and Glass industry, particularly ready-mix concrete firms and firms producing concrete products, generally require water which is clean and free of oils, acids, alkalis, salt and organic materials[2].

Livestock Water Use

Livestock water quality requirements are satisfied by water of satisfactory quality for domestic water use, although it appears livestock can tolerate water of lesser quality. The total dissolved solids concentration is the most common livestock water quality problem. High concentrations of dissolved solids in the form of salts can cause physiological disturbances in animals such as gastrointestinal symptoms, wasting disease, and death. Animals whose productivity depends upon such functions as lactation, reproduction and rapid growth may have these functions impeded by high salinity concentrations. There are indications that even low concentrations of some compounds such as nitrates, fluorides, and the salts of selenium and molybdenum can be specifically toxic to livestock. Recommended limits[23] of total dissolved solids for various livestock are shown in Table 7.

TABLE 7
LIMITS OF TOTAL DISSOLVED SOLIDS FOR LIVESTOCK

Animal	Threshold Salinity Concentration TDS in ppm
Poultry	2,860
Pigs	4,290
Horses	6,435
Dairy Cattle	7,150
Beef Cattle	10,000
Sheep	12,000

Generally, livestock may consume, or are able to consume, bacterially polluted water over long periods with no apparent detrimental effects although water is suspected of transmitting animal diseases. Organic pollution improves the probability of the production of bluegreen algaes which are toxic to livestock. Livestock can be infested with waterborne parasitic worms such as tapeworms and flukes which may be transmitted to humans[36].

Governmental, Commercial and Other Water Use

Water of quality meeting the recommended limits of the Public Health Service Drinking Water Standards is generally adequate for governmental, commercial and other water uses. Water hardness is particularly objectionable to commercial laundries as it increases the service costs by increased soap and detergent consumption, water softening costs, and equipment damage.

DISTRIBUTION SYSTEMS AND SOURCES

The 1965 Regional M&I withdrawal requirements supplied by various distribution systems are summarized in Table 8. Seventy-four percent of the requirements were supplied by ground water sources and the remainder by surface water sources.

TABLE 8
REGIONAL SUMMARY OF 1965
MUNICIPAL AND INDUSTRIAL WITHDRAWAL REQUIREMENTS
BY SYSTEM AND SOURCE

System	Source: Ground Water	Source: Surface Water	Total System Withdrawal Requirement
		(acre-feet)	
Municipal	260,400	103,800	364,200
Rural-Domestic	12,600	200	12,800
Self-Supplied Manufacturing, Commercial and Governmental	55,800	14,100	69,900
Livestock	15,300	1,600	16,900
Regional Total	344,100	119,700	463,800

Municipal systems serve domestic, manufacturing, commercial, and governmental water uses. An estimated population of 1,603,700 or 87 percent of the Regional population within the hydrologic boundaries was served by 190 municipal systems in 1965. 1/ The average municipal withdrawal requirement was 201 gpcd. There were 186 municipal systems with an independent source of supply of which 171 (92%) utilized a ground water source, seven (4%) utilized a surface water source, and eight (5%) utilized combination ground-surface water sources. There were at least five municipal systems wholly or partially dependent upon other municipal systems for their supply. Seventy-two percent of the Regional municipal withdrawal requirement was supplied by ground water sources. The remainder was supplied by surface water sources. The number of independent municipal systems serving various population ranges is shown in Table 9.

TABLE 9
REGIONAL MUNICIPAL DISTRIBUTION SYSTEMS
AND PERCENT OF POPULATION SERVED

Population Served	Number of Systems	Percent of Regional Population Served
More than 50,000	3	66
5,000 - 49,999	25	23
1,000 - 4,999	50	8
Less than 1,000	108	3
	186	100

Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

The metropolitan areas of Phoenix, Tucson, and Las Vegas had a total 1965 population of 1,352,200 accounting for 74% of the Regional population. Over ninety-three percent of the metropolitan population of these cities was served by municipal systems. The remainder was served by rural-domestic systems. Municipal systems supplied a large portion of the manufacturing, commercial and governmental water requirements in these metropolitan areas. Economic considerations are

1/ The total number of municipal systems in the Region was compiled from numerous sources and is not considered to be all inclusive. There are numerous small private water companies serving municipal needs, particularly in the Phoenix and Tucson areas, which were not included. References: 3, 11, 13, 14, 15, 16, 20, 21, 28, 31, 32, 34, 41, 42, 46.

major factors in determining whether municipal systems, private self-supplied systems, or a combination of the two are utilized to supply manufacturing, commercial, and governmental requirements.

The 1965 M&I water requirements in the metropolitan areas were satisfied primarily from ground water sources. Most surface water sources have been appropriated for irrigation and livestock use and are unavailable for municipal and industrial purposes. There is an unavailability of alternative water supply sources for municipal and industrial purposes which has contributed to the necessary utilization of available ground water reserves resulting in a general ground water overdraft. Such overdraft cannot continue indefinitely without having an adverse impact upon metropolitan and Regional growth.

Outside of the metropolitan areas, many municipal systems provide inadequate service because of needed improvements in sources of supply and distribution systems. Ground water is the main source of supply in all but a few cases. As ground water supplies are being depleted, pumping costs are increasing and ground water quality is often deteriorating as the salinity concentration commonly increases with depth.

The 1963 Public Health Service Inventory of Municipal Water Facilities(42), the most comprehensive source of municipal systems and sources, does not list system capacities for ground water sources. Since about three-fourth of the Region's requirements were met by ground water, insufficient data precluded an evaluation of municipal system capabilities.

Treatment provided by the 163 municipal water systems in the Region listed by the 1963 U. S. Public Health Service Inventory of Municipal Water Facilities is shown in Table 10(42).

TABLE 10
REGIONAL MUNICIPAL WATER TREATMENT

Type of Treatment	Number of Systems
More than disinfection 1/	14
Disinfection only	45
None	104
	163

1/ Includes one or more of the following treatment processes: aeration, sedimentation, coagulation, and filtration.

Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

Disinfection is used to kill pathogenic organisms that cause waterborne disease. Disinfection alone may be adequate treatment for ground water depending on the quality of the supply; however, it generally is not adequate treatment for surface water supplies.

The extent of the water treatment necessary in a municipal system is dependent upon the water quality of the source of supply. High concentrations of dissolved solids are present in most of the ground water and surface water sources of the Region. Dissolved solids concentrations in ground water are generally higher than in surface water. Many municipalities use water that exceeds concentrations of 500 ppm of total dissolved solids, the recommended limit of the Public Health Service Drinking Water Standards. In the absence of water of better quality persons often adjust to water containing substantially higher concentrations of dissolved minerals. Adherence to the Drinking Water Standards would restrict domestic use of surface and ground supplies in many parts of the Region.

Buckeye, Arizona with an estimated 1965 population of 2,500 utilizes a ground water source with a dissolved solids concentration ranging from 1,400 to 2,400 ppm and chloride concentrations exceeding 1000 ppm. A desalting plant using the electrodialysis process has been in operation since 1962, providing a potable domestic supply with dissolved solids concentration reduced to less than 500 ppm and chloride concentrations reduced to less than 250 ppm(13).

Hardness (as $CaCO_3$) associated with dissolved solids is found in practically all ground waters and generally exceeds 120 ppm. Various water softening processes can be used either at the municipal treatment plant or on an individual water user basis. Water softening at municipal water treatment plants is not practiced in the Region. Home softeners are in widespread use.

The presence of pathogenic bacteria and viruses in municipal waters does not appear to be a significant problem, according to data in the <u>Water Quality, Pollution Control and Health Factors Appendix</u>. Occasionally, isolated problems do occur. For this reason, disinfection should be considered a minimum public health safeguard against the chance of bacterial or viral contamination of ground water supplies; and coagulation, sedimentation, filtration, and disinfection should be the minimum public health safeguard against the chance of bacterial or viral contaminations of surface water supplies. There is a possibility of bacterial contamination of Lake Mead at points of municipal and industrial intake from pollutants originating at recreational areas and from discharges into the lake from Las Vegas Wash(48). Las Vegas Wash also discharges high nutrient and mineral loadings into the lake.

An estimated population of 243,600 or 13 percent of the Regional population within the hydrologic boundaries was served by rural-domestic systems. Ground water from individual wells was utilized to provide 98 percent of the rural-domestic supply. A large percentage of the Indian population are without adequate water supply facilities.

Rural-domestic water supplies receive little or no treatment. Problems can arise in areas where there are concentrations of population using individual water supply systems and individual septic tank waste disposal systems. There are numerous rural communities with no central municipal system where such problems could arise.

There were insufficient data available to evaluate the adequacy of sources and the effects of water quality on self-supplied manufacturing, governmental and commercial establishments. The problems associated with a diminishing ground water supply are equally as serious to self-supplied users. High concentrations of dissolved solids and hardness involve significant treatment costs for some manufacturing activities which need to prevent corrosion, scale formation, and process water damage.

High dissolved solids concentrations also affect the use of Regional source waters for livestock watering, but to a much lesser extent.

Lower Main Stem Subregion

The 1965 subregional M&I withdrawal requirements supplied by various distribution systems are summarized in Table 11. Sixty-seven percent of these requirements were supplied by ground water sources and the remainder by surface water sources.

An estimated population of 250,220 or 80 percent of the subregional population within the hydrologic boundaries was served by 46 municipal systems. 1/ The average municipal withdrawal requirement was 342 gpcd.

1/ See footnote 1/ on page 29.

TABLE 11
SUMMARY OF 1965 MUNICIPAL AND INDUSTRIAL
WITHDRAWAL WATER REQUIREMENTS BY SYSTEM AND SOURCE
LOWER MAIN STEM SUBREGION

System	Source: Ground Water	Source: Surface Water	Total System Withdrawal Requirements
	(acre-feet)		
Municipal	59,400	36,400	95,800
Rural-Domestic	3,900	100	4,000
Self-Supplied Manufacturing, Commercial and Governmental	18,300	4,600	22,900
Livestock	2,800	1,500	4,300
Subregional Total	84,400	42,600	127,000

All of the municipal systems had an independent source of supply of which 39 (85%) utilized a ground water source, four (9%) utilized a surface water source and three (6%) utilized a combination ground-surface water source. One municipal system, North Las Vegas, was partially dependent upon the Las Vegas Valley Water Users Association which serves Las Vegas for its supply. Sixty-two percent of the subregional municipal withdrawal requirements was supplied by ground water sources. 1/ The number of municipal systems serving various population ranges is shown in Table 12.

1/ Although only four municipal systems in the subregion use a surface water source, these four, Las Vegas, Henderson, Yuma, and Boulder City, are large population centers.

TABLE 12
MUNICIPAL DISTRIBUTION SYSTEMS AND PERCENT OF
POPULATION SERVED
LOWER MAIN STEM SUBREGION

Population Served	Number of Systems	Percent of Subregional Population Served
More than 50,000	1	42
5,000 - 49,999	6	44
1,000 - 4,999	8	9
Less than 1,000	31	5
	46	100

Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

The largest municipalities in the subregion with their estimated 1965 populations are: Las Vegas, Nevada (127,180); North Las Vegas, Nevada (29,547); Yuma, Arizona (28,005); Henderson, Nevada (15,475); Ajo, Arizona (7,100); Kingman, Arizona (6,021); St. George, Utah (5,370); and Boulder City, Nevada (4,829). The boundaries of the Las Vegas SMSA correspond to the boundaries of Clark County, Nevada and include the municipalities of Las Vegas, North Las Vegas, Henderson and Boulder City. A population of 211,400 or 68 percent of subregional population was located in the SMSA.

Over eighty-two percent of the Las Vegas metropolitan population was served by municipal systems. The remainder was served by rural-domestic systems. There were also numerous self-supplied manufacturing, commercial, and governmental systems in the area including Basic Management Incorporated chemical industries in the Henderson area, numerous night clubs and casinos in the Las Vegas area, and Nellis Air Force Base near Las Vegas.

The Las Vegas Metropolitan area has experienced rapid population and economic growth in recent years. Water requirements have been met by utilizing the supply of an artesian ground water basin in the area and surface water supplies from Lake Mead. The ground water basin has been critically depleted with resultant reduction in artesian pressures over much of the area. Exploitation of the ground water supplies has been necessary to satisfy requirements. Southern parts of the area, including the City of Henderson and its industrial complex, do not have access to large ground water supplies. Surface water from Lake Mead is utilized in this area and is supplied by a pipeline owned by BMI Chemical Industries. This pipeline is operated near full capacity during peak periods[16] [34].

Declining ground water levels and deteriorating ground water quality have created supply problems for Kingman, Arizona. A small community in southern Yuma County uses water that often exceeds 1000 mg/l of dissolved solids.

Yuma, Arizona has an adequate source of supply from the Colorado River, but high concentrations of dissolved solids and hardness have been a continuing problem. During the 1960-1964 period, dissolved solids concentrations at the Yuma intake on the Colorado River averaged about 1,900 mg/l and reached a maximum of 3,360 mg/l. 1/ Hardness concentrations averaged 700 mg/l (as $CaCO_3$) and reached a maximum of 1,180 mg/l.

In 1964, Yuma changed its water supply intake point. It now diverts water from the Yuma Main Canal that originates at Imperial Dam, about 15 miles upstream of the original intake point. Average long-term concentrations of dissolved solids and hardness of water at this location are 840 mg/l and 380 mg/l respectively. The concentrations are projected to increase significantly, however, due to intensification of water resources development.

The extent of water treatment provided by the 42 municipal systems in the subregion listed by the PHS inventory is shown in Table 13.

An estimated population of 62,600 or 20 percent of the subregional population within the hydrologic boundaries was served by rural-domestic systems. There are many rural communities in the subregion which do not have central municipal systems.

1/ Quality data were taken from the records of the U. S. Geological Survey and the Environmental Protection Agency for the Colorado River at Yuma with 82 samples during the period of record.

TABLE 13
MUNICIPAL WATER TREATMENT
LOWER MAIN STEM SUBREGION

Type of Treatment	Number of Systems
More than disinfection	5
Disinfection only	11
None	26
	42

Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

Little Colorado Subregion

The 1965 subregional M&I withdrawal water requirements supplied by various distribution systems are summarized in Table 14.

TABLE 14
SUBREGIONAL SUMMARY OF 1965 MUNICIPAL AND INDUSTRIAL
WITHDRAWAL WATER REQUIREMENTS BY SYSTEM AND SOURCE
LITTLE COLORADO SUBREGION

System	Source: Ground Water (acre-feet)	Source: Surface Water (acre-feet)	Total System Withdrawal Requirement (acre-feet)
Municipal	4,800	2,000	6,800
Rural-Domestic	3,000	-	3,000
Self-Supplied Manufacturing, Commercial and Governmental	3,700	900	4,600
Livestock	2,100	100	2,200
Subregional Total	13,600	3,000	16,600

An estimated population of 73,600 or 49 percent of the subregional population within the hydrologic boundaries was served by 32 municipal systems. 1/ The average municipal withdrawal requirement was 83 gpcd. All of the municipal systems had an independent source of supply of which 30 (94%) utilized a ground water source and two (6%) utilized a combination ground-surface water source. Seventy-one percent of the subregional municipal withdrawal requirement was supplied by ground water sources. The remainder was supplied by surface water. The number of municipal systems serving various population ranges is shown in Table 15.

TABLE 15
MUNICIPAL DISTRIBUTION SYSTEMS AND PERCENT OF POPULATION SERVED
LITTLE COLORADO SUBREGION

Population Served	Number of Systems	Percent of Subregional Population Served
More than 5,000	3	65
1,000 - 4,999	6	21
500 - 999	7	8
Less than 500	16	6
Subregional Total	32	100

Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

The largest municipalities in the subregion with their estimated 1965 populations are: Flagstaff, Arizona (27,592); Gallup, New Mexico (16,100); Winslow, Arizona (9,600); and Holbrook, Arizona (4,481).

Gallup, New Mexico has an acute need for municipal and industrial water supplies. A declining ground water supply of poor quality from low yielding wells is inadequate to sustain the existing population and economy and to provide for anticipated needs.

1/ See footnote 1/ on page 29.

Additional low yielding wells are being drilled to provide for immediate shortages[14] [20].

Many small communities in the subregion have erratic and undependable water supplies. In some communities, ground water supplies are diminishing in volume as well as quality. The entire municipal supply of one community is delivered by railroad car at a cost to consumers of more than $3.00/1000 gallons[14].

The extent of water treatment provided by the 21 municipal systems in the subregion listed by the PHS inventory is shown in Table 16.

An estimated population of 77,700 or 51 percent of the subregion population within the hydrologic boundaries was served by rural-domestic systems. There are many rural communities in the subregion which do not have central municipal systems.

There was an estimated Indian and non-Indian population of 56,800 living on or near the Navajo, Hopi and Zuni Indian Reservations in the subregion. A significant portion of this Indian population hauls water from nearby sources to satisfy minimal requirements. Although measures are being taken to provide municipal systems and wells, further improvements are needed to provide adequate service.

TABLE 16
MUNICIPAL WATER TREATMENT
LITTLE COLORADO SUBREGION

Type of Treatment	Number of Systems
More than disinfection	2
Disinfection only	7
None	12
	21

Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

Gila Subregion

The 1965 subregional M&I withdrawal water requirements supplied by various distribution systems are summarized in Table 17. Seventy-seven percent of these requirements were supplied by ground water sources and the remainder by surface water sources.

TABLE 17
SUMMARY OF 1965
MUNICIPAL AND INDUSTRIAL
WITHDRAWAL WATER REQUIREMENTS BY SYSTEM AND SOURCE
GILA SUBREGION

System	Source		Total System Withdrawal Requirement
	Ground Water	Surface Water	
	(acre-feet)		
Municipal	196,200	65,400	261,600
Rural-Domestic	5,700	100	5,800
Self-Supplied Manufacturing, Commercial and Governmental	33,800	8,600	42,400
Livestock	10,400	- 1/	10,400
Subregional Total	246,100	74,100	320,200

1/ Although it is possible that some surface water is used for livestock no data are available to quantify this.

An estimated population of 1,279,800 or 93 percent of the subregional population within the hydrologic boundaries was served by 112 municipal systems. 1/ The average municipal withdrawal requirement was 184 gpcd. There were 108 municipal systems with an independent source of supply of which 102 (94%) utilized a ground water

1/ See footnote 1 on page 29. Reference 32 shows that there are more than 11 private water companies in the Phoenix area and Reference 42 that there are 39 private water companies in the Tucson area. The population served by each of these companies ranges from 100 to 20,000 people.

source, three (3%) utilized a surface water source, and three (3%) utilized a combination ground-surface water source. There were at least four municipal systems which were dependent upon other municipal systems for their supply. Seventy-five percent of the subregional municipal withdrawal requirement was supplied by ground water sources. The remainder was supplied by surface water. The number of municipal systems serving various population ranges is shown in Table 18.

TABLE 18
MUNICIPAL DISTRIBUTION SYSTEMS AND PERCENT OF
POPULATION SERVED - GILA SUBREGION

Population Served	Number of Systems	Percent of Subregional Population Served
More than 50,000	2	73
5,000 - 49,999	16	18
1,000 - 4,999	36	8
Less than 1,000	54	1
	108	100

1/ Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

The largest municipalities in the subregion with their estimated 1965 populations are shown in Table 19.

The boundaries of the Phoenix SMSA correspond to the boundaries of Maricopa County. 1/ The boundaries of the Tucson SMSA correspond to the boundaries of Pima County. 2/ In 1965, population in the Phoenix SMSA amounted to 834,600 or 45 percent of the economic subregional population. The Tucson SMSA in 1965

1/ A very small area of Maricopa County with an estimated population of 100 is located hydrologically in the Lower Main Stem Subregion.

2/ A portion of Pima County with an estimated population of 7,500 including the City of Ajo, is located hydrologically in the Lower Main Stem Subregion.

reported population of 306,200 or 16 percent of the economic subregional total.

TABLE 19
PRINCIPAL MUNICIPALITIES IN GILA SUBREGION

State/County		Municipality	Estimated 1965 Population
Arizona			
	Cochise	Bisbee	9,268
		Douglas	12,370
		Sierra Vista	4,635
	Gila	Globe	6,299
	Graham	Safford	5,165
	Greenlee	Clifton	4,200
	Maricopa	Avondale	6,581
		Chandler	12,181
		Glendale	30,760
		Mesa	50,529
		Paradise Valley	4,650
		Phoenix	505,666
		Scottsdale	54,504
		Sun City	11,000
		Tempe	45,919
		Tolleson	4,000
	Pima	South Tucson	6,600
		Tucson	236,877
	Pinal	Casa Grande	8,485
		Coolidge	5,012
		Eloy	5,373
		San Manuel	4,000
		Superior	5,000
	Santa Cruz	Nogales	8,000
	Yavapai	Prescott	13,823

The combined 1965 population of the two metropolitan areas was 1,140,800 or 61 percent of the economic subregional total. Ninetysix percent of the population in these areas is served by municipal systems. The remainder are supplied by rural-domestic systems. There are numerous self-supplied manufacturing, commercial and governmental systems in these areas.

Characteristic of the metropolitan areas are large manufacturers which have high product values but consume very little water per dollar of value produced. Such companies as Air Research, Allison Steel, General Electric, Goodyear Aircraft, Kaiser Aircraft and Electronics, Motorola, Reynolds Extrusion, Sperry Phoenix, and Hughes Aircraft are typical. Encouraging manufacturers with low water requirements per dollar of value produced to locate in these areas represents a very practical water conservation alternative.

The Phoenix and Tucson metropolitan areas need a dependable supplemental supply of water for municipal and industrial uses. The Phoenix area is currently utilizing both surface and ground water sources while the Tucson area relies exclusively on ground water. There has been rapid population and economic growth in these areas in recent years. Resulting requirements for municipal and industrial water supplies have been met by increased pumping of ground water and by converting surface water for irrigation to municipal and industrial use in areas where irrigated lands have been urbanized. Other municipal systems outside of the metropolitan areas are similarly in need of improvements. Virtually all of the problems relate to declining ground water levels and deteriorating ground water quality.

The extent of water treatment provided by the 100 municipal systems in the subregion listed by PHS inventory is shown in Table 20.

TABLE 20
MUNICIPAL WATER TREATMENT
GILA SUBREGION

Type of Treatment	Number of Systems
More than disinfection	7
Disinfection only	27
None	66
	100

Source: Public Health Service Inventory of Municipal Water Facilities, 1963.

An estimated population of 103,400 or seven percent of the subregional population within the hydrologic boundaries was served by rural-domestic systems. There are many rural communities in the subregion which do not have central municipal systems.

FUTURE DEMANDS

CHAPTER C-FUTURE DEMANDS

MODIFIED OBE-ERS LEVEL OF DEVELOPMENT

Water Supply Requirements

The basis for the water supply projections is described in Chapter D - Methodology and Assumptions. This section presents the calculated withdrawal and depletion requirements for the Region, subregions, and critical service areas with appropriate discussions of water quality requirements and problems. Where adequate information is available, present source and system capabilities are compared with future requirements.

An indication of the growth projected for the Region is shown by the following tabulation of the present and projected populations.

TABLE 21
POPULATION OF THE
LOWER COLORADO REGION
MODIFIED OBE-ERS PROJECTIONS BY ECONOMIC SUBREGION

	1965	1980	2000	2020
Lower Main Stem Subregion	345,200	815,600	1,519,700	2,020,500
Arizona	120,700	147,100	197,700	290,500
Nevada	213,900	653,500	1,305,000	1,708,000
Utah	10,600	15,000	17,000	22,000
Little Colorado Subregion	125,000	183,500	240,400	326,400
Arizona	85,500	124,800	152,200	181,400
New Mexico	39,500	58,700	88,200	145,000
Gila Subregion	1,406,800	1,911,500	3,036,600	4,636,200
Arizona	1,379,400	1,870,800	2,970,700	4,531,400
New Mexico	27,400	40,700	65,900	104,800
Lower Colorado Region	1,877,000	2,910,600	4,796,700	6,983,100

Region

A Regional summary of projected domestic, manufacturing, livestock, governmental, and commercial and other (M & I) water requirements for each target year is presented in Table22. The M & I requirements are based on data for the economic boundaries of the Region and the modified OBE-ERS level of development. Municipal and industrial (excluding livestock water use) withdrawal and depletion requirements are summarized by states for hydrologic subregions of the Lower Colorado Region in Table 23. Livestock water requirements are summarized by states for hydrologic subregions in Table 24.

Withdrawal requirements are projected to increase from 464,000 acre feet/year (AF/YR) in 1965 to 2,840,000 AF/YR in 2020, as shown in Table 22, representing more than a five-fold increase over the study period. Withdrawals for commercial uses will be largest with needs of 1,046,000 AF/YR projected in 2020. The requirement for the commercial water-use category is projected to be three times greater than that projected for the manufacturing water-use category in 2020. Domestic uses are the next largest category with 990,000 AF/YR projected. In descending order, the next largest withdrawal requirements are for governmental, manufacturing and livestock uses.

A 270 percent increase in population between the years 1965 and 2020, a fifteen-fold increase in the value of manufacturing output, a fourteen-fold increase in economic activity in the commercial category, and a rising water-use rate by rural residents are the major reasons for the growth of municipal and industrial water demands.

A limited water supply and deterioration of the supply's quality are two major problems in the Region. Further, the majority of the Region's present municipal and industrial requirements are being met by continued depletion of ground water reserves. This practice cannot continue indefinitely, not only because the volume is limited, but also because of increasing pumping costs, occurrence of land subsidence, and deteriorating water quality. Thus, the well-being of the Lower Colorado Region's populace can be assured only by planning to meet the water needs developed to satisfy projected water needs.

TABLE 22
REGIONAL SUMMARY OF PROJECTED
MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS
BY ECONOMIC SUBREGION FOR MODIFIED OBE-ERS PROJECTIONS
(ACRE-FEET PER YEAR)

Water Use	1965	1980	2000	2020
		Withdrawal		
Domestic	273,300	437,600	712,900	990,300
Manufacturing	24,300	60,000	151,100	340,800
Livestock 1/	16,900	25,800	32,200	39,600
Governmental	52,100	118,100	264,600	427,700
Commercial	97,200	245,400	585,300	1,045,500
Total	463,800	886,900	1,746,100	2,843,900
		Depletion		
Domestic	137,500	225,300	368,300	514,400
Manufacturing 1/	12,900	30,700	80,400	182,400
Livestock 1/	16,900	25,800	32,200	39,600
Governmental	5,200	14,100	39,700	85,500
Commercial	31,200	71,000	172,100	354,300
Total	203,700	366,900	692,700	1,176,200

1/ Consumption of water by farm animals only.

TABLE 23
MUNICIPAL AND INDUSTRIAL WATER SUPPLY REQUIREMENTS 1/
BY HYDROLOGIC SUBREGION FOR THE MODIFIED OBE-ERS PROJECTIONS
(ACRE-FEET PER YEAR)

State/Subregion	1965		1980		2000		2020	
	Withdrawal	Depletion	Withdrawal	Depletion	Withdrawal	Depletion	Withdrawal	Depletion
Arizona	30,800	12,100	39,100	14,700	50,900	18,800	73,000	29,700
Nevada	76,100	30,000	272,300	102,300	618,400	228,600	861,700	350,800
Utah	4,400	1,800	6,300	2,400	8,100	3,000	11,100	4,500
Lower Main Stem	111,300	43,900	317,700	119,400	677,400	250,400	945,800	385,000
Arizona	13,700	5,200	26,600	10,500	44,500	17,000	67,000	25,500
New Mexico	3,600	1,400	7,700	3,000	16,300	6,300	35,400	13,400
Little Colorado	17,300	6,600	34,300	13,500	60,800	23,300	102,400	38,900
Arizona	302,900	129,700	481,800	197,600	925,000	367,700	1,677,900	680,400
New Mexico	1,800	800	3,300	1,400	7,300	2,900	12,700	5,100
Gila	304,700	130,500	485,100	199,000	932,300	370,600	1,690,600	685,500
Arizona	347,400	147,000	547,500	222,800	1,020,400	403,500	1,817,900	735,600
Nevada	76,100	30,000	272,300	102,300	618,400	228,600	861,700	350,800
New Mexico	5,400	2,200	11,000	4,400	23,600	9,200	48,100	18,500
Utah	4,400	1,800	6,300	2,400	8,100	3,000	11,100	4,500
Region Total	433,300	181,000	837,100	331,900	1,670,500	644,300	2,738,800	1,109,400

1/ Does not include livestock water use.

TABLE 24
LIVESTOCK WATER REQUIREMENTS 1/
FOR THE MODIFIED OBE-ERS PROJECTIONS
(ACRE-FEET PER YEAR)

State/Subregion	1965	1980	2000	2020
Arizona	3,400	4,400	5,500	6,800
Nevada	300	400	500	600
Utah	600	700	900	1,100
Lower Main Stem	4,300	5,500	6,900	8,500
Arizona	1,700	1,700	1,800	1,800
New Mexico	500	500	600	600
Little Colorado	2,200	2,200	2,400	2,400
Arizona	9,500	16,500	20,800	26,100
New Mexico	900	1,600	2,100	2,600
Gila	10,400	18,100	22,900	28,700
Arizona	14,600	22,600	28,100	34,700
Nevada	300	400	500	600
New Mexico	1,400	2,100	2,700	3,200
Utah	600	700	900	1,100
Regional Total	16,900	25,800	32,200	39,600

1/ Includes only consumption by animals. Evaporation from stock watering ponds is included in the reservoir evaporation totals shown in the Water Resources Appendix. Water requirements are based on hydrologic subregions, and depletions are assumed to equal withdrawals.

Continued water quality degradation of both surface and ground water sources will place an added constraint on the Region's water resource development. (See Water Quality, Pollution Control and Health Factors Appendix.) Some sources may have to be abandoned or given expensive treatment such as desalination prior to use or reuse. This is particularly true of many ground water sources that are being extensively mined. In the Central Arizona Project area, for example, the mineral quality of the water deteriorates as the water level drops because of salinity accretions from the deep deposits of salt and gypsum, and the concentrating effect of recycling. Much of the water now pumped in this area does not meet recommended criteria for dissolved solids and hardness nor minimum requirements for many salt-sensitive crops. Conditions will become worse in the future if the projected increases in ground water use occur.

The quality of Colorado River water available to the Lower Colorado Region is significantly affected by development and water management practices in both the Upper and Lower Colorado Regions. As measured by total dissolved solids concentrations, the average annual quality at Hoover and Imperial Dams are projected to increase from 730 mg/l and 840 mg/l in 1965 to 1,050 mg/l and 1,350 mg/l in 2020, respectively, assuming no salinity improvement program or augmentation. With the basinwide salinity improvement program outlined in the Water Quality, Pollution Control and Health Factors Appendixes for the Upper Colorado and Lower Colorado Regions, the salinity concentrations at Hoover and Imperial Dams would be reduced to an estimated 850 mg/l and 1,030 mg/l.

Because of the projected increase in livestock a corresponding increase in the consumption of water is expected. The increase will be 22,700 acre-feet by the year 2020. Of this increase 21,300 acre-feet will be developed from ground water and 1,400 acre-feet will be from surface water supplies. Because of the large increase projected for feeder livestock, ground water use will nearly double from the base year since feeding operations depend almost exclusively upon ground water. The projected increase in range livestock is slight. Since range livestock use ground water and surface water about equally, this increase is almost insignificant. No problems of any magnitude are foreseen in meeting the increased water demand for livestock. Local problems will continue to occur where ground water supplies are not available or where present surface water storage methods are not practical. These problems should only occur with range cattle as livestock feeding operations are not likely to develop where the water supply is limited.

Subregions

The projected M & I water requirements for the Lower Main Stem, Little Colorado, and Gila Subregions are presented in Tables 26, 27, and 28. The requirements are based on economic subregional boundaries.

For the Region and subregions, descriptive facts can be obtained from an analysis of the percentage change in requirements between 1965 and 2020. Results of such an analysis are presented in Table 25.

TABLE 25
PERCENTAGE INCREASE IN WITHDRAWAL REQUIREMENTS BETWEEN YEARS
1965-2020

Water Use	Lower Main Stem	Little Colorado	Gila	Regional Summary
Domestic	419	362	200	262
Manufacturing	1,551	600	1,313	1,302
Livestock	98	09	176	134
Governmental	1,092	735	607	721
Commercial	1,158	597	884	976
Average	709	431	440	513

Increased municipal and industrial water requirements in the Lower Main Stem and Gila Subregions result from the growth in the expanding population centers of Las Vegas, Nevada, and Phoenix and Tucson, Arizona. The largest percentage increases within the Lower Main Stem and Gila Subregions are for the commercial and manufacturing categories. The large percentage increase shown for the Commercial category in the Lower Main Stem Subregion is due to a 36-fold increase in economic activity projected for the Lodging sector. In the Little Colorado Subregion, the growth is attributed to a rising domestic-use rate for the rural population as well as to the projected growth of several medium-sized cities. A five-fold increase in withdrawals is projected in the Little Colorado Subregion compared to more than an eight-fold increase for the Lower Main Stem Subregion.

To delineate the problems of the subregions in more detail, the discussion now turns to the specific service areas in each subregion.

TABLE 26
MUNICIPAL AND INDUSTRIAL
PROJECTED WATER REQUIREMENTS
FOR MODIFIED OBE-ERS PROJECTIONS LOWER MAIN STEM ECONOMIC SUBREGION
(ACRE-FEET PER YEAR)

Water Use	1965	1980	2000	2020
		Withdrawal		
Domestic	71,900	164,500	292,800	373,500
Manufacturing	3,700	11,900	29,800	61,100
Livestock 1/	4,300	5,500	6,900	8,500
Governmental	11,600	40,900	97,800	138,300
Commercial	35,500	122,700	299,900	446,500
Total	127,000	345,500	727,200	1,027,900
		Depletion		
Domestic	36,000	87,700	160,000	206,000
Manufacturing	2,400	7,600	19,500	39,800
Livestock 1/	4,300	5,500	6,900	8,500
Governmental	1,200	4,900	14,700	27,700
Commercial	9,000	27,600	72,100	141,600
Total	52,900	133,300	273,200	423,600

1/ Consumption of water by farm animals only.

TABLE 27
MUNICIPAL AND INDUSTRIAL
PROJECTED WATER REQUIREMENTS
FOR MODIFIED OBE-ERS PROJECTIONS LITTLE COLORADO ECONOMIC SUBREGION
(ACRE-FEET PER YEAR)

Water Use	1965	1980	2000	2020
		Withdrawal		
Domestic	7,600	14,000	22,100	35,100
Manufacturing	1,600	4,200	7,100	11,200
Livestock 1/	2,200	2,200	2,400	2,400
Governmental	2,300	4,500	9,800	19,200
Commercial	2,900	5,400	10,900	20,200
Total	16,600	30,300	52,300	88,100
		Depletion		
Domestic	3,800	7,000	11,000	17,600
Manufacturing	600	1,900	3,500	5,400
Livestock 1/	2,200	2,200	2,400	2,400
Governmental	200	500	1,500	3,800
Commercial	900	1,600	3,100	5,800
Total	7,700	13,200	21,500	35,000

1/ Consumption of water by farm animals only.

TABLE 28
MUNICIPAL AND INDUSTRIAL
PROJECTED WATER REQUIREMENTS
FOR MODIFIED OBE-ERS PROJECTIONS GILA ECONOMIC SUBREGION
(ACRE-FEET PER YEAR)

Water Use	1965	1980	2000	2020
	Withdrawal			
Domestic	193,800	259,100	398,000	581,700
Manufacturing	19,000	43,900	114,200	268,500
Livestock 1/	10,400	18,100	22,900	28,700
Governmental	38,200	72,700	157,000	270,200
Commercial	58,800	117,300	274,500	578,800
Total	320,200	511,100	966,600	1,727,900
	Depletion			
Domestic	97,700	130,600	197,300	290,800
Manufacturing	9,900	21,200	57,400	137,200
Livestock 1/	10,400	18,100	22,900	28,700
Governmental	3,800	8,700	23,500	54,000
Commercial	21,300	41,800	96,900	206,900
Total	143,100	220,400	398,000	717,600

1/ Consumption of water by farm animals only.

Service Areas

A service area is defined as an area where problems are interrelated and where planning for water supply and waste disposal should be carried out on an integrated basis. These areas have also been defined as Standard Metropolitan Statistical Areas (SMSA's) by the U. S. Bureau of Census. The populated areas of Clark County (Las Vegas), Nevada, Maricopa County (Phoenix), Arizona, and Pima County (Tucson), Arizona qualify as service areas. Several other service areas are projected to experience rapid growth. They are Washington County, Utah and the Cities of Kingman and Yuma, Arizona in the Lower Main Stem Subregion; Gallup, New Mexico, and the joint areas of Flagstaff-Williams and Winslow-Holbrook, Arizona in the Little Colorado Subregion; and the Prescott, Arizona area in the Gila Subregion. Projected withdrawal and depletion requirements for the three largest service areas (SMSA's) and seven smaller areas are presented in Table 29.

The following discussion relates to the larger or more severe problem areas within each subregion. Descriptions of the smaller service areas are not included other than to note that new sources of water are scarce, often of marginal mineral quality, and existing supplies are dwindling. In some cases, collection and distribution systems have deteriorated severely.

Clark County -- Population and commercial expansion in this service area have taken place at such an accelerated rate that existing supplies and distribution facilities are inadequate to meet the present and future requirements (16). Ground water withdrawals in excess of recharge have resulted in a critical depletion of the ground water resource and a reduction in artesian pressures in the area. Consequently, peak demands for fire protection cannot be met in at least one segment of the service area, Nellis Air Force Base. Water supplies from Lake Mead for Boulder City and the City of Henderson are the only surface water supplies in the service area, and both of these systems are presently operating near full capacity during periods of peak demand.

The first stage of the Southern Nevada Water Project, now under construction, will deliver 132,000 acre-feet of municipal and industrial water for use in the Las Vegas area, alleviating to a large extent the present ground-water overdraft in southern Nevada. The second stage should be completed by year 2000 and, as presently contemplated, would provide an additional 180,000 acre-feet of water for municipal and industrial uses.

TABLE 29
MUNICIPAL AND INDUSTRIAL WATER SUPPLY REQUIREMENTS 1/
FOR SERVICE AREAS BASED
ON THE MODIFIED OBE-ERS PROJECTIONS
(ACRE-FEET PER YEAR)

	Depletion				Withdrawal			
	1965	1980	2000	2020	1965	1980	2000	2020
Lower Main Stem								
Clark County, Nevada	35,070	101,800	227,600	349,200	88,900	270,900	616,100	857,600
Washington County, Utah	1,500	2,350	3,000	4,500	3,800	6,200	8,100	11,100
City of Kingman, Arizona	840	2,800	6,900	13,400	2,140	7,500	18,800	32,900
City of Yuma, Arizona	2,790	4,500	6,500	9,100	7,060	12,100	17,600	22,400
Service Area Total	40,200	111,500	244,000	376,200	101,900	296,800	660,500	924,000
Little Colorado								
City of Gallup, New Mexico	700	1,440	2,860	5,890	1,840	3,660	7,470	15,500
Cities of Glagstaff-Williams, Arizona	1,240	2,800	6,250	13,520	3,240	7,080	16,320	35,600
Cities of Winslow-Holbrook, Arizona	620	1,500	3,240	6,660	1,610	3,780	8,450	17,520
Service Area Total	2,560	5,740	12,350	26,070	6,700	14,520	32,240	68,620
Gila								
Maricopa County, Arizona	78,740	128,500	253,200	483,000	183,900	313,300	637,000	1,191,200
Pima County, Arizona	29,590	41,500	74,600	129,100	69,100	101,250	187,700	318,400
City of Prescott, Arizona	1,300	2,350	4,270	7,640	3,040	5,720	10,750	18,840
Service Area Total	109,630	172,350	332,070	619,740	256,040	420,270	835,450	1,528,440

1/ Livestock use not included.

The Clark County service area may face three critical problems towards the end of the study period. The first is an inadequate distribution system to satisfy the area's demands. Secondly, development of the State of Nevada's remaining apportioned share of Colorado River water would be required prior to year 2000. And finally, the present quality of the water at Lake Mead does not meet the Public Health Service Drinking Water Standards for total dissolved solids and sulfates. These quality indices are projected to worsen by 2020. If associated taste and hardness problems become too objectionable, the future water supply may require softening.

Maricopa County -- As discussed in the Present Status Section, municipal and industrial demands are being met, in part, by depleting the area's ground water reserves. Continued overdraft will meet the needs of the area until about 1980 when Central Arizona Project water is expected to become available. However, with delivery of Central Arizona Project water there would remain a deficiency of 1.5 million acre-feet in 1980 that would need to be supplied by continued ground-water overdraft. Imported water from outside the Region would be needed if the ground-water overdraft is to be alleviated. Deterioration of water quality and increasing pumping costs are expected as ground-water levels decline.

An engineering consultant's waterworks study for the Valley Metropolitan Area of Phoenix estimated that the overall needs of the metropolitan area for urban and agricultural diversions and export commitments presently (1968) exceed the water supply by 873,000 acre-feet/year or 34 percent and will exceed the supply by 459,000 acre-feet/year or 34 percent and will exceed the supply by 459,000 acre-feet/year or 21 percent in 2000 (32). The decrease is due to conversion of agricultural water to municipal and industrial uses as urbanization of agricultural lands continues.

Pima County - The problems of Pima County parallel those of Maricopa County in that present requirements are satisfied by depleting local ground water reserves. Tucson, as mentioned earlier, depends entirely on ground water. Declining ground water levels result in increased pumping costs and in increasing salinity and nitrates in ground water north of the City.

<u>Means to Satisfy Demands</u>

Six potential means by which the projected municipal and industrial demands may be met are available. These are the increased conservation of existing supplies, more efficient use of existing supplies, additional water reclamation for reuse, economic incentives, desalting brackish water and augmentation. In essence, these alternatives are means of developing "new" water for municipal and industrial needs.

Conservation of existing supplies includes canal lining and sealant programs, evaporation suppression, vegetative manipulation, phreatophyte control and channelization. Included in the more efficient use of existing supplies group are reduction of use in homes, industry, and agriculture, the establishment of metropolitan services rather than "piecemeal" development, development of surface and ground water sources, and the recirculation of water where possible. Wastewater treatment and desalination can provide for reuse of water. Economic incentives may include effective pricing policies and transfers of water between uses. Importation from outside the Region, precipitation management, vegetative management for water yield, and sea water conversion are potential means of augmenting the Region's water supply.

All possible means of meeting the Region's future water supply requirements should be explored. There are, of course, legal and administrative restrictions which tend to limit the implementation of many alternatives. Although difficult, these restrictions can be changed and future design and development should contain the flexibility necessary to meet new and changing conditions of water use. For more detail of the legal and institutional framework refer to Appendix III, Legal and Institutional Environments.

While reduction of use by municipal users generally will not reduce requirements significantly, the reduction of use for landscaping may have some potential. Domestic water use can be reduced in arid regions by converting irrigated lawns to desert landscaping. The U.S. Water Conservation Laboratory in Phoenix changed 18,000 square feet of grassed lawn to desert landscaping, saving 500,000 gallons of water annually (39). While of limited potential for home owners, this alternative should be considered by manufacturing, commercial and governmental users.

Combining the water supply and wastewater treatment functions under a single district is recommended for the metropolitan areas. Recent experiences of the Santee Project in the Pacific Southwest clearly demonstrate that notable water saving economics can be realized by such a management scheme, especially in water-short areas.

There are several programs, either under construction or in the planning stage, which are designed to meet the future municipal and industrial requirements of the subregions. These will now be discussed by individual service area within each subregion.

Lower Main Stem Subregion

The future municipal and industrial water withdrawal needs of the economic subregion, projected to be 946,000 acre-feet per year by 2020, can be met by development of authorized river supplies, ground water development, desalination of brackish supplies, and reuse.

The needs of Clark County, Nevada, could be met by developing Nevada's full allotment of the Colorado River water, pumping ground water locally for peaking purposes, desalting treated municipal waste effluents in the 1980-2000 timeframe, and recycling the product water back into the municipal distribution system. The recycling scheme is portrayed in Figure 2. A 100 mgd (112,000 acre-feet per year) desalination plant is suggested for the 1980-2000 period. In the 2000-2020 timeframe, 347,000 acre-feet of additional water would need to be provided by additional reuse and/or importation from outside the Region.

There are numerous self-supplied ground water users in the service area of the Las Vegas Valley Water District. Better overall management would result if these users were consolidated into one overall water district.

The scheme outlined on Figure 2 not only helps to meet the M & I water supply needs, but also may eliminate the current pollution problem caused by excessive nutrient discharged to Las Vegas Bay. Additionally, the salinity contribution to the Colorado River would be decreased. Reuse of reclaimed effluents is presently restricted due to potential health hazards. It is assumed that advancements in tertiary treatment will permit unrestricted use of municipal and industrial effluents in the near future.

Future needs for Washington County, Utah, will be met by the construction of an authorized multi-purpose project. For the Kingman, Arizona area future needs could be met by developing local ground water in the 1980-2000 timeframe and pumping Colorado River water in the 2000-2020 timeframe. A reconnaissance-level report on the Colorado River pumping scheme has been developed.

Yuma, Arizona presently uses Colorado River water diverted from Imperial Dam. The supply is adequate to meet future needs but the quality of the supply presents problems. With increased use of Colorado River water upstream, the dissolved solids and hardness concentrations of Yuma's supply are projected to increase. The suggested plan, then, includes a 10 mgd desalting plant for the Yuma area.

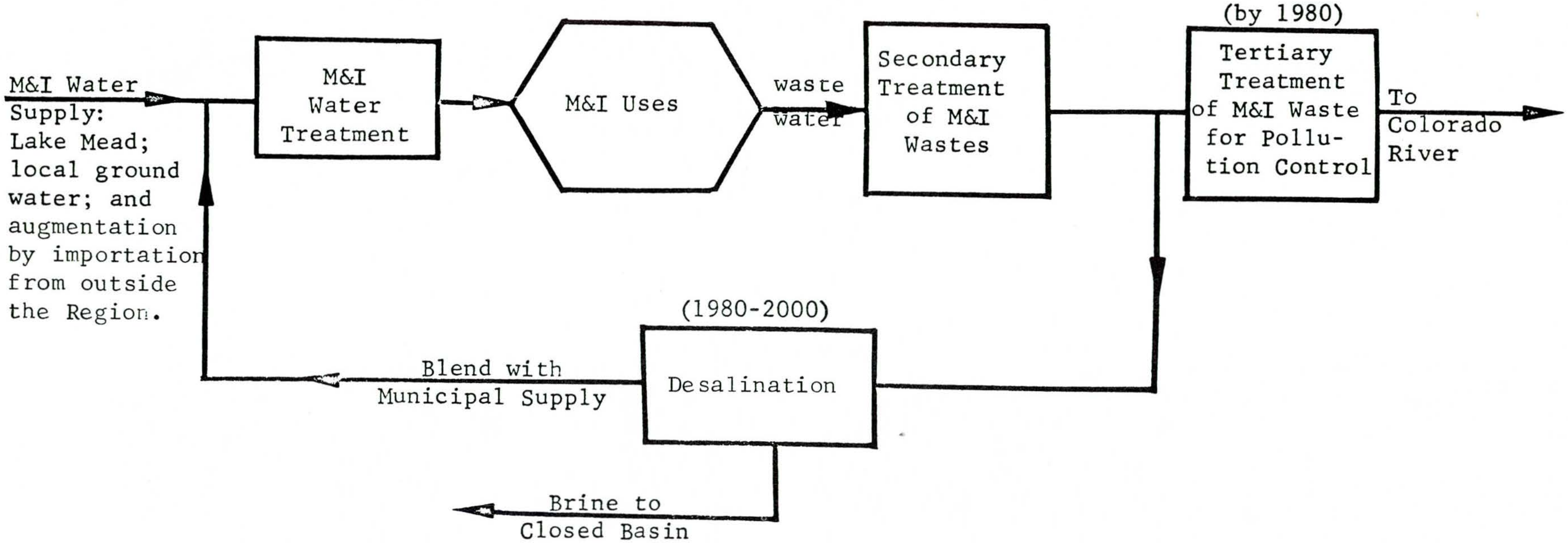

Figure 2--Schematic Diagram of Program for Water Use and Reuse for Metropolitan Las Vegas, Nevada
SOURCE: Water Quality, Pollution Control and Health Factors Appendix.

A small town in the southern portion of the subregion will also desalt its supply throughout the study period. The remaining demand centers in the Lower Main Stem Subregion are small. For these centers it is expected that future needs will be met by continued use of ground water.

Little Colorado Subregion

The Little Colorado Subregion is rural in character. Three medium-sized demand centers were considered, they are Gallup, New Mexico, and Flagstaff-Williams and Winslow-Holbrook, Arizona. Reconnaissance-level planning for future municipal and industrial water has been conducted for all three areas. The water requirements are met by ground water use and by a small importation from the Upper Colorado Region, by desalination of ground water, and by developing water from a small local tributary.

Obtaining an adequate supply of municipal and industrial water has presented problems in the past in the Gallup, New Mexico area. Needs to 1980 can probably be met by a recently developed ground water supply. This source should provide about 5 mgd of marginal mineral quality (about 1,000 mg/l of TDS); this could be followed by an importation of 7,500 AF/YR from the Upper Colorado Region in 1980, if found feasible; and, prior to 2000, by developing and desalting brackish ground water in the area. For the purpose of this study, the ground water supply developed in the first timeframe is assumed to be abandoned after the importation reaches the area. Thus, in the last timeframe, the importation and the water from the 8 mgd desalting plant should meet the needs.

The Flagstaff-Williams area, located on the western edge of the subregion, will meet its demands by improving the reservoir system to decrease water losses, by developing local ground water reserves in the first timeframe and, by developing water from East Clear Creek, more than 50 miles away during 1980-2000.

Future needs in the Winslow-Holbrook area could be met by developing local ground water, desalting a portion of the ground water, both in the first timeframe and in the last timeframe, and by using surface water from the project developed to meet the Flagstaff-Williams area needs. One of the communities could desalt the ground water portion of its supply throughout the study period. There are numerous small demand centers scattered throughout the subregion which were not identified for purposes of this study. It is assumed that these rural communities will develop local ground water supplies and may, at times, require desalting facilities.

Gila Subregion

To meet the needs of the subregion, a major evaluation of the previously mentioned alternatives will be required. When Central Arizona Project water becomes available, it alone will initially meet the projected municipal and industrial requirements of the Subregion. However, this excludes other uses and does not take into account that the delivery of 1,670,000 acre-feet per year in 1980 will decrease to 830,000 acre-feet per year in 2020. Consequently, vigorous development of other programs and policies is urgently required.

Water reclamation projects offer promise of increasing the efficiency of water reuse. Research and pilot studies are underway at Phoenix's Flushing Meadows Project and Tucson's Wastewater Reclamation Project where municipal wastewater will be reclaimed for irrigation and recreation uses. Future satisfaction of water requirements in the subregion's service areas are predicated on both the availability of Central Arizona Project water and increasing volumes of reclaimed wastewater.

There are many sources of brackish water in the subregion which are amenable to desalination. One domestic desalination plant is in operation at Buckeye, Arizona. The potential that desalination and wastewater reclamation offer should be evaluated in all future water resource schemes for this subregion. The location of brackish ground water is shown in the Water Quality, Pollution Control and Health Factors Appendix on a figure entitled, "Total Dissolved Solids in Ground Water."

The conversion of agricultural use to urban use is expected to continue as a major source of "new" municipal and industrial water in the Phoenix area. In the Salt River Project area, water is tied to and transferred with the land. Legal restrictions inhibit transfer of agricultural water from irrigation use to municipal and industrial uses on lands that are not irrigated.

In the Phoenix and Tucson areas, for example, urbanization has taken place and is projected to continue on desert land that has no previous history of irrigation and for which no possibilities are present for transferring irrigation supplies directly to municipal and industrial use. Ground water sources have been primarily relied upon to meet increased water requirements, in part, because available surface water sources are appropriated for irrigation, industrial and livestock purposes. The result has been a necessary utilization of ground water resulting in declining ground water levels, deteriorating ground water quality, and increased pumping cost. 1/

Most of the high density urbanization in the Phoenix area is occurring on the lands of irrigation projects. There are indications that urban water requirements per acre are less than agricultural water requirements per acre. 2/ Thus, it may be possible to serve a larger area with the available water, thereby satisfying the municipal and industrial requirements on urbanized desert lands lying outside of the presently irrigated areas, were it not for existing state laws which attach water to the land and prohibit such a transfer in the absence of consent and approval by all interested parties. These laws make it necessary to develop additional sources of supply for urbanized desert lands lying outside of the irrigated areas. In the interest of conservation and efficient management of supplies, existing regulations should be changed to facilitate such transfers.

More than 80 percent of the M & I water demands of the Gila Subregion are found in Maricopa and Pima Counties where the SMSA's of Phoenix and Tucson are located. The means of meeting the needs of these two metropolitan areas are varied and in considering proposals for developing the water supply for future needs, no constraints were considered from a water rights point of view.

In Maricopa County, where 2020 withdrawals will be 1.2 MAF/YR, the needs will be met by continued conversion of irrigation lands, and thus the water associated with it, to urban and industrial uses, continued use of existing surface and ground water supplies, and receipt and use of water via the Central Arizona Project (CAP). The shift of irrigated land to urban and industrial uses from the 1965 conditions is estimated by the Economics Workgroup to be 22,000, 66,000 and 82,000 acres in the 1965-1980, 1980-2000, and 2000-2020 time periods.

Nearly 80 percent of present withdrawals for irrigation are from ground water in the Gila Subregion, much of which is dependent on overdrafting reserves. Since an objective of the framework program presented in the General Program and Alternatives Appendix is to nearly eliminate ground water overdraft, this supply would not exist in 2020 but would be replaced by imported water. Thus, the amount of water available for transfer from irrigation to municipal and industrial use would be limited. Municipal and industrial water deficiencies could be met by the use of the desalted irrigation return flows and by importation from outside the Region. A suggested program for water use and reuse in the Metropolitan Phoenix area is outlined in Figure 3.

1/ References: 13, 17, 28, 31, 32
2/ References: 28, 31, 32

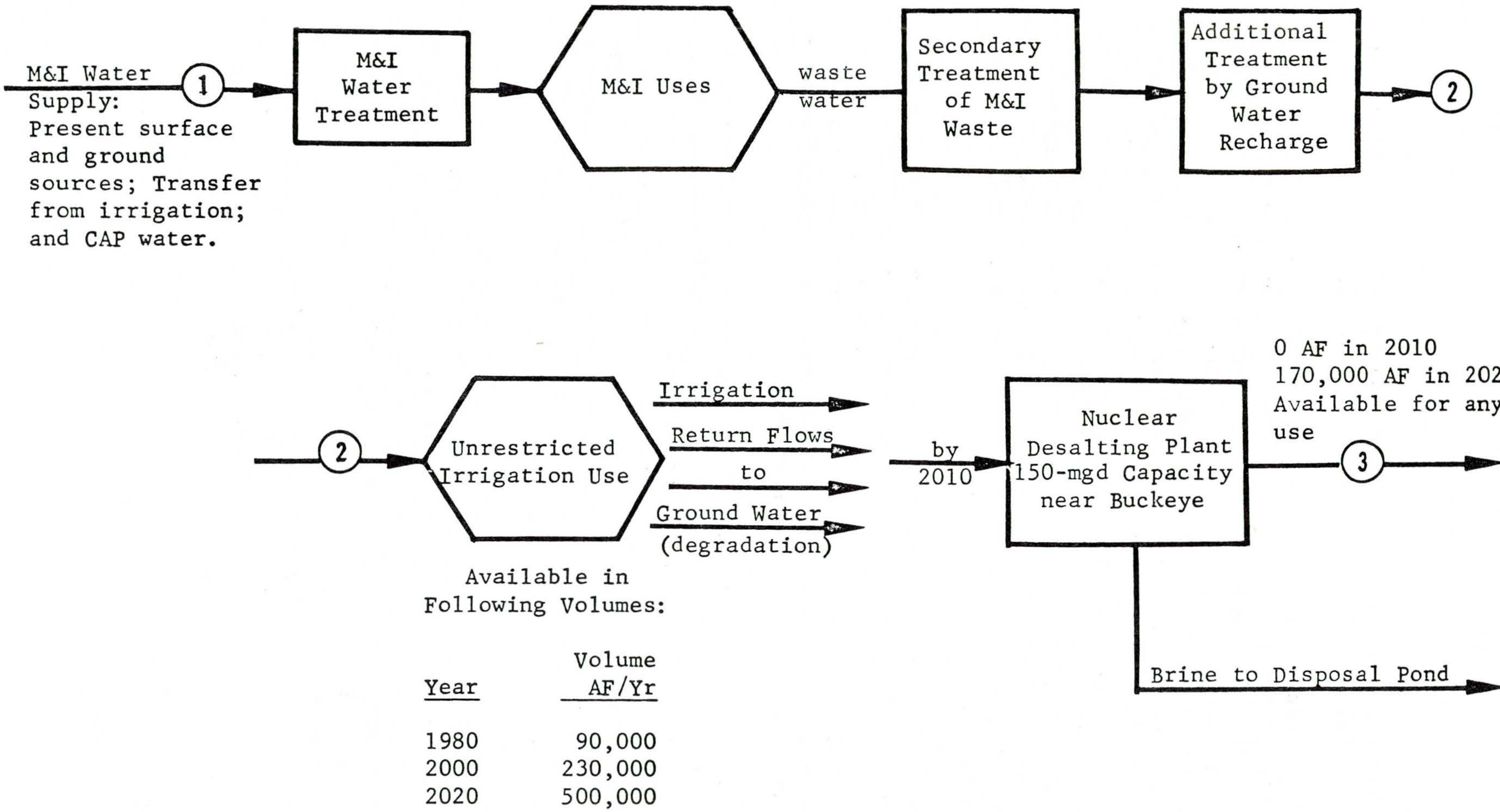

Figure 3--Schematic Diagram of Program for Water Use and Reuse for Metropolitan Phoenix, Arizona

SOURCE: Water Quality, Pollution Control and Health Factors Appendix.

The program for meeting Maricopa County needs also includes use of three desalting facilities for small cities which appear to be located too far from the CAP delivery area. No studies were carried out to determine whether Central Arizona Project water, located at some distance, or desalting local ground water would be the more economical means of meeting the needs.

Long-range plans have been developed for Phoenix to the year 2000 anticipating the water needs of its projected population. The City had water works surveys made in 1960 and 1965 to determine both present and future needs in the Phoenix Metropolitan Water Service Area. Minimum water production needs, based on projected population increases, are estimated at 780 mgd by the year 2000. The need for large transmission and distribution mains and additional storage capacity have also been determined (19).

The needs of Pima County, Arizona will be met by shifting agricultural land to urban and industrial uses, by use of surface supplies from two multi-purpose projects, and between 2000 and 2020, importation of water from outside the Region. The estimated shift of irrigated land to urban land is estimated at 2,500, 5,500, and 4,600 acres for the 1965-1980, 1980-2000, and 2000-2020 timeframes. A suggested program for wastewater reclamation in the Metropolitan Tucson area is presented in Figure 4.

A medium-sized city in the northern half of the subregion may meet its needs exclusively by ground water development. The numerous and small demand centers scattered throughout the remainder of the subregion may meet their needs by continued ground water use or surface water use, if presently available. Further, two small communities may desalt brackish ground water to meet their future needs.

Single-purpose development and treatment costs for the suggested program are shown in Table 30. The costs are $109.5, $178.9 and $139.6 million for the 1965-1980, 1980-2000 and 2000-2020 timeframes. Included are the costs of ten desalting plants varying in size from 0.5 mgd to 100 mgd, surface water development by government agencies, widespread development of ground water reserves, a small importation from the Upper Colorado Region, and water treatment plants to treat the total projected requirements. Costs of distribution systems from the treatment plant to the consumer are not included. Costs of federal multi-purpose projects with a M & I water supply allocation, such as the Central Arizona Project, are also not included but are included in the costs shown in the General Program and Alternatives Appendix.

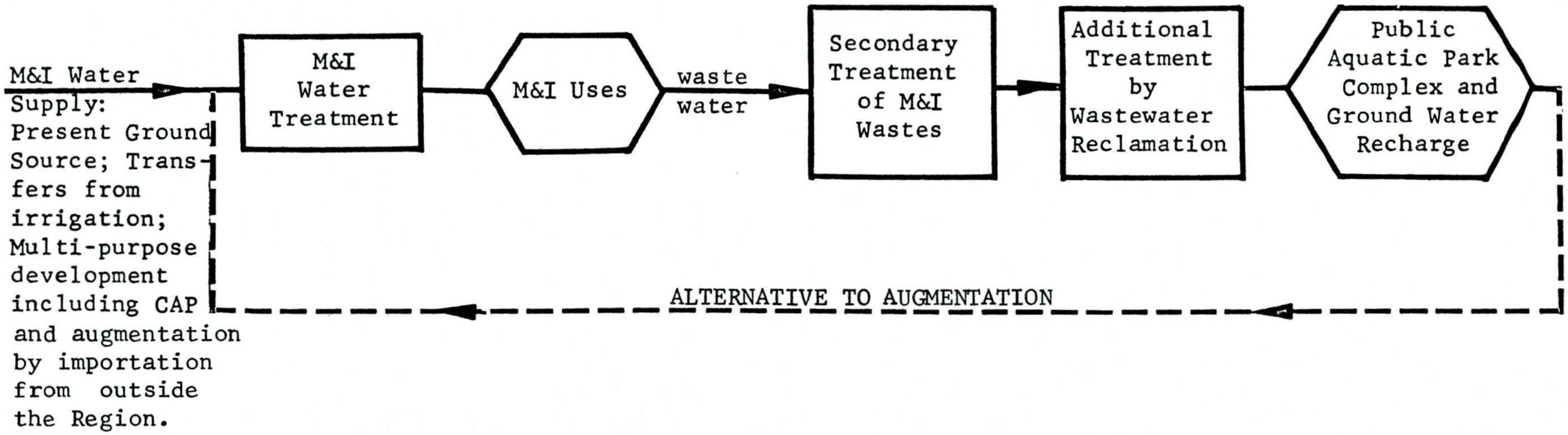

Figure 4--Schematic Diagram of Program for Water Use and Reuse for Metropolitan Tucson, Arizona

SOURCE: Water Quality, Pollution Control and Health Factors Appendix.

TABLE 30
REGIONAL MUNICIPAL AND INDUSTRIAL WATER SUPPLY PROGRAM COSTS 1/
($ MILLION)

Subregion	1965-1980 Fed	1965-1980 Non Fed	1980-2000 Fed	1980-2000 Non Fed	2000-2020 Fed	2000-2020 Non Fed
Lower Main Stem	47.0	28.9	50.5	128.0	0	66.8
Little Colorado	0	11.8	36.0	14.7	0	5.8
Gila	0	21.8	3.0	46.7	0	67.0
Region	47.0	62.5	89.5	189.4	0	139.6

1/ Single-purpose cost of developing, desalting, and treating water.

OBE-ERS LEVEL OF DEVELOPMENT

The OBE-ERS population projections dated March 1968 are compared in Table 31 with the Modified OBE-ERS level used throughout this report. Arizona, which would comprise about 76 percent of the projected Regional population in 2020, has no modification or change for the modified OBE-ERS level of development. All other states projected larger increases than did the Office of Business Economics, as shown in Table 31. Utah increased the OBE-ERS level by 5,400 in 2020, a 33 percent increase; New Mexico increased the OBE-ERS level by 80,900, a 92 percent increase. Although the percent increases are large, both increases are small from a regional point of view. Nevada's percent increase is largest in 1980, where an additional 256,000 people were projected, an increase of 64 percent over OBE-ERS levels. The greatest difference shown for Nevada is in the year 2000 where an additional 492,300 people are projected, an increase of 61 percent over OBE-ERS level.

The projected M & I water requirements, based on the OBE-ERS level of development, for the Region and each subregion are presented in Tables 32, 33, 34, and 35. The requirements are based on economic boundaries of each area. In Table 36, the M & I withdrawal and depletion requirements are summarized by the municipal and industrial (M & I) category and listed by state for the hydrologic boundaries of the region

TABLE 31
DIFFERENCES BETWEEN THE MODIFIED OBE-ERS and the OBE-ERS
POPULATION PROJECTIONS BY HYDROLOGIC BOUNDARIES

	1965	1980			2000			2020		
Area		Mod. OBE-ERS	OBE-ERS	Diff.	Mod. OBE-ERS	OBE-ERS	Diff.	Mod. OBE-ERS	OBE-ERS	Diff.
Lower Colo. Region	1,847,280	2,866,800	2,602,100	264,700	4,722,400	4,195,700	526,700	6,876,800	6,534,000	342,800
Lower Main Stem Subreg.	312,780	762,300	504,800	257,500	1,429,300	935,000	494,300	1,874,700	1,612,800	261,900
Arizona	86,500	93,800	93,800	0	107,300	107,300	0	144,700	144,700	0
Nevada	213,900	653,500	397,500	256,000	1,305,000	812,700	492,300	1,708,000	1,451,500	256,500
Utah	12,380	15,000	13,500	1,500	17,000	15,000	2,000	22,000	16,600	5,400
Little Colo. Subreg.	151,300	223,900	218,200	5,700	293,100	267,500	25,600	389,400	320,000	69,400
Arizona	119,900	173,900	173,900	0	214,400	214,400	0	254,900	254,900	0
New Mexico	31,400	50,000	44,300	5,700	78,700	53,100	25,600	134,500	65,100	69,400
Gila Subreg.	1,383,200	1,880,600	1,879,100	1,500	3,000,000	2,993,200	6,800	4,612,700	4,601,200	11,500
Arizona	1,375,100	1,867,700	1,867,700	0	2,976,700	2,976,700	0	4,578,100	4,578,100	0
New Mexico	8,100	12,900	11,400	1,500	23,300	16,500	6,800	34,600	23,100	11,500
Arizona Total	1,581,500	2,135,400	2,135,400	0	3,298,400	3,298,400	0	4,977,700	4,977,700	0
Nevada Total	213,900	653,500	397,500	256,000	1,305,000	812,700	492,300	1,708,000	1,451,500	256,500
New Mexico Total	39,500	62,900	55,700	7,200	102,000	69,600	32,400	169,100	88,200	80,900
Utah Total	12,380	15,000	13,500	1,500	17,000	15,000	2,000	22,000	16,600	5,400

TABLE 32
REGIONAL SUMMARY OF PROJECTED
MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS BY ECONOMIC BOUNDARIES
FOR THE OBE-ERS PROJECTIONS
(ACRE-FEET PER YEAR)

Water Use	1965	1980	2000	2020
		Withdrawal		
Domestic	273,300	384,400	613,200	932,500
Manufacturing	24,300	57,900	143,700	328,200
Livestock 1/	16,900	25,800	32,200	39,600
Governmental	52,100	104,900	229,400	404,900
Commercial	97,300	199,400	468,100	944,800
Total	463,800	772,400	1,486,600	2,650,000
		Depletion		
Domestic	137,500	197,100	314,000	483,000
Manufacturing	12,900	29,300	75,500	174,200
Livestock 1/	16,900	25,800	32,200	39,600
Governmental	5,200	12,600	34,300	81,000
Commercial	31,200	63,300	150,800	332,600
Total	203,700	328,100	606,800	1,110,400

1/ Consumption of water by farm animals only.

TABLE 33
PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS
FOR THE OBE-ERS PROJECTIONS
LOWER MAIN STEM ECONOMIC
SUBREGION
(ACRE-FEET PER YEAR)

Water Use	1965	1980	2000	2020
		Withdrawal		
Domestic	71,900	112,100	197,100	324,600
Manufacturing	3,700	10,200	23,700	51,600
Livestock 1/	4,300	5,500	6,900	8,500
Governmental	11,600	27,900	64,300	120,100
Commercial	35,500	77,000	189,100	356,200
Total	127,000	232,700	481,100	861,000
		Depletion		
Domestic	36,000	59,800	107,700	179,000
Manufacturing	2,400	6,400	15,100	32,900
Livestock 1/	4,300	5,500	6,900	8,500
Governmental	1,200	3,400	9,600	24,000
Commercial	9,000	19,900	52,700	123,100
Total	52,900	95,000	192,000	367,500

1/ Consumption of water by farm animals only.

TABLE 34

PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS
FOR THE OBE-ERS PROJECTIONS
LITTLE COLORADO ECONOMIC SUBREGION
(ACRE-FEET PER YEAR)

		Withdrawal		
Domestic	7,600	13,700	20,200	28,100
Manufacturing	1,600	3,800	6,400	8,400
Livestock 1/	2,200	2,200	2,400	2,400
Governmental	2,300	4,400	8,900	15,400
Commercial	2,900	5,200	9,500	15,200
Total	16,600	29,300	47,400	69,500
		Depletion		
Domestic	3,800	6,900	10,100	14,100
Manufacturing	600	1,800	3,300	4,200
Livestock 1/	2,200	2,200	2,400	2,400
Governmental	200	500	1,300	3,100
Commercial	900	1,600	2,800	4,700
Total	7,700	13,000	19,900	28,500

1/ Consumption of water by farm animals only.

TABLE 35
PROJECTED MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS
FOR THE OBE-ERS PROJECTIONS
GILA ECONOMIC SUBREGION
(ACRE-FEET PER YEAR)

Water Use	1965	1980	2000	2020
		Withdrawal		
Domestic	193,800	258,600	395,900	579,800
Manufacturing	19,000	43,900	113,600	268,200
Livestock 1/	10,400	18,100	22,900	28,700
Governmental	38,200	72,600	156,200	269,400
Commercial	58,800	117,200	269,500	573,400
Total	320,200	510,400	958,100	1,719,500
		Depletion		
Domestic	97,700	130,400	196,200	289,900
Manufacturing	9,900	21,100	57,100	137,100
Livestock 1/	10,400	18,100	22,900	28,700
Governmental	3,800	8,700	23,400	53,900
Commercial	21,300	41,800	95,300	204,800
Total	143,100	220,100	394,900	714,400

1/ Consumption of water by farm animals only.

TABLE 36
MUNICIPAL AND INDUSTRIAL WATER SUPPLY REQUIREMENTS 1/
BY HYDROLOGIC SUBREGION FOR THE OBE-ERS PROJECTIONS
(ACRE-FEET PER YEAR)

State/Subregion	1965		1980		2000		2020	
	Withdrawal	Depletion	Withdrawal	Depletion	Withdrawal	Depletion	Withdrawal	Depletion
Arizona	30,800	12,100	38,300	15,100	49,800	19,400	70,200	29,600
Nevada	76,100	30,000	162,400	63,900	376,600	147,000	704,700	296,700
Utah	4,400	1,800	5,500	2,200	6,900	2,700	8,100	3,400
Lower Main Stem	111,300	43,900	206,200	81,200	433,300	169,100	783,000	329,700
Arizona	13,700	5,200	26,100	10,400	43,900	17,100	65,300	25,400
New Mexico	3,600	1,400	6,700	2,700	10,900	4,200	16,700	6,500
Little Colorado	17,300	6,600	32,800	13,100	54,800	21,300	82,000	31,900
Arizona	302,900	129,700	481,900	197,700	921,700	366,600	1,675,000	679,300
New Mexico	1,800	800	3,000	1,200	5,100	2,000	8,400	3,400
Gila	304,700	181,000	484,900	198,900	926,800	368,600	1,683,400	682,700
Region Total	433,300	181,000	723,900	293,200	1,414,900	559,000	2,548,400	1,044,300

1/ Does not include livestock use.

and subregions. The livestock requirements for the OBE-ERS level are the same as those shown in Table 24 for the Modified OBE-ERS level.

The means of meeting the needs of the service areas projected from the OBE-ERS level are the same as those given for the Modified OBE-ERS level. The nature of the problems do not change. Only the timing and magnitude of the two service area problems are affected. They are: Clark County, Nevada and Gallup, New Mexico. For Clark County, Nevada the augmentation programmed for the last timeframe would not be needed to meet the projected OBE-ERS water requirements. In the case of Gallup, New Mexico, the withdrawal requirement would be 7,400 AF/YR in 2020. The importation from the Upper Colorado Region (7500 AF/YR) alone would meet the 2020 needs. From a regional view, the differences between the two projection levels shown in Figure 5 are not great.

ADDITIONAL STUDIES AND RESEARCH NEEDED

Further study is needed to refine the development of water-use coefficients used in this report. Three basic relationships should be investigated. They are: further refinement of current water-use data which would require excellent records of water withdrawals, consumption and returns to streams for many industries; the relative importance of variables that effect changes in water-use coefficients over time; and the relation of scarcity or price (cost per unit volume) on quantity of water used.

The need for studies concerning the future relationships between water use and technological changes, water substitution possibilities and the relationship of water to other inputs in the production process are also important and needed.

Further research is needed in the fields of wastewater reclamation and desalination. Research into the development of more efficient stock watering devices is also needed.

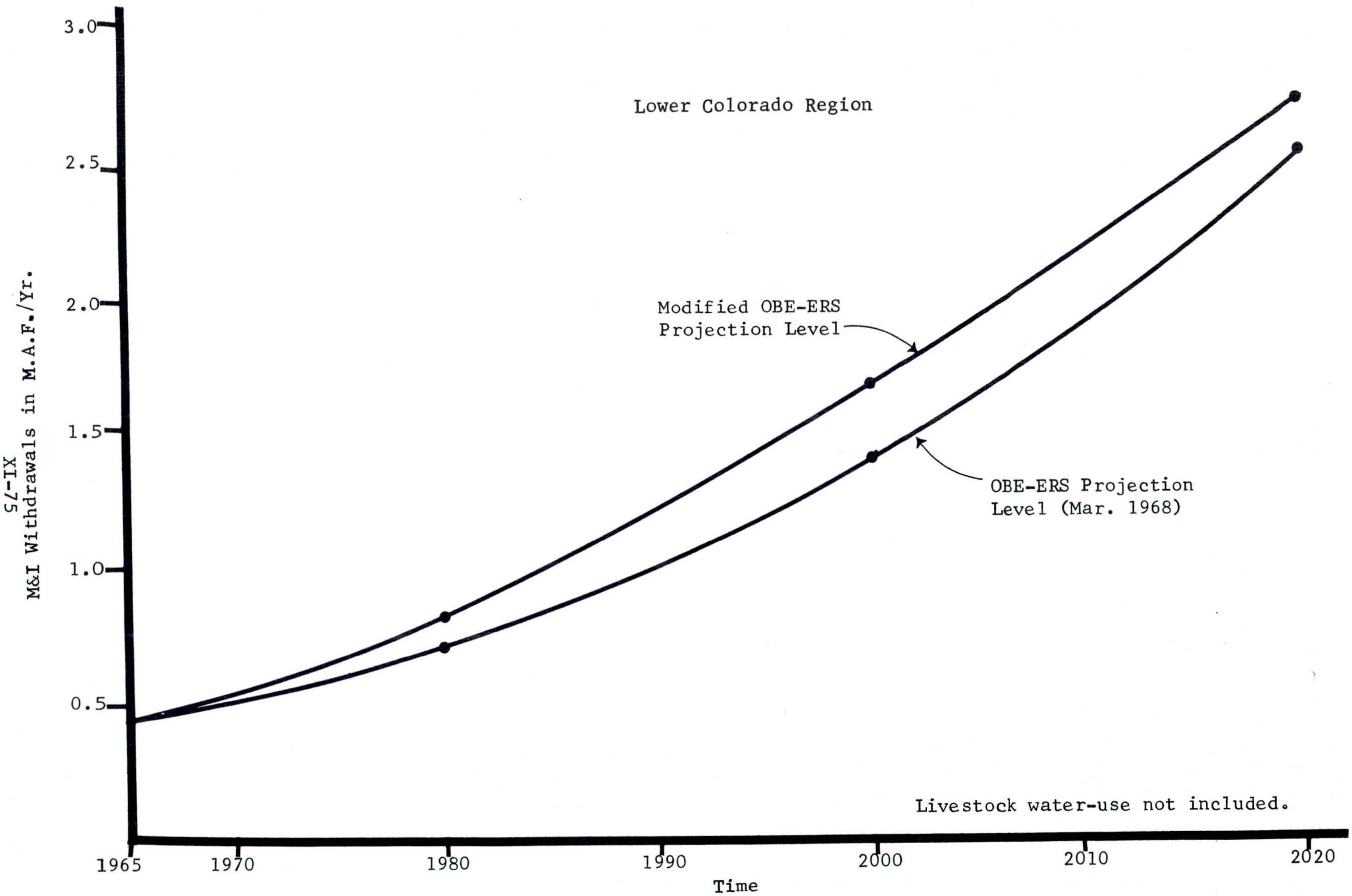

Figure 5 - Municipal and Industrial Water Supply Withdrawal Requirements

METHODOLOGY AND ASSUMPTIONS

CHAPTER D - METHODOLOGY AND ASSUMPTIONS

Municipal and industrial water demands in the Lower Colorado Region were determined by a systematic analysis of the water requirements for each industrial use. The systems which collect and distribute the water and the sources of supply were also analyzed. Present and future municipal and industrial water requirements were determined by correlating water use with the economic and demographic characteristics of the subregions. A conceptual diagram for this systematic analysis is depicted in Figure 6.

Water requirements for each industrial sector shown in the economic models were developed using the following measures of use:

W = Withdrawal
R = Return water
D = Depletion

Using the above measures of water use an equation can be drawn to express the equilibrium condition in the water-use cycle, i.e., withdrawal (W) is equal to depletion (D) plus return (R).

Water-use data by disaggregated industrial sectors at the regional level are almost non-existent. Considerable effort, however, was devoted to the development of water-use coefficients relating water intake and depletion to value of output on a regional basis in recent studies of the Colorado River Basin(52). These water-use coefficients formed the basis for the municipal and industrial water requirements analysis. Members of the Municipal and Industrial Water Supply Workgroup suggested and incorporated numerous revisions and refinements based on additional research and limited field work in updating the water-use coefficients to 1965 and developing projected coefficients for 1980, 2000 and 2020.

Economic output data and the developed water-use coefficients were used to estimate the withdrawal and depletion water needs in the manufacturing, governmental, and commercial and other water-use categories for 1965, 1980, 2000, and 2020. The total present and future annual quantity of water required by each economic sector was determined by multiplying the annual total gross output (TGO) for each sector by the appropriate water-use coefficient. For example, the Food and Kindred Products sector in the Gila Subregion had a 1965 total gross output of $261.9 million, a withdrawal coefficient of 4.6 gallons per dollar, and a depletion coefficient of 2.2 gallons per dollar. This yields 1,204.7 million gallons (MG) and 576.2 million gallons as the 1965 withdrawal and

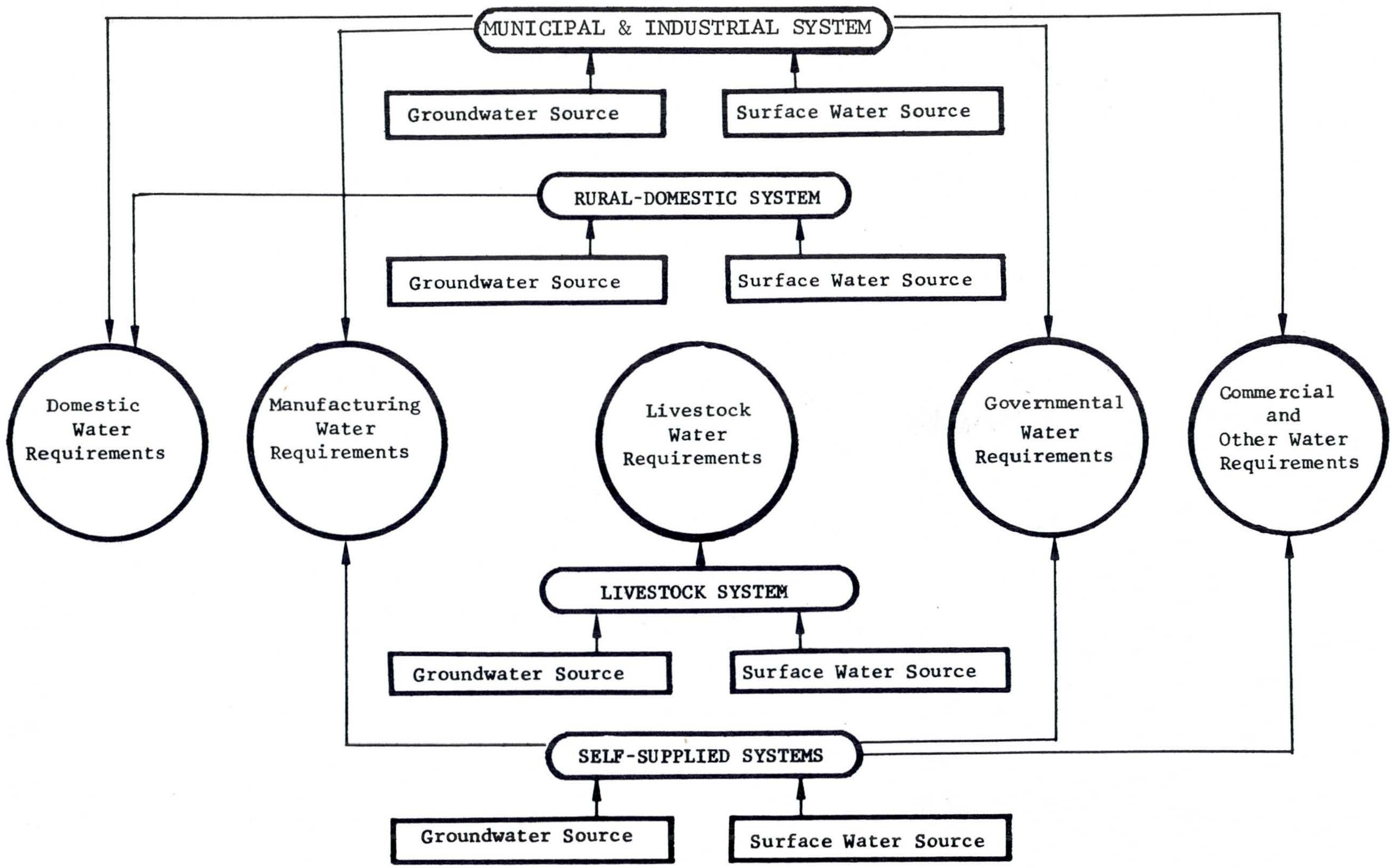

Figure 6 - Conceptual Flow Diagram for Municipal and Industrial Water Requirements.

depletion requirements, respectively.

Water requirements for all other manufacturing, commercial and governmental sectors were similarly developed for each economic subregion economy based on total gross output data contained in the Economic Base and Projections Appendix.

Recirculation, encouraged in part by increasing water costs and future water quality needs, was considered as having the largest future impact on the withdrawal coefficients. The results of a regression analysis of the relationship between Regional and national water-use coefficients indicated that the major influence of Regional factors is on the withdrawal coefficients.

Depletion coefficients for the trades and services sectors were estimated to be between 10 and 20 percent of the withdrawal coefficients.

Water requirements for the Households Sector were developed using withdrawal and depletion coefficients in units of gallons per capita per year (gpcy). The population of a subregion within the economic boundary was multiplied by the Households Sector coefficient for that subregion to determine the requirement. For example, the 1965 population of the Gila economic subregion was 1,406,800, the withdrawal coefficient was 44,895 gpcy, and the depletion coefficient was 22,630 gpcy. This yields 63,158 MG/year and 31,836 MG/year as the withdrawal and depletion requirements, respectively. Water-use coefficients for the household sector represent a weighted average of municipal-domestic and rural-domestic rates. To derive the Household water-use rates, the following steps were taken:

1. Develop municipal-domestic water use rates

A weighted average municipal water-use rate which includes all uses served by municipal systems was developed for each subregion for 1965. 1/ The municipal-domestic withdrawal water-use rate was estimated to be 70 percent of the municipal withdrawal water-use rate in the Lower Main Stem and Gila Subregions and 75 percent of the municipal withdrawal water-use rate in the Little Colorado Subregion in 1965. 2/ For example, the municipal withdrawal water-use rate in the Gila subregion for 1965 was 184 gallons per capita per day (gpcd) -- the municipal-domestic water-use rate, therefore, was 70 percent of 184 gpcd

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1/ References: 3, 11, 13, 14, 15, 16, 20, 21, 31, 32, 42.
2/ Data in reference No. 47 indicates that municipal domestic use is 76 percent of the total municipal use in Phoenix, Arizona.

or 129 gpcd. It was estimated that these percentages would decrease in all three subregions in the target years.

2. Develop rural-domestic water-use rates

The 1965 rural-domestic withdrawal water-use rate in the Lower Main Stem, Gila and Little Colorado Subregions was estimated to be 60, 60 and 50 gpcd respectively[13] [33]. This rate was estimated to increase to 75 gpcd in the Lower Main Stem and Gila Subregions and to 65 gpcd in the Little Colorado Subregion by year 2020.

Because the water-use rate by Indians living in rural areas is much less than the average rural domestic rates shown above and because of the relatively large number of rural Indians living in the Little Colorado Subregion, water requirements for the rural-domestic population in the Little Colorado Subregion were adjusted to reflect water use by the Indian population. The withdrawal water-use rate by the Indian population was estimated to be 28 gpcd in 1965 and to increase to 65 gpcd by 2020. Indian populations in the other subregions were not large enough for independent consideration.

3. Determine the weighted-average Household water-use rate

In order to determine a weighted average household withdrawal water-use coefficient for each subregion, it was first necessary to determine the percentage breakdown of the population served by municipal, and rural Indian and non-Indian systems. A procedure was used which utilized 1960 population and estimated 1965 county population data and the estimated population served by municipal systems in 1963 from U. S. Public Health Service inventories[42]. The basic assumption in the procedure was that changes in population served by rural systems from 1960 to 1965 would occur at the same rate as changes in the farm labor force[52].

As a result of this procedure, for example, it was estimated that in the Gila Subregion in 1965, a population of 1,301,600 were served by municipal systems and a population of 105,200 were served by rural-domestic systems. The population served by each system multiplied by the withdrawal rate (gpcd) for each system gives total water use in million gallons per day (mgd). The proportion of the population served by municipal and rural systems in the Little Colorado Subregion was estimated to remain the same in the target years. The proportion of the population served by municipal systems in the Lower Main Stem Subregion was estimated to increase from 80 percent in 1965 to 96 percent in 2020 and, in the Gila Subregion, to increase from 93 percent in 1965 to 96 percent in 2020.

The 1965 Households Sector weighted-average withdrawal coefficients for the Lower Main Stem and Gila Subregions in each year were developed as illustrated by the following example for the Gila Subregion.

Type of System	1965 Population Served	Domestic Withdrawal Use Rate (gpcd)	Total Use (mgd)
Municipal	1,301,600	129	167.906
Rural-Domestic	105,200	60	6.312
	1,406,800		174.218

1965 Household Withdrawal Coefficient $= \frac{174.218 \text{ mgd}}{1{,}406{,}800}$ = 123 gpcd or 44,895 gpcy.

The Households Sector withdrawal coefficients for the Little Colorado Subregion in each year were determined by a similar procedure as the weighted average of the municipal-domestic and rural-domestic water-use rates. Assumptions given in the above procedure resulted in the Subregional Household Sector coefficients shown in Tabel 37.

TABLE 37
PRESENT AND PROJECTED WITHDRAWAL RATES
FOR THE HOUSEHOLD SECTOR
(gpcd)

Location	1965	1980	2000	2020
Lower Main Stem	186	180	172	165
Little Colorado	54	68	82	96
Gila	123	121	117	112

Water depletion coefficients for the Households Sector in all the subregions were estimated to be about 50 percent of the withdrawal coefficients throughout the study period. For example, the 1965 depletion coefficient in the Gila Subregion is 50 percent of 123 gpcd or, 62 gpcd (22,630 gpcy).

Water requirements of the Livestock Sector normally include water evaporated from stock ponds and water consumed by the animals. Only water consumed by the animals is presented in this appendix, the evaporation is included in data presented in the Water Resources Appendix.

The 1964 Census of Agriculture provided an estimate of the number of farm animals in the base year. The projected number of farm animals was developed from the Modified OBE-ERS Projections, as interpreted by the Economic Base and Projections Workgroup.

It was assumed that livestock withdrawal requirements equal livestock depletion requirements. Water depleted by the animals was determined by estimating the livestock numbers and multiplying by the following animal water-use coefficients: 1/

Feeder and range cattle	- 12 gallons/day
Dairy cattle	- 80 gallons/day (1965)
	-100 gallons/day (1980-2000-2020)
Sheep	- 1 gallon/day
Horses	- 13 gallons/day

Dairy cows consume 15 gallons/day. The remainder is used to wash cows and stalls.

The municipal and industrial withdrawal requirements were supplied by four types of water supply systems, namely: municipal; rural-domestic; self-supplied manufacturing, governmental and commercial; and livestock. The quantity of withdrawal water supplied by municipal systems for all municipally supplied services in each subregion in 1965 was determined by the following equations:

$$M = \sum N \, (Y) \, (P)$$

where: M = Subregion municipal withdrawal in MG per year,

Y = Weighted average county municipal water-use rate in gpcy,

P = County population served by municipal systems,

N = Number of counties in the subregion.

The quantity of withdrawal water required by municipal systems in

1/ The coefficients were developed by the U. S. Department of Agriculture Task Force.

future years was determined by multiplying the weighted-average municipal water-use rate for each subregion by the subregion population served by municipal systems.

The quantity of withdrawal water required by rural-domestic systems for each subregion in each target year was determined by multiplying the estimated average subregional rural-domestic water-use rate times the population served by rural-domestic systems.

The quantity of water supplied by livestock systems is considered equal to the withdrawal requirement of the Livestock Sector.

The quantity of water supplied by self-supplied manufacturing, governmental and commercial systems was determined by the following equation:

$$S = T - M - Z - L$$

where:

S = self-supplied manufacturing, governmental and commercial withdrawal quantity,

T = total subregion withdrawal requirement,

M = municipal withdrawal quantity,

Z = rural-domestic withdrawal quantity,

L = livestock withdrawal quantity.

The various systems collected their supplies from ground water and surface water sources. The proportionate quantity of water obtained from each source by each system was developed only for the base-year 1965. The percentages used are given in Table 38.

TABLE 38
SURFACE AND GROUND WATER USE
1965

System/Source	Subregion: Lower Main Stem	Little Colorado	Gila
	percent		
Municipal			
Ground Water	62	71	75
Surface Water	38	29	25
Rural Domestic			
Ground Water	98	98	98
Surface Water	2	2	2
Self-supplied manufacturing, governmental and commercial			
Ground Water	80	80	80
Surface Water	20	20	20

For the livestock sources, it was estimated that sheep and range cattle depend 40 percent on ground water and 60 percent on surface water. Dairy and feeder cattle were estimated to depend totally on ground water. All of the water evaporated from stock ponds was assumed to come from surface water sources.

Problems and needs were determined by comparing municipal and industrial water requirements with alternative means to satisfy these requirements. Numerous references were consulted to identify present and future problems and to identify alternative means to satisfy needs.

Detailed water withdrawal and depletion coefficients by economic sector for each of the subregion economic models are not presented in this report. The water-use data have been aggregated into five major categories for evaluation and analysis. More appropriately, however, water depletion coefficients by detailed economic sector and a discussion of the economics of water uses are presented in the Economic Base and Projections Appendix.

GLOSSARY

WITHDRAWAL REQUIREMENT - The quantity of water which must be available at the point of use to supply the consumptive and nonconsumptive requirements of various water uses.

DEPLETION REQUIREMENT - The quantity of water consumptively used or discharged to the atmosphere and no longer available as a water source.

GROSS WATER USE - The total quantity of water which would have been needed if no water were recirculated or reused.

RECIRCULATION RATIO - Indicates the number of times a given quantity of water is recirculated and is defined as the gross water use divided by the total withdrawal volume.

MUNICIPAL AND INDUSTRIAL (M&I) WATER REQUIREMENTS - Defined to include domestic, manufacturing, livestock, governmental, and commercial and other water-use categories.

MUNICIPAL AND INDUSTRIAL WATER-USE RATE - The quantity of water used per person in a specified amount of time for domestic, manufacturing, governmental, and commercial purposes which is supplied by a municipal system; the rate is expressed in terms of gallons per capita per day.

MUNICIPAL-DOMESTIC WATER-USE RATE - The quantity of water used per person in a specified amount of time for domestic purposes in households served by municipal systems; the rate is expressed in terms of gallons per capita per day.

RURAL-DOMESTIC WATER-USE RATE - The quantity of water used per person in a specified amount of time for domestic purposes in households served by rural-domestic systems; the rate is expressed in terms of gallons per capita per day.

MUNICIPAL AND INDUSTRIAL SYSTEM - The physical facilities of a central distribution system which collect, treat, and distribute water from the source to domestic, manufacturing, governmental, and commercial water users in a municipality or community.

RURAL-DOMESTIC SYSTEM - Physical facilities other than a municipal system which collect and distribute water directly from the source to one household for domestic use.

SELF-SUPPLIED SYSTEM - The physical facilities other than municipal systems which collect, treat, and distribute water directly from the source to individual manufacturing, governmental, and commercial water uses.

LIVESTOCK SYSTEM - The physical facilities for stock watering purposes which collect and distribute water from the source to the point of use.

TDS - Total dissolved solids. A measure of the mineral content or salinity in water.

ppm - Parts per million which is a unit for expressing the concentration of chemical constituents by weight, usually as grams of constituents per million grams of a solution. By assuming that a liter of water weighs 1 kilogram, parts per million is equivalent to milligrams per liter for concentrations roughly less than 10,000 ppm.

ECONOMIC SECTOR - An aggregation of Standard Industrial Classification codes representing a segment of the regional economy for the convenient presentation and analysis of economic data. The economic sectors are listed under WATER-USE CATEGORY. (For more information refer to the <u>Economic Base and Projections Appendix</u>.)

WATER-USE CATEGORY - The various economic sectors were conveniently aggregated into five water-use categories, namely:

Water-Use Category	Economic Sector
Domestic	Households
Manufacturing	Food & Kindred Products Lumber & Wood Products Printing & Publishing Stone, Clay & Glass Chemicals, Petroleum & Coal Fabricated Metals All Other Manufacturing
Livestock	Livestock
Governmental	Government

Commercial & Other	Wholesale Trade Service Stations All Other Retail Eating & Drinking Places Agricultural Services Lodging All Other Services	Trade and Services Sectors
	Transportation	
	All Other Utilities	
	Contract Construction	
	Rentals & Finance	

(For a description of the Economic Sectors refer to the Standard Industrial Classification Manual[53]).

WATER-USE COEFFICIENT - For the sectors listed in the manufacturing, governmental, and commercial and other water use categories, the coefficient is equal to the quantity of water required to produce one dollar's worth of total gross output annually. Each sector has two coefficients, a withdrawal coefficient and depletion coefficient, both of which are expressed in terms of gallons per dollar of TGO annually. For the households sector, the coefficients are expressed in terms of the quantity of water withdrawn and depleted for domestic purposes per person per year. For the livestock sector the coefficients are expressed in terms of the quantity of water withdrawn and depleted per animal unit (AU) per year.

SIC - Standard Industrial Classification - The Standard Industrial Classification is used to classify establishments by types of economic activity. See ECONOMIC SECTOR.

TGO - Total gross output of each economic sector expressed in dollars annually. For each processing sector, the total gross output is equal to the total value of goods and services sold to all other industries or sectors.

OBE-ERS PROJECTIONS - Projections prepared for the Water Resources Council by the Office of Business Economics (OBE), U. S. Department of Commerce, and the Economic Research Service (ERS), U. S. Department of Agriculture.

SMSA - Standard metropolitan statistical area which represents a county or group of contiguous counties which contains as least one city of 50,000 inhabitants or more or "twin cities" with a combined population of at least 50,000.

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